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URBAN–RURAL DIFFERENCES IN PRIMARY SCHOOL RESOURCES IN CHINA: A CASE STUDY OF YUNCHENG COUNTY

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Abstract. Resources in primary schools can be classified into three types: campus, teaching, and community resources. Urban–rural differences in the resources of Chinese county schools, which are triggered by population migration and residents' preference for high-quality schools, are a common phenomenon emerging in the context of rapid urbanization. Despite the negative effects of these resource differences on social sustainability and the increasing need to comprehensively analyze urban–rural differences in school resources, to date there has not been an effective analytical framework for resolving these issues. To address this research gap, this study develops a method using the entropy-based Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), spatial analysis, and statistical analysis for assessing resource equity in primary schools by means of the relative proximities of resources. The resource differences between urban and rural primary schools are quantitatively investigated through taking Yuncheng County as a case study. The urban–rural differences in the three types of resources are discovered and presented according to geographical location. The research findings make contributions to understanding the unbalanced distribution of school resources, promoting equity in education, and improving the social sustainability of counties. Additionally, the analytical framework has the potential to be extended to analyzing urban–rural resource differences in secondary or high schools.

Keywords: equity in education, primary school, school resource, social sustainability, TOPSIS, urban–rural difference.

Introduction

In the context of the rapid urbanization of China, an increasing number of people have been migrating from villages into towns in their counties for employment, education, and lifestyle reasons (He et al., 2019). Counties and urban districts of cities are the basic government divisions for public administration of their localities, including children's education, people' health and aging, changes in land use, housing, employment, and other aspects. Unlike urban districts, a significant number of families in counties have resided in the same villages for generations and lived by farming the land around their villages. According to the latest national census of China, there are approximately 1,800 counties where about half of the Chinese population lives (Bureau of Statistics, 2022). The continuous migration of populations inside counties results in uneven demand in of urban versus rural areas for various public facilities, most of which are rapidly developed in a county capital and its other towns but undergo no significant change or even deteriorate in the villages. These urban–rural differences in Chinese counties may accelerate the decline of villages and interrupt the process of urban–rural integration (Sun et al., 2021).

The clear polarization of urban and rural development in Chinese counties can be seen in their educational facilities (Luo et al., 2022), in particular, in primary schools. The movement of families with school-aged children from villages to towns has doubly challenged the education departments in counties, requiring increased construction costs for new primary schools in towns and increased operating costs per student in rural primary schools. On one hand, children require accessibility of primary schools (Jing et al., 2022). On the other hand, however, primary schools are unaffordable in terms of operating expenditure and are forced to merge or close when the numbers of students are lower than the minimum needed. As a result, over the period from 2010 to 2020, the numbers of public primary schools in towns grew from 30,116 to 42,687 and those in rural areas dropped drastically from 210,894

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to 86,085 (Ministry of Education, 2020). The closure of primary schools in villages increases the travel distance for local pupils to reach neighboring schools (Long et al., 2020) and the expansion of primary schools in towns is constrained by the availability of school resources such as land and teachers (National Development and Reform Commission, 2020). The quality differences between urban and rural primary schools in counties will be increased as there exists a clear positive correlation between the density of school-aged children and school quality (Wu et al., 2020). For simplicity, in the rest of this paper primary schools that are located inside the boundary of a town are referred to as urban primary schools, abbreviated to UPSs, and primary schools that are located outside the boundary of a town are referred to as rural primary schools, abbreviated to RPSs.

A number of school resources are required for operating a primary school and insufficiency or ineffectiveness in one resource can make a school unsustainable. So far, extensive research on school resources in China has been conducted such as studies on the shortage of high-quality teachers in rural schools (An, 2018; Li et al., 2020), the accessibility of schools (Long et al., 2020), and the impacts of rural school consolidation (Hannum & Wang, 2022). Resource equity in urban versus rural primary schools has more significant effects on the social sustainability of a county than in other schools because of the fundamental role of primary schools in education and communities (Jing et al., 2022). Different school resources, such as teachers, campuses, and the accessibility determined by the geographical location of schools and settlements, have their own attributes. The traditional classification does not consider the attributes of school resources affected by the process of urbanization (Echazarra & Radinger, 2019). It is difficult to reflect these attributes in quantitative analysis based on the traditional classification. There has been a growing need to quantify the urban–rural differences in terms of a new classification of school resources to assess resource equity, gain insight into the status quo of school resources, and propose feasible public policies to reduce the negative effects. Although urban–rural differences in primary school resources are often observed, perceived, and discussed, there is no analytical framework and new classification of school resources to analyze urban–rural differences in primary school resources quantitively and provide insight into the status quo of primary school resources in the existing literature. To address the above-mentioned research gap, this study aims to develop a quantitative analytical framework of urban-rural differences in primary school resources. Following this Introduction section, a literature review on urban–rural differences in primary school resources and resource quantification is presented to point at the scope and breadth of the consequence of educational resource inequality. This is followed by determining the school-resource indicators and reclassifying the types of school resources in Section 2. The next section elaborates and illustrates the three steps for the development of the quantitative analytical framework. First, the resources in primary schools are quantified based on relative proximity using the entropy-based Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), which is generally employed in a multi-indicator assessment (Juan et al., 2021). Second, the relative proximities for all primary schools and their kernel density estimations are calculated and presented in one geographical map to identify the resource-rich areas. Third, the relative proximities of the primary schools are grouped and compared in a scatter plot using two-sample Kolmogorov–Smirnov tests to analyze the resource differences between UPSs and RPSs. In Section 4, the proposed analytical framework is examined in an empirical study by assessing the resource equity in primary schools in Yuncheng County, in the south-west of China's Shandong Province, as a case study to test its effectiveness. The calculation outcomes comprehensively and accurately reflect resource equity by illustrating the resource differences in urban versus rural primary schools and propose the need for support to facilitate equity in school education and improve social sustainability. Section 5 covers discussion on potential influences of the administration system of Yuncheng County and the types, attributes, and stakeholders of its educational resources on the case study results. The last section summarizes the outcomes and limitations of this study.

