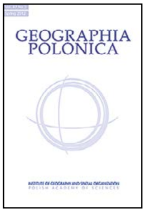


Geographia Polonica
2025, Volume 98, Issue 3, pp. 339-356
https://doi.org/10.7163/GPol.0306

INSTITUTE OF GEOGRAPHY AND SPATIAL ORGANIZATION
POLISH ACADEMY OF SCIENCES
www.igipz.pan.pl

www.geographiapolonica.pl

THE ROLE OF HISTORICAL AND CONTEMPORARY SETTLEMENT FACTORS IN SHAPING THE SIZE OF RURAL PRIMARY SCHOOLS IN POLAND: A MULTI-STAGE REGRESSION ANALYSIS

Artur Bajerski[1] • Wojciech Kisiała[2]

[1] Faculty of Human Geography and Planning
Adam Mickiewicz University, Poznań
Krygowskiego 10, 61-680 Poznań: Poland
e-mail: bajerski@amu.edu.pl (corresponding author)

[2] Institute of Informatics and Quantitative Economics
Poznań University of Economics and Business
Al. Niepodległości 10, 61-875 Poznań: Poland
e-mail: wojciech.kisiala@ue.poznan.pl

Abstract

School size is an essential characteristic of the school network and one of the key conditions for the functioning and financing of schools. The main aim of this article is to assess the extent to which school size results from the influence of settlement and population factors (both historical and contemporary). We analysed data for all rural and urban-rural communes in Poland in 2022. A unique three-stage research procedure was applied, combining different categories of regression models (nationwide, regional, and geographically weighted regression [GWR]). The results indicate that settlement and population conditions are significant factors that shape the average school size. Their impact at the national scale is relatively small, but – according to the results of GWR modelling – it is strong in the vicinity of the largest cities and decreases with distance. In addition, four regional models seem to suggest the role of historical factors. These results, however, should be regarded as research artefacts reflecting the specificity of the spatial distribution of contemporary urbanisation processes.

Keywords

settlement system • rural schools • school size • regression analysis • Poland

Introduction

The size of a school (the number of students) is an essential characteristic of the school network and is also treated as one of the key conditions for the functioning of schools (Piwowarski, 1992, 2000; Domalewski, 2010; Bajerski, 2014). In most countries, local governments shape the public primary school network, and school size is one of the features that local policymakers can directly influence (Gershenson & Langbein, 2015). In recent decades, many authors have treated school size as a variable that influences various aspects of how schools and school networks function. School size has been seen as an essential condition that influences the unit cost of educating students (McKenzie, 1983) and the differences in cost intensity between urban and rural education (Gallego et al., 2010). Hence, in recent years, high unit costs of education in small schools have led to dynamic processes of school closure and so-called school network consolidation, as observed in rural areas of various countries (Egelund & Laustsen, 2006; Kučerová & Kučera, 2009; Autti & Hyry-Beihammer, 2014; Bajerski, 2020).

Many analyses have covered the issue of the impact of school size on teaching and learning, including students' educational outcomes (e.g., external examinations at the end of a given stage of education). In their meta-analysis, Leithwood and Jantzi (2009) found that in the case of elementary schools, school size either has a negative effect or no effect on student achievement. It is also worth noting more in-depth studies. For example, Gershenson and Langbein (2015) found no causal relationship between school size and student achievement in North Carolina schools. However, they discovered that the achievements of students with learning disabilities and socioeconomically disadvantaged are disproportionately harmed by increases in school size. Some researchers have also indicated that the social class of students' families is a strong moderator of school size effects (Howley, 1995). Giambona and Porcu (2018) showed that the relationship between the educational outcomes of schools (in this case, data from the 2012 Programme for International Student Assessment survey) and the number of their students is spatially differentiated, that is, the shape of the relationship between both variables is different for individual groups of Italian regions.

One of the challenges in research on the impact of school size on educational outcomes is the adopted methodology, including the definition of a small school. For example, Lee and Loeb (2000) showed that in elementary schools in Chicago, the highest exam scores were achieved by students in small schools, which they defined as those with fewer than 400 students. In contrast, in Poland, some authors consider schools with more than 300 students to be large (e.g., Bajerski, 2021). When discussing the significance of school size, it is common to compare extremes, that is, the specific features of large and small schools. Large schools tend to have better teaching and sports facilities, offer more extracurricular activities, and have more specialised teaching staff (McGuire, 1989; Jacob et al., 2008). Small schools have certain social and educational benefits, such as the lack of student anonymity, a closer teacher–student relationship, which could potentially result in a more secure and student-friendly learning environment, and greater engagement between teachers and students (Darling-Hammond et al., 2002).

When considering the various dimensions of how the size of a school impacts its functioning, it may also be worthwhile to explore whether school size is a highly 'controllable' feature, independent of 'hard' and 'external' conditions such as settlement and population factors. The urban-rural dichotomy can offer a useful illustration of their significance. In urban areas, where population density is high, school size is considered to be a derivative of specific systemic conditions and the relatively free decisions of local authorities in this respect, often resulting in large schools in school networks. In rural areas, the shape of local school networks is also influenced by differences in the density of the settlement network, the size of rural settlements, and population density (which is much lower than in cities), leading to significant spatial differences in the types of school networks. There is a wealth of documentation on this subject in Poland (Piwowarski, 1992; Bajerski, 2014, 2021). It is worth noting that the research conducted to date has indicated a relatively modest impact of certain characteristics of the settlement network on the average size of a primary school (e.g., population density and the average size of the town; see Bajerski, 2021). This has led to the observation that school size appears to be somewhat loosely associated with settlement and population conditions (Domalewski, 2010). This emphasises the significant role of local government authorities in shaping the structure of the local school network. They can decide whether this network is based on a smaller number of larger schools, located far from home, or a larger number of smaller schools, located closer to home (Piwowarski, 2000, 2006, 2008, Domalewski, 2010; Bajerski, 2014). In Poland, financial resources transferred from the state budget to local governments for the operation of primary schools have consistently fallen short of the actual expenditure on their operation and maintenance (Kotlinska et al., 2021). Consequently, decisions regarding so-called school network consolidation, namely the closure of small, economically unviable schools and the establishment of a school network based on larger, more financially efficient institutions, remain prevalent (Bajerski, 2020).

In this article, our main objective was to verify whether settlement and population conditions significantly shape the average size of primary schools in Poland. We considered three research questions to address this objective: (1) what part of the variation in the average size of primary schools in Polish communes can be explained by variables illustrating the essential settlement and population conditions? (2) Does the impact of settlement and population conditions on the size of a school vary spatially, and if so, to what extent and why? (3) Which factors have the greatest impact on shaping the average size of schools: historical factors[1] responsible for the differences in the settlement network in individual regions or contemporary factors related primarily to urbanisation processes? We considered rural and urban-rural communes, that is, those categories of communes in which the above conditions can shape the school network, including the size of schools (we excluded urban communes, covering about one third of Polish cities).

We adopted a three-stage research procedure for this study. In stage I, we constructed ordinary least squares (OLS) regression models for the entire country, in which the explained variable was the average size of primary schools in communes, and the explanatory variables were the essential settlement and population characteristics. In stage II, we constructed separate OLS models for four historical regions of Poland, whose settlement network is largely a remnant and still represents 'living' evidence of development in different sociopolitical and socioeconomic conditions. Finally, in stage III, we constructed a model explaining the spatial differentiation of school size by using geographically weighted regression (GWR) to verify the correctness of the interpretation of the 'partition models' obtained in the second stage.

Before presenting our quantitative analysis, we provide two sections that introduce the local context. The first presents the historical conditions justifying the creation of separate regression models for different parts of Poland. The second presents the current spatial variation in the sizes of primary schools in Poland, together with selected population and settlement indicators.

The most important historical conditions for the development of the primary school network in Poland

To understand the spatial differentiation of the average size of primary schools in Poland,

[1] By historical factor, we mean any event, condition, or process that took place in the past that influences the current state of the phenomena under consideration.

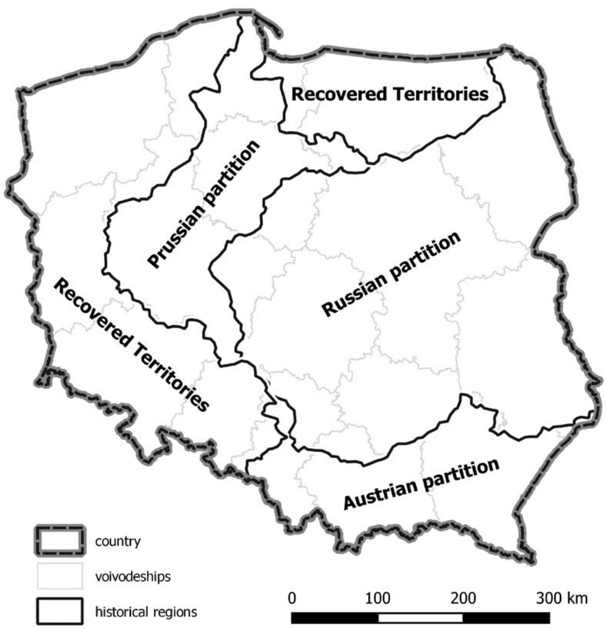


Figure 1. Division of Poland into four historical regions (referring to the division into partitions and 20th century border changes)

we need to discuss historical events that have had a particular impact on the shape of the school network in Poland.

The initial loss of Poland's independence in the latter half of the 18th century, subsequently followed by the 123-year division of its territory between three neighbouring powers (Austria, Prussia, and Russia), is a pivotal moment in Polish history. This division, known as partitions[2] (Fig. 1), resulted in the functioning of different regions of the country within separate economic systems, exhibiting different levels of socioeconomic development and varying degrees of educational prioritisation. These disparities are exemplified by the introduction of compulsory education in Polish territories (i.e., the enrolment of specific age groups of children and adolescents). In Prussia, compulsory education was introduced in 1819 (with slightly later implementation in 1825 in the Polish regions within the Prussian partition, specifically Greater Poland and Pomerania). In Austria, compulsory education commenced in 1869 (with Galicia, situated within the Austrian partition, being incorporated in 1873). In the Polish territories under Russian governance, compulsory education was implemented only in 1919, that is, after Poland had regained independence (Szymański, 1978; Herbst, 2012).

The second period of significance in this regard was the territorial changes in Poland after World War II, which entailed the loss of eastern territories and the gain in 1945 of the so-called Recovered Territories formerly belonging to Prussia. In this instance, a school network had to be organised from scratch, utilising a significant part of the previously existing school infrastructure. Notwithstanding the socialistic policy of developing a dense network of rural schools in the countryside and then consolidating them,

[2] The Austrian partition refers to all lands under Austro-Hungarian control in the 19th century, which are part of modern-day Poland (even if they were not part of Poland at the beginning of the partition).

aiming at a smaller number of larger schools (Ozga, 1974; Piwowarski, 1992), fundamental differences in the characteristics of the school network between different parts of the country persist (Piwowarski, 1992; Bajerski, 2014, 2021).

Spatial variation in the size of primary schools and basic parameters of the settlement network

The average size of a primary school in rural and urban-rural communes in Poland in 2022 exhibited significant variation. It ranged from 39 to 844 students, with an average of 178 students. The spatial distribution of the average size of primary schools in Poland exhibits two distinct regularities. The first of these regularities is the significantly higher average sizes of schools in the western part of Poland (where the average school size exceeds 210 students) and lower in the central and eastern parts (where the average school size is less than 150 students). This corresponds to the division of Poland according to relic borders into the Recovered Territories and the Prussian partition in the west and north, and the Russian and Austrian partitions (in the centre, east and south; Fig. 2). Second, the largest schools are found in rural and urban-rural communes that are part of the largest urban agglomerations in the country. Conversely, the smallest schools are located in areas distant from these larger centres, which often exhibit below-average levels of economic development and are frequently classified as peripheral and problematic (Rosner, 2010). The distribution of the average size of primary schools in rural and

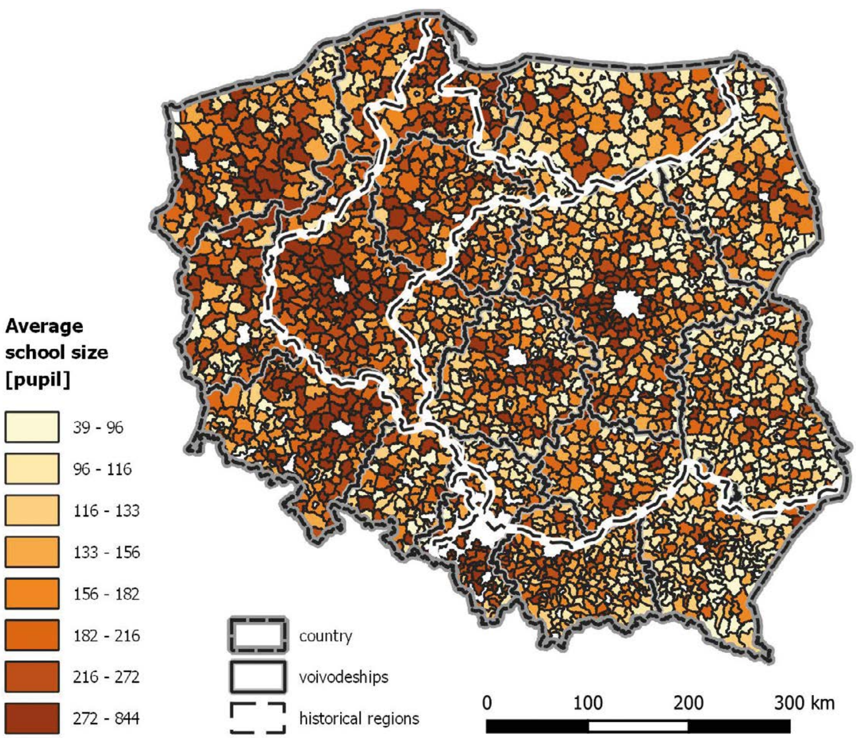


Figure 2. Spatial differentiation of the average primary school size in rural and urban-rural communes of Poland in 2022

Source: Our elaboration based on the Local Data Bank of Statistics Poland.

urban-rural communes in Poland appears to be influenced by a combination of historical processes, including the aforementioned need to organise a new school network in the Recovered Territories according to new principles, and contemporary socioeconomic processes such as the depopulation of villages and the dynamic development of metropolitan areas, leading to the deepening of differences in centre–periphery relations.