1. Literature review

1.1. Urban–rural differences in primary school resources

The differences in diverse resources between urban and rural primary schools caused by the rapid urbanization in the counties of China can be conceptualized as urban–rural differences in primary-school resources, which creates the coexistence of resource lost and resource concentrated areas within geographical locations. The resource differences between urban and rural schools in OECD countries have been verified by comparing diverse statistical data from national governments, the forms of which vary according to countries and time periods (Echazarra & Radinger, 2019). Resource differences between urban and rural primary schools have negatively influenced social sustainability. The justice and equity associated with the distribution of resources, employment, education, and the provision of basic infrastructure and services have been identified as important aspects of social sustainability (Yıldız et al., 2020). Social sustainability is a critical component of a community's wellbeing and longevity (Pradhananga & ElZomor, 2023). In the context of social sustainability, the influence of the equity of school resources on educational services and the daily life of residents has expanded. For instance, the safety level of educational facilities has a direct correlation with the investment in education resources (Wang et al., 2022). Moreover, the impacts of learners' experience as influenced by educational resources on their lives are extensive and long term, and some studies have even found that there is a relationship with health (Banerjee et al., 2022). The attention of city planners and policymakers alike should be on those goals that come under the banner of social sustainability, such as educational resource equity, especially when designing new human settlements or retrofitting existing ones (Sodiq et al., 2019).

1.2. Resource quantification

Choosing a suitable model to quantify school resources is important. The Gini coefficient and concentration index are often used to measure the equality of allocation of resources such as health resources (Sun & Luo, 2017) and public facilities (Tahmasbi et al., 2019). Both two methods are single-indicator models in determining whether a resource is allocated fairly or not. The multi-agent system is widely used in the virtualization and simulation of the allocation of facilities (Yu et al., 2018). Data envelopment analysis is to measure system efficiency through input and output factors (Sarah & Khalili-Damghani, 2019). Principal component analysis uses the concept of dimensional reduction to convert multiple indicators into a few comprehensive indicators (Zhang et al., 2011). This method requires a high cumulative contribution rate of the first few principal components. The TOPSIS was first put forward by Hwang and Yoon in 1981 and then expanded as the entropy-based TOPSIS method (Kaynak et al., 2017). The entropy-based TOPSIS method is widely applied in multiple-indicator evaluation in different disciplines with satisfactory results, such as the comparison of sustainability models in the development of electric vehicles (Samaie et al., 2020) and the assessment of sustainable urban development (Foroozesh et al., 2022). Additionally, the limitation of school resources means that it is necessary to use a relative standard to measure the resource allocation of each school within a study area. The entropy-based TOPSIS method is a sorting model based on relative closeness to the ideal solution for each indicator. A practical problem in this resource assessment method is determining the weights of indicators when comprehensively scoring individual samples. This problem is solved by using the entropy-based TOPSIS approach, which combines the TOPSIS method with the information entropy method (Chen, 2019). Therefore, it is suitable for developing a resource assessment method for quantifying the resources of primary schools. The main principle of the TOPSIS method is to calculate a quantitative score for each sample by integrating multiple attribute indicators to achieve a comprehensive assessment of the overall samples (Kaynak et al., 2017). The relative resource assessment of each primary school is achieved by mapping the resource assessment indicators of each primary school based on the relative distance from the two ideal solutions in a given area. One of the ideal solutions is called the positive ideal solution for school resources in a given study area and consists of the optimal values of each indicator. The other is called the negative ideal solution and is composed of the worst values of each indicator. The two ideal solutions comprise the maximum and the minimum values of all indicator vectors, which are the relative standards for calculating the relative resource proximities of all primary school resources (Kaynak et al., 2017).