The distribution of the average size of primary schools in rural and urban-rural communes exhibits a certain degree of similarity to the distribution of each of the three essential characteristics of the settlement network. It is hypothesised that these characteristics constitute potential factors that shape the size of schools.

The first of the analysed characteristics is the average settlement size. As with the average school size, an above-average settlement size is characteristic of western Poland and the areas with the largest urban agglomerations in the country (Fig. 3). Furthermore, south-eastern Poland (the former Austrian partition) is characterised by the presence of very large settlements. The average population of settlements in urban and urban-rural communes in this area exceeds 1,500 inhabitants, with a national average of 564 inhabitants.

The contemporary distribution of settlement size is profoundly influenced by historical factors. Significant disparities in the settlement structure of contemporary Poland were already evident in the pre-partition period (i.e., in the mid-18th century). A notable disparity emerged between the western regions, characterised by the predominance of large, regular villages, and the central and

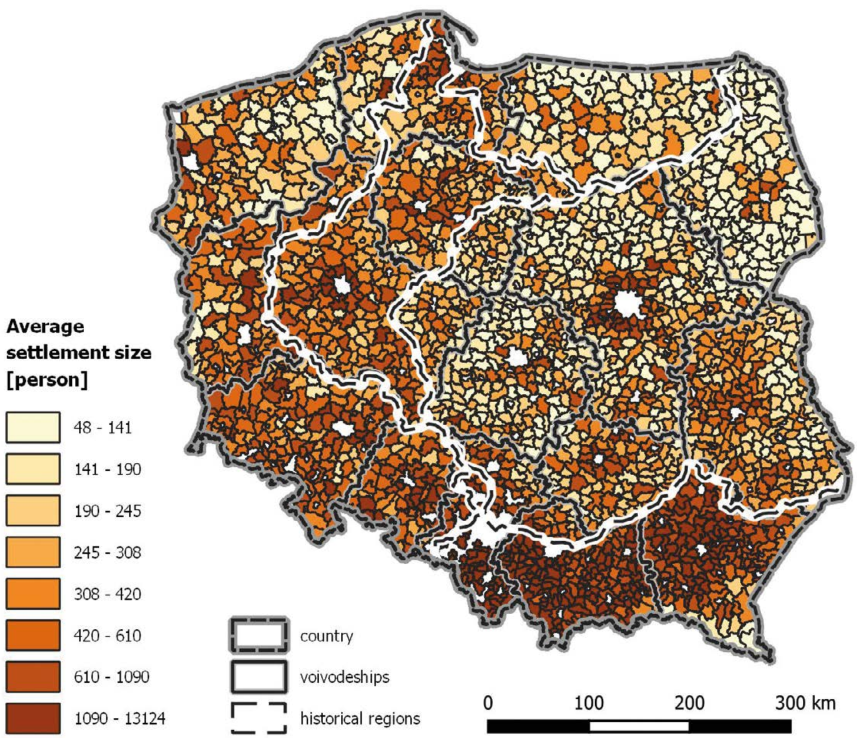


Figure 3. Spatial differentiation of the average number of inhabitants per settlement in rural and urban-rural communes in Poland in 2022

Source: our elaboration based on the Local Data Bank of Statistics Poland.

eastern regions, where smaller, irregular, and so-called row villages constituted the majority (Szulc, 1995). These disparities were further exacerbated by subsequent processes following 1795, a period which marked the dissolution of Poland as a sovereign state. During the period of partitions, changes in the settlement network proceeded differently in each partition (Austrian, Prussian, and Russian), a phenomenon that was primarily due to differences in the economic policy towards Polish lands as well as different levels of economic development of the partitioning countries (Szulc, 1995). A particular illustration of these disparities was the process of dispersing settlements in the territory of the Russian partition, which – although in a slightly different form – continued after Poland regained independence in 1918 (Kiełczewska-Zaleska, 1970, 1972; Szymańska, 2008).

The spatial consequences of the above-described processes can be observed by analysing the distribution of the settlement network density (expressed as the number of settlements per 100 km^2). This distribution – with some generalisation – can be considered to be the inverse of the distribution of the average settlement size in rural and urban-rural communes (Fig. 4). The highest density is observed in the central part of Poland, in the area of the former Russian partition, where – as mentioned above – the settlement network was administratively reorganised in the 19th and 20th centuries towards a large number of small rural settlements. For rural and urban-rural communes, the average settlement network density is less than 19 settlements per 100 km^2, but for central Poland, the settlement network density is almost 30 settlements per 100 km^2 (range: 2-57 settlements per 100 km^2).

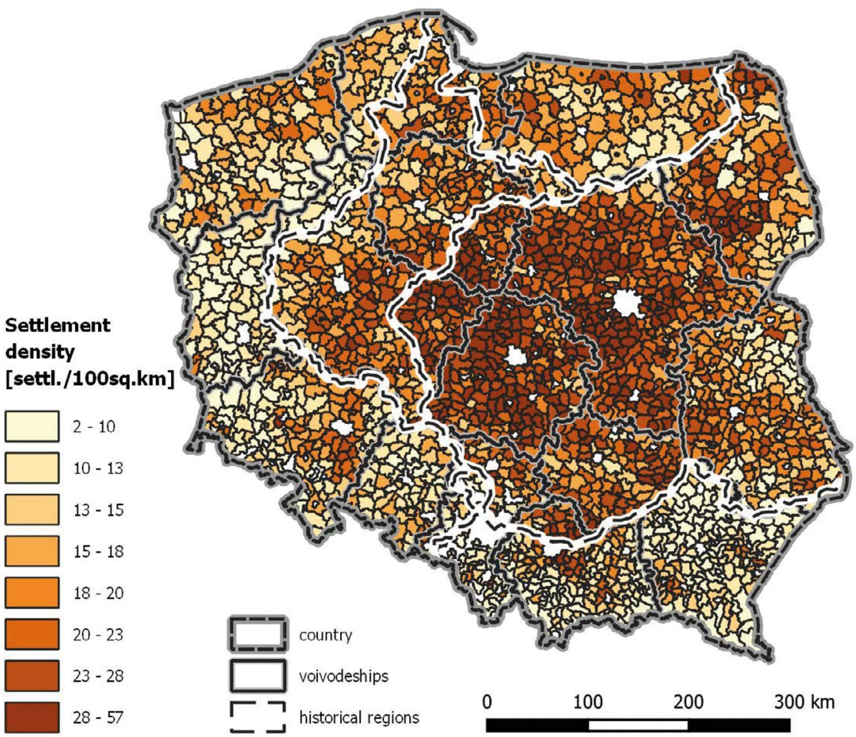


Figure 4. Spatial differentiation of the average number of settlements per 100 km^2 in rural and urban-rural communes of Poland in 2022

Source: Our elaboration based on the Local Data Bank of Statistics Poland.

Two regularities may be observed in the case of the spatial distribution of population density. First, there is a marked disparity in the population density between the individual historical regions (Fig. 5). The area of the former Austrian partition has the highest average population density, slightly over 150 people per km^2. Historians have noted that at the beginning of the 17th century, this area had a higher population density than other regions. This advantage increased after the so-called Swedish Deluge (the invasion of Poland by Swedish troops and the devastation of its northern and central regions), leading to a situation where, already at the threshold of the final partition of Poland, the population density in south-eastern Poland was over 50% higher than in central Poland (Jezierski & Leszczyńska, 2003).

The Recovered Territories and the former Russian partition demonstrate the lowest population density. The former is characterised by depopulation processes initiated prior to World War II, exacerbated by the underpopulation of these lands following their annexation to Poland in 1945, and the subsequent outflow of the German population (Kosiński, 1963; Gawryszewski, 2005). The latter is due to the problematic conditions for settlement development, the low level of economic development, and contemporary depopulation trends. Similarly to the previously analysed settlement characteristics, the second regularity is the occurrence of high values in the areas of the largest urban agglomerations and their vicinity, as well as low values far away from them. This phenomenon is associated with the previously discussed processes of metropolisation of space

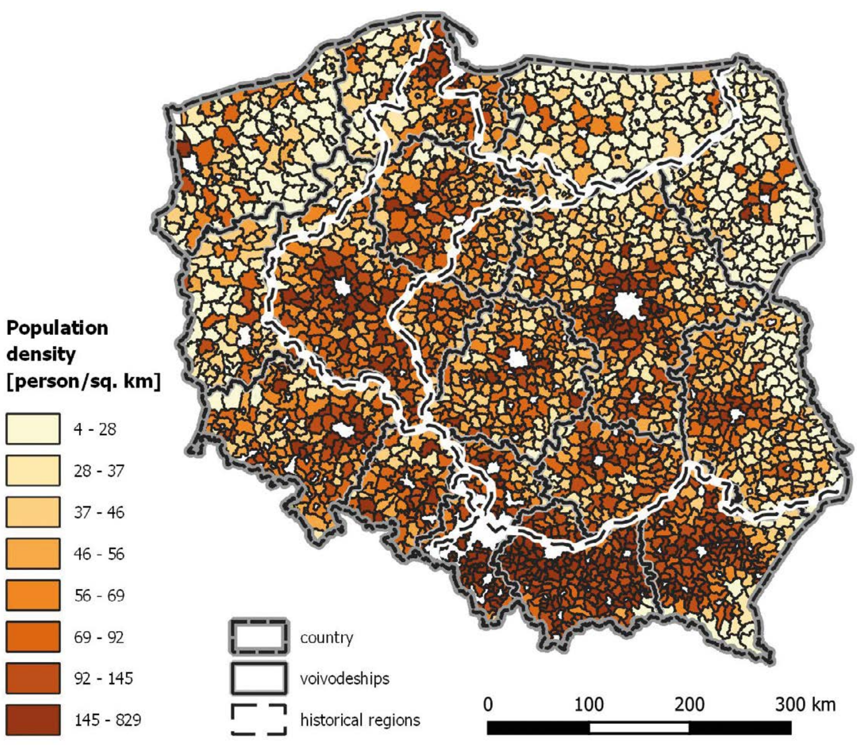


Figure 5. Spatial differentiation of population density of rural and urban-rural communes in Poland in 2022

Source: our elaboration based on the Local Data Bank of Statistics Poland.

and depopulation tendencies in peripherally located rural and urban-rural communes.

Method

Regression modelling

As mentioned, the research procedure comprised three stages to achieve the main study objective. Stages I and II were related to classical regression modelling of the relationship between the average primary school size and variables characterising the settlement network and population distribution. These models were based on the assumption that the relationship between the explained variable and the explanatory variables is stable. In practice, this meant that the studied relationship was stable regarding the analytical form, the list of explanatory variables, and the values of parameters for all observations (Greene, 2019).

Traditional linear regression models with multiple explanatory variables were used in the form of:

$$y_i = \sum_j x_{ij} a_j + \varepsilon_i$$

where:

y – denotes the explained variable,

x – is an explanatory variable,

a – is an estimated structural parameter, and

ε – is a random component (error term).

Stages I and II differed based on the spatial scope of the units covered by this study. In stage I, the model was estimated based on observations encompassing all rural and urban-rural communes in Poland (the nationwide model). In stage II, the set of studied units (communes) was divided into four groups depending on the location in one of the regions marked by the historical partition borders and the borders of the Second Polish Republic (the Prussian, Russian, Austrian partitions and the Recovered Territories; see Fig. 1). In this stage, independent models were estimated for each of the separate subsets, assuming the invariance (stability) of the analytical form and the set of explanatory variables and allowing for differences in the range of estimated parameters between the analysed groups (the regional models). Subsequently, the results were compared in terms of estimated parameters and how well the model fit the empirical data. Stage III involved spatial modelling of local regression equations using a GWR model. The distinguishing characteristic of this model is the presence of an identical analytical form and a list of explanatory variables for all possible observations. However, it assumes changes in the estimated parameters when moving from observation to observation. This spatial nonstationarity implies that some variables can positively affect some territorial units, while negative effects can be observed in others (Meloche & Shearmur, 2010)

The GWR model 'allows for capturing of the variations of regression coefficients in space for each observation' (Suchecki, 2010: 264). According to this assumption, model parameters are estimated separately for each observation for which the values of the explained and explanatory variables are known. When estimating the parameters of local regression models, characteristics (explanatory variables) derived primarily from neighbouring observations are considered, with the importance of subsequent observations decreasing with distance (Fotheringham et al., 2002).

The parameters of the GWR model are related to location, and the equation of a typical local model can be written as follows (Charlton & Fotheringham, 2009; Fotheringham et al., 2002):

$$y_i = \sum_j x_{ij} a_j (u_i, v_i) + \varepsilon_i$$

where:

(u_i, v_i) – are the coordinates of the i-th location (observation), and the remaining notations are identical to those described for the classical multiple regression model.

The result of modelling is an n-element set of localised parameter estimates (n local regression equations) and measures of the quality of local models (such as local standard errors of estimation or local R^2). Therefore, it is possible to present the variability of each parameter and local R^2 coefficients on a map. This enables the assessment of spatial differentiation of the relationship between the explained variable and the explanatory variables, and conclusions can be drawn about the role of individual variables in different locations.

The results from each stage of regression modelling were intended to verify the statistical relationships between the average school size and settlement and population characteristics. This approach placed particular emphasis on the spatial differentiation of the examined relationships. This differentiation may be due to the effect of historical conditions (partitions and changes in borders resulting from the decisions after World Wars I and II that took place in the first half of the 20th century) and/or contemporary urbanisation processes.

Characteristics of the variables

When examining the statistical relationships between the school network and settlement system, the average primary school size (measured by the average number of students) in a commune was assumed to be the explained variable. Data on the number of students in individual schools were obtained from the Education Information System as of 30 December 2022. These values were aggregated at the commune level and averaged in relation to the number of schools in a given commune.

The initial list of potential explanatory variables consisted of basic characteristics of the settlement network and population distribution, including:

1. average settlement size (SETTL.SIZE) [population/settlement], the ratio of the number of people living in individual communes and the number of settlements located within them;
2. settlement network density (SETTL.DENS) [number of settlements/100 km^2], an indicator of the degree of dispersion of the settlement network in individual communes;
3. population density (POP.DENS) [persons/km^2], an indicator illustrating the size of the population and the degree of its concentration in the area of the studied units (communes).

Data on the population, area, and number of settlements in communes were obtained from Statistics Poland (Local Data Bank). The number of settlements was taken as the number of so-called basic settlements, excluding small colonies and hamlets, which are treated as integral parts of villages. The values of the variables characterised the year 2022.

To eliminate the problem of possible deviations from the linear relationship between variables, the original values for the variables were subjected to logarithmic transformation. This approach enabled the estimated parameters to be treated in terms of the elasticity of the explained variable concerning individual explanatory variables (Greene, 2019). Moreover, logarithmic transformation improved the fit of the estimated models to the empirical data.

The dependencies in the set of potential explanatory variables were analysed. Due to the high covariation of population density with the other two explanatory variables (of which population density is de facto the result), we decided to carry out regression modelling without population density.

Results

According to the model based on observations encompassing all rural and urban-rural communes in Poland (stage I), the tested variables characterising the settlement network and population distribution had a significant effect on the average size of primary schools (Tab. 1). Schools in communes with larger settlements and a higher settlement network density had a higher average number of students. School size demonstrated a stronger response to the relative increase in the average settlement size rather than to the analogous increase in the settlement network density. However, it should be noted that the differences in the estimated elasticities were small (0.24 for SETTL.SIZE vs 0.23 for SETTL.DENS). The model had weak explanatory power, with the analysed settlement and population conditions explaining only 15% of the variability of school size in Polish rural and urban-rural communes.

The poor fit of the model to the empirical data could be due to the spatial heterogeneity of the studied variables resulting from the previously described historical conditions. Therefore, in stage II we modelled results in four groups distinguished by historical boundaries. Modelling the dependencies in the historical regions confirmed the previously identified regularities of the stimulating effect of both population and settlement variables on the average school size. At the same time, the goodness of fit improved markedly. The variables included in the models accounted for almost 40% of the variability of the average school size in the areas of the Austrian partition, almost 30% in the Prussian partition, and over 20% in the Russian partition. Only in the Recovered Territories was the model quality similar to the global model ($R^2 = 15\%$).

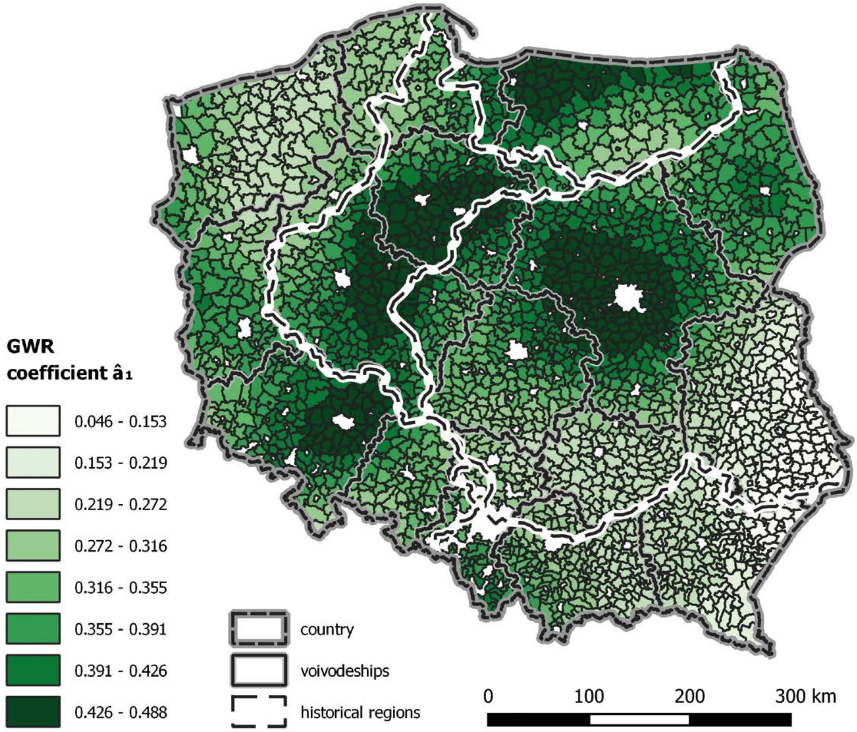
Analysis of the estimated regression coefficients showed a significant difference in how the average settlement size and settlement network density shape the studied phenomenon. In the Austrian and Prussian partitions and the Recovered Territories, a relative increase in the average settlement size and settlement network density had a greater effect on school size. There were notable differences in the elasticity of the average school size in the model for the Austrian partition (0.34 for SETTL.SIZE and 0.09 for SETTL.DENS). On the other hand, in the model for the Russian partition, a percentage increase in the average settlement network density had a more significant role in shaping the variability of the average school size than a percentage increase in the average settlement size ($\hat{a} = 0.41$ for SETTL.DENS and $\hat{a} = 0.29$ for SETTL.SIZE).

The identified differences in the estimated parameters of the individual models support our hypothesis that there is a lack of stability in the relationship between the studied phenomena. This situation could result from spatial heterogeneity, manifested by the instability of the structural parameters of the regression model. Therefore, we decided to use GWR, which, as mentioned earlier, allows one to identify spatial differentiation of parameter values at individual observation points and to verify the quality of local models.

Analysis of the local GWR coefficients indicated large spatial differentiation regarding the influence of the individual explanatory variables. Figure 6 illustrates the entire picture of the variability of local GWR coefficients related to SETTL.SIZE and SETTL.DENS. The $\hat{a}_1$ coefficients (related to SETTL.SIZE) ranged from 0.046 to 0.488. The areas in which school size was particularly vulnerable to a percentage increase in the average settlements size were around large cities

Table 1. Results of ordinary least squares regression modelling

	All communes		Austrian partition		Russian partition		Prussian partition		Recovered Territories	
	$\hat{a}$	*p*-value	$\hat{a}$	*p*-value	$\hat{a}$	*p*-value	$\hat{a}$	*p*-value	$\hat{a}$	*p*-value
Intercept	3.05	0.00	2.40	0.00	2.16	0.00	2.30	0.00	3.08	0.00
SETTL.SIZE	0.24	0.00	0.34	0.00	0.29	0.00	0.39	0.00	0.27	0.00
SETTL.DENS	0.23	0.00	0.09	0.02	0.41	0.00	0.24	0.00	0.20	0.00
R^2	0.15		0.38		0.21		0.29		0.15	
n	2175		346		1000		277		552	



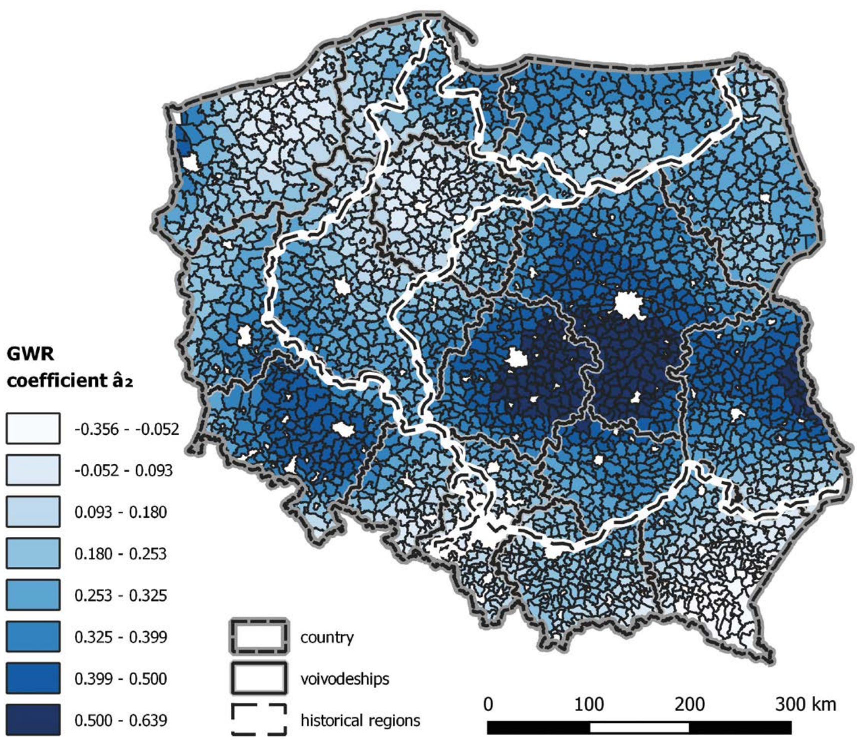


Figure 6. Spatial variation of the estimated geographically weighted regression model parameters values

(Warsaw, Wrocław, Poznań, and Bydgoszcz). On the other hand, this factor had the smallest role in the south-eastern communes of Poland. The local $\hat{a}_2$ coefficients (related to SETTL.DENS) ranged from -0.356 to 0.639. This means that the SETTL.DENS was a negative variable in some areas, specifically 65 communes located in south-eastern Poland (Podkarpackie Voivodeship) and communes located in the north-eastern part of the West Pomeranian Voivodeship. The highest $\hat{a}_2$ coefficients occurred in central Poland, in the area between Warsaw, Łódź, and Radom.

The use of GWR improved the quality of the model. The global coefficient of determination of the GWR model was 0.47 (compared with 0.15 for the analogous OLS model), and the Akaike information criterion was 331.19 (compared with 2381.51 for the OLS model). In turn, the locally weighted R^2 values – which characterise how well the variability of the average school size in a given commune is explained by the equation appropriate for that location (estimation based on SETTL.SIZE and SETTL.DENS coming primarily from the neighbourhood), ranged from 0.003 to 0.501 (Fig. 7).

Spatial variability of the local R^2 values proved that, similarly to the GWR coefficients, this parameter did not show regularities regarding the division of Poland into historical regions. It can be seen that the distance from the largest cities matters to a much greater extent. The highest local R^2 values occurred in the vicinity of Warsaw, the urban agglomerations of Upper Silesia and western Małopolska (Kraków), Poznań, and Tri-City, and decreased with the distance from these agglomerations. Although of a lower intensity, we observed a similar gradient with the distance from other large Polish cities, such as Wrocław, Szczecin, Białystok, and Zielona Góra. The peripheral areas of south-eastern Poland and the West Pomeranian

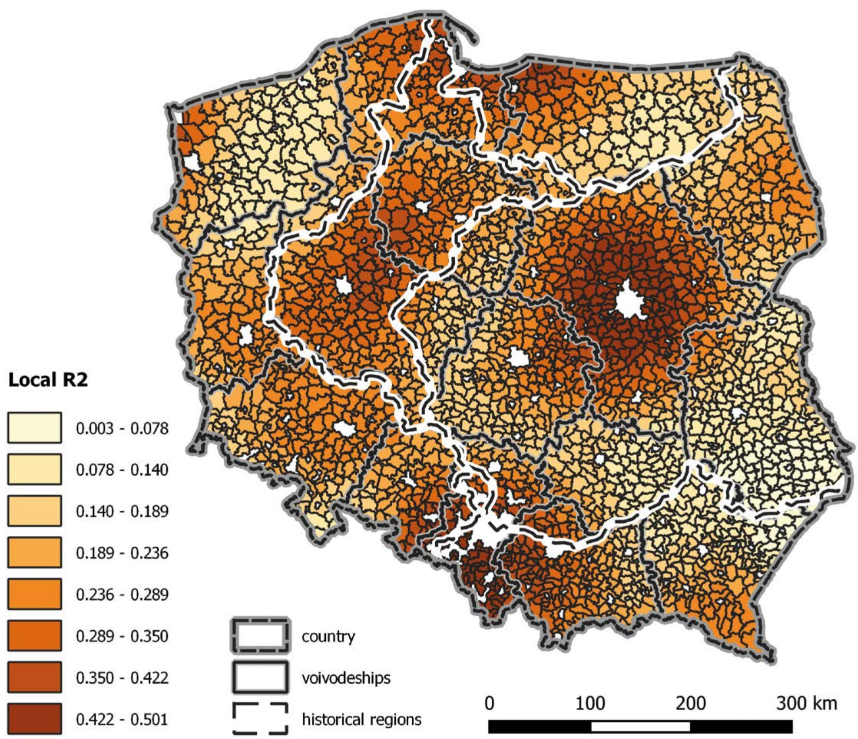


Figure 7. Spatial differentiation of the local R^2 values of the geographically weighted regression model

and Warmian-Masurian Voivodeships presented the lowest local R^2 values. These areas have experienced the most intense closing of small rural schools since 1989 (Bajerski, 2020), a phenomenon that followed particularly strong depopulation processes (Majdzińska, 2018; Bański & Wesołowska, 2020).

Discussion and conclusions

Our research results lead to several basic empirical conclusions and allow us to formulate certain methodological findings.

First, we showed a statistical relationship between selected essential settlement and population characteristics and the average school size. However, the extent to which they are related is complex. In general, as shown by the nationwide model, settlement and population conditions explain a small part of the variability in the average primary school size in Poland (approximately 15%), which seems to support the hypothesis that internal conditions play a dominant role in shaping the size of schools in a given commune, related to the shape of local educational policy (Domalewski, 2010).

The regional models constructed in stage II of the research (for historical regions) explained 15%–38% of the variability, which indicated the spatial heterogeneity of the studied relationships and suggested that, depending on the region and its specific conditions, local governments are limited to a varying extent when organising the school network. These preliminary conclusions are supported by the results for the two 'extreme' regions: the Recovered Territories, where the school network was created anew after World War II (R^2 = 15%), and the Austrian partition, which has an 'old' school network characterised by the presence of large villages (R^2 = 38%). The GWR model constructed in stage III showed yet another picture. For about one third of the territory of Poland, the influence of settlement and population conditions on the primary school size was minimal. In contrast, for another one third, this influence was locally very strong (explaining up to half of the variability of the average size of primary schools).

Second, some additional explanations are necessary to explain the research results fully. Each subsequent stage of the analysis introduced new findings in statistical and spatial terms. The GWR model was of particular importance here; one of its aims was to verify the findings made based on the regional models. The GWR model de facto overturned the conclusions that could be drawn based on the regional models. The spatial distribution of the R^2 values and the estimates of individual parameters, which do not correspond to the boundaries of historical regions, indicate that the results obtained using regional models should be treated as research artefacts. Differences in the degree to which settlement and population variables explain the differences in the average school size between regions seem to result much less from the historical conditions we have mentioned and, to a greater extent, from contemporary settlement and population processes.

Third, the research results do not directly clarify the reasons for the spatial differentiation of the local R^2 values and the estimated parameters of the GWR model. These can be found by looking at their specificity (primarily SETTL.SIZE and R^2). For both, the highest values occur near the largest urban agglomerations. This suggests that these areas are characterised by an above-average statistical connection between the average settlement and school sizes in the communes and the strength of this relationship between both variables should decrease with distance from the central city. The general regularities of the development of suburban zones of large Polish cities – that is, the phasic nature of this process, its largely spontaneous nature, and the significant acceleration of its course after 1989 (Wdowicka & Mierzejewska, 2012; Heffner, 2016) – often leads to a significant delay in the development of educational infrastructure with respect to population growth. This phenomenon translates into the occurrence of villages in suburban zones with both population and school sizes that are higher than the averages (Bajerski, 2021). In these institutions, the number of students often significantly exceeds the infrastructural possibilities, which leads to the need to organise education in shifts.

The population and educational data we used in this study allowed to determine whether the relationship described above can be considered an explanation of the problem in question. As a case study, we selected rural and urban-rural communes in the suburban area of Poznań (the fifth most populated city in Poland). Figure 8, which illustrates this case, shows that with the distance from the city, there is an apparent decrease in the average settlement size in the communes and a decrease in the average school size (both relationships are observed primarily in the subset of communes located up to 30 km from the centre of the agglomeration). In the analysed area, almost half of the variability in the average school size can be explained by the average settlement population.

Fourth, in light of the research results, one can see the full value of the three-stage research procedure we adopted a priori, consisting of constructing nationwide, regional, and GWR models. According to the original assumption, the GWR model mainly verified the correctness of the conclusions we drew based on the regional models. We started our study with strong arguments for the spatial heterogeneity of the relationship between settlement and population conditions and the average school size based on different rules of development of the settlement network and the school network in different historical regions of Poland. On the other hand, we did not have such strong arguments for using the GWR model. However, thanks to the three-stage analysis, we constructed models based on empirical and theoretical premises (regional models) and critically verified their conclusions (the GWR model). We also avoided a specific trap of regional models, which led to results that were de facto research artefacts in the case of the discussed studies. We explain the occurrence of this problem based on the modifiable area unit problem (Fotheringham & Wong, 1991) and the significant inadequacy of using historical regions of Poland as spatial units within which the relationship between the settlement system and the size of primary schools is studied.

Finally, it is worth noting some limitations. First, when examining the impact of settlement factors on the size of rural primary schools, the key issue is what is considered a settlement (in the case of schools, there is no such doubt). We considered so-called basic settlements; they do not include small colonies and hamlets, which are treated as integral parts of villages. The prevalence and administrative delimitation of these small parts of villages vary across Poland (Szmytkie & Tomczak, 2020). Considering them could change the parameters of the settlement network in some regions of Poland and thus, to some extent, the results of the analyses we conducted. Second, it would be advisable

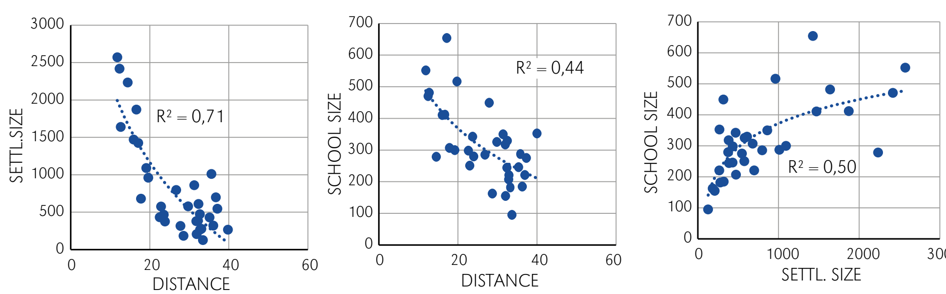


Figure 8. Relationships between the average settlement size (SETTL.SIZE), the average school size (SCHOOL SIZE), and the distance from Poznań (DISTANCE) in the set of communes surrounding Poznań

Source: our elaboration based on the Local Data Bank of Statistics Poland.

to carry out analyses similar to the one presented in this article for earlier years. This approach would facilitate the assessment of the stability of the identified spatial regularities and the determination of whether the influence of the partition borders was already irrelevant in the 1990s, for example. Third, we focused on settlement-related determinants while omitting other potentially important factors that may influence school size, such as the economic situation of the municipality or its demographic structure and prospects for change. These are among the basic determinants of rural school closures in Poland (Bajerski, 2020), the actual impact of which has not yet been analysed in detail. This is also one of the directions for further research.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

References

Autti, O., & Hyry-Beihammer, E. K. (2014). School closures in rural Finnish communities. *Journal of Research in Rural Education*, *29*(1), 1-17.

Bajerski, A. (2014). Klasyfikacja typologiczna sieci szkół podstawowych w gminach Polski, *Przegląd Geograficzny*, *86*(4), 541-566. https://doi.org/10.7163/PrzG.2014.4.5

Bajerski, A. (2020). Rural schools in Poland in the period of post-socialist decentralization and demographic decline. In C. Gristy, L. Hargreaves, & S. R. Kučerová (Eds.), *Educational research and schooling in rural Europe: An engagement with changing patterns of education, space, and place* (pp. 125-145). Information Age Publishing.

Bajerski, A. (2021). *Osadniczo-ludnościowe uwarunkowania organizacji przestrzennej szkolnictwa podstawowego w Polsce. Ujęcie ilościowe*. Bogucki Wydawnictwo Naukowe.

Bański, J., & Wesołowska, M. (2020). Disappearing villages in Poland–selected socioeconomic processes and spatial phenomena. *European Countryside*, *12*(2), 221-241. https://doi.org/10.2478/euco-2020-0013

Charlton, M., & Fotheringham, A. S. (2009). *Geographically weighted regression* [White paper]. Maynooth. https://www.geos.ed.ac.uk/~gisteac/fspat/gwr/gwr_arcgis/GWR_WhitePaper.pdf

Darling-Hammond, L., Ancess, J., & Ort, S. W. (2002). Reinventing high school: Outcomes of the coalition campus schools project. *American Educational Research Journal*, *39*(3), 639-673. https://doi.org/10.3102/00028312039003639

Domalewski, J. (2010). Edukacja a procesy rozwoju obszarów wiejskich. In M. Stanny & M. Drygas (Eds.), *Przestrzenne, społeczno-ekonomiczne zróżnicowanie obszarów wiejskich w Polsce. Problemy i perspektywy rozwoju* (pp. 181-201). Instytut Rozwoju Wsi i Rolnictwa PAN.

Egelund, N., & Laustsen, H. (2006). School closure: What are the consequences for the local society? *Scandinavian Journal of Educational Research*, *50*(4), 429-439. https://doi.org/10.1080/00313830600823787

Fotheringham, A. S., Brunsdon, C., & Charlton, M. (2002). *Geographically weighted regression – The analysis of spatially varying relationships*. John Wiley & Sons Ltd.

Fotheringham, A. S., & Wong, D. W. (1991). The modifiable areal unit problem in multivariate statistical analysis. *Environment and Planning A*, *23*(7), 1025-1044. https://doi.org/10.1068/a231025

Gallego, F. A., Rodriguez-Sickert, C., & Sauma, E. (2010). The political economy of school size: Evidence from Chilean rural areas. *Working Paper IE-PUC*, (375). https://doi.org/10.2139/ssrn.1718706

Gawryszewski, A. (2005). *Ludność Polski w XX wieku*. Warszawa: Instytut Geografii i Przestrzennego Zagospodarowania PAN.

Gershenson, S., & Langbein, L. (2015). The effect of primary school size on academic achievement. *Educational Evaluation and Policy Analysis*, *37*(1 suppl), 135S-155S. https://doi.org/10.3102/0162373715576075

Giambona, F., & Porcu, M. (2018). School size and students' achievement. Empirical evidences from PISA survey data. *Socio-Economic Planning Sciences*, *64*, 66-77. https://doi.org/10.1016/j.seps.2017.12.007

Greene, W. H. (2019). *Econometric analysis* (8th global ed.). Pearson Education.

Heffner, K. (2016). Proces suburbanizacji a polityka miejska w Polsce. In T. Marszał (Ed.), *Miasto–region–gospodarka w badaniach geograficznych. W stulecie urodzin Profesora Ludwika Straszewicza* (pp. 75-110). Łódź: Wydawnictwo Uniwersytetu Łódzkiego.

Herbst, M. (2012). *Edukacja jako czynnik i wynik rozwoju regionalnego*. Wydawnictwo Naukowe Scholar.

Howley, C. (1995). The Matthew principle: A West Virginia replication. *Educational Policy Analysis Archives*, *3*(18), 1-25.

Jacob, V., Kochar, A., & Reddy, S. (2008). School size and schooling inequalities. *Stanford Center for International Development Working Papers, 354*.

Jezierski, A., & Leszczyńska, C. (2003). *Historia gospodarcza Polski*. Warszawa: Wydawnictwo Key Text.

Kiełczewska-Zaleska, M. (1970). Rozmieszczenie wiejskich osiedli rozproszonych w Polsce. *Przegląd Geograficzny*, *42*(2), 225-234.

Kiełczewska-Zaleska, M. (1972). *Geografia osadnictwa*. Warszawa: Wydawnictwo Naukowe PWN.

Kosiński, L. (1963). *Procesy ludnościowe na Ziemiach Odzyskanych w latach 1945-1960*. Warszawa: Państwowe Wydawnictwo Naukowe.

Kotlinska, J., Nucinska, J., & Bednarz, J. (2021). Education financing: Explaining the expenditure concentration gap between the state and local governments in Poland 2008-2019. *European Research Studies Journal*, *24*(2), 564-578. https://doi.org/10.35808/ersj/2143

Kučerová, S., & Kučera, Z. (2009). Changes in the rural elementary schools network in Czechia during the second half of the 20 century and its possible impact on rural areas. *European Countryside*, *1*(3), 125-140. https://doi.org/10.2478/v10091/009-0011-7

Lee, V., & Loeb, S. (2000). School size in Chicago elementary schools: Effects on teachers' attitudes and students' achievement. *American Educational Research Journal*, *37*(1), 3-31. https://doi.org/10.2307/1163470

Leithwood, K., & Jantzi, D. (2009). A review of empirical evidence about school size effects: A policy perspective. *Review of Educational Research*, *79*(1), 464-490. https://doi.org/10.3102/0034654308326158

Majdzińska, A. (2018). Obszary depopulacyjne w Polsce w latach 2002-2014. *Studia Demograficzne*, *173*(1), 23-54.

McGuire, K. (1989). School size: The continuing controversy. *Education and Urban Society*, *21*(2), 164-174. https://doi.org/10.1177/0013124589021002005

McKenzie, P. (1983, April 11-15). The distribution of school size: Some cost implications. Paper presentation. Annual Meeting of the American Educational Research Association, Montreal, Quebec, Canada.

Meloche, J. P., & Shearmur, R. (2010). Emploi dans le secteur public et croissance économique régionale au Canada: Quelques limites inhérentes aux régressions spatiales (Public sector employment and regional economic growth in Canada: Some limitations of spatial regressions). *Canadian Journal of Regional Science*, *33*(1), 101-114.

Ozga, W. (1974). *Rozmieszczenie szkół w Polsce. Analiza, wnioski, propozycje*. Warszawa: Wydawnictwa Szkolne i Pedagogiczne.

Piwowarski, R. (1992). *Sieć szkolna a dostępność kształcenia*. Warszawa: Wydawnictwo Naukowe PWN.

Piwowarski, R. (2000). *Szkoły na wsi – edukacyjne wyzwanie*. Instytut Badań Edukacyjnych.

Piwowarski, R. (2006). *Edukacja z perspektywy lokalnej i międzynarodowej*. Instytut Badań Edukacyjnych.

Piwowarski, R. (2008). *Modele edukacji dla potrzeb koncepcji przestrzennego zagospodarowania kraju*. Warszawa: Ministerstwo Rozwoju Regionalnego.

Rosner, A. (2010). Przestrzenne zróżnicowanie poziomu rozwoju społeczno-gospodarczego obszarów wiejskich a dynamika przemian. In M. Stanny & M. Drygas (Eds.), *Przestrzenne, społeczno-ekonomiczne zróżnicowanie obszarów wiejskich w Polsce* (pp. 11-27). Instytut Rozwoju Wsi i Rolnictwa PAN.

Suchecki, B. (Ed.), (2010). *Ekonometria przestrzenna. Metody i modele analizy danych przestrzennych*. Warszawa: Wydawnictwo C.H. Beck.

Szmytkie, R., & Tomczak, P. (2020). Wiejska sieć osadnicza Polski w XXI wieku. *Studia Obszarów Wiejskich*, *57*, 89-113. https://doi.org/10.7163/SOW.57.6

Szulc, H. (1995). *Morfogeneza osiedli wiejskich w Polsce*. Prace Geograficzne nr 163. Instytut Geografii i Przestrzennego Zagospodarowania PAN.

Szymańska, D. (2008). *Geografia osadnictwa*. Państwowe Wydawnictwo Naukowe.

Szymański, M. (1978). *Modernizacja systemu szkolnego na wsi*. Państwowe Wydawnictwo Naukowe.

Wdowicka, M., & Mierzejewska, L. (2012). Chaos w zagospodarowaniu przestrzennym stref podmiejskich jako efekt braku zintegrowanego systemu planowania (na przykładzie strefy podmiejskiej Poznania). *Problemy Rozwoju Miast*, (1), 40-52.

Article first received • 15 January 2025
Article accepted • 12 May 2025