2. School-resource indicators and types

2.1. School-resource indicators

School-resource indicators are the specific, observable, and measurable characteristics of school resources and are important for decision-makers in accounting for and monitoring the balanced development of school resources. To be more specific, these indicators allow comparison between primary schools in terms of school resources. For this research study, the school-resource indicators are determined based on the existing literature, informed by valuable comments and amendments made within the literature. A selected list of 10 school-resource indicators and the corresponding references is given in Table 1. These 10 school-resource indicators jointly characterize the overall resources in primary schools.

In a study on rural schools of OECD countries, the built environment and human, financial, and material resources were all recognized as integral components of school resources in creating a rich teaching and learning environment (Echazarra & Radinger, 2019). These components are particularly important when distinguishing between urban and rural schools. Additionally, school land is a school resource that cannot be ignored in comprehensive resource quantification. School land can effectively differentiate between the resources occupied by each primary school in a large-scale spatial reorganization (Sun et al., 2021). The areas of school land, buildings, green space, and playgrounds characterize the land and

Table 1. School-resource indicators and types

Type	Indicator	References
Campus resources	School land area	Sun et al. (2021)
	Building area	Echazarra and Radinger (2019); Hassanain et al. (2022)
	Playground area	Hassanain et al. (2022)
	Green space area	Hassanain et al. (2022)
Teaching resources	Number of fixed assets (furniture and equipment)	Echazarra and Radinger (2019); Mansor et al. (2022)
	Number of teachers	Echazarra and Radinger (2019); Mansor et al. (2022)
	Number of reading books	Echazarra and Radinger (2019); Mansor et al. (2022)
Community resources	Commuting distance	He and Giuliano (2018)
	Coverage radius	Sumari et al. (2019)
	Number of pupils	Hannum and Wang (2022)

built environment resources (Hassanain et al., 2022). The number of teachers, the cost of furniture and equipment, and the language and literacy materials such as reading books represent the human, financial, and material resources, respectively (Mansor et al., 2022). Moreover, low spatial accessibility and limited pupil resources are critical factors for consideration which highlight proper delineation of the context in which rural schools operate (Echazarra & Radinger, 2019). From the perspective of spatial accessibility, there are two key indicators. The first is the commuting distance, which is described as the average actual travel distance from all settlements in a school district to the primary school (He & Giuliano, 2018). The second indicator is the coverage radius, which refers to the straight-line distance from the furthest settlement in a school district to the primary school, often used in a school site-selection process (Sumari et al., 2019). These two indicators, combined with the number of pupils, characterize the spatial aggregation of pupils in a school district (Hannum & Wang, 2022).

2.2. School-resource types

Considering the differences in resource attributes, the 10 school-resource indicators are classified into three types: campus, teaching, and community resources, as shown in Table 1. The first type refers to the land and built environment resources constructing the physical environment of a primary school and is named campus resources. These school resources reflect the essential components for providing education services that are directly informed by public policies (Chow et al., 2019). Due to this immutable attribute, the adjustment of campus resources usually lags behind the movement of pupils (Sun et al., 2021). The national government of China has promulgated a series of public policies to encourage the construction of physical environments for school facilities in the past few years (Ministry of Housing and Urban-Rural Development, 2018; National Development and Reform Commission, 2020; Shandong Provincial Department of Education, 2008). In a recent Chinese national notice issued in 2020, campus resources in counties remain the focus of school-resource allocation (National Development and Reform Commission, 2020).

The second type of school resources is teaching resources and this refers to the human, financial, and material resources provided for teaching (Pulker & Kukulska-Hulme, 2020). Due to the differences in socio-economic conditions, there is a significant gap in the teaching resources of schools between areas of high and low socio-economic status (Echazarra & Radinger, 2019). Highly educated teachers and diverse educational funds tend to gather in towns to form high-quality schools in China (An, 2018). In contrast, less educated teachers and limited educational funds usually characterize villages, which leads to poor quality schools (An, 2018).

The third type of school resources, called community resources, relates to the geographical location of a primary school and its spatial relationship with surrounding residential settlements in the school district. In China, every public primary school is assigned to a specific school district. As such, the availability of community resources as reflected in the number of pupils and commuting distance in a school district affects the enrolment in a primary school, commuting costs, and operating costs per pupil (Sumari et al., 2019).

In China, specific separate departments oversee and manage the three types of school resources (campus, teaching, and community resources) to achieve equity of education and advance social sustainability. School land, buildings, green space, and playgrounds are planned and constructed by the Planning Department (Chow et al., 2019). Teachers, furniture and equipment, and language and literacy materials, which are the essential school resources directly determining the quality of education services, are managed and supervised by the Education Department (Li et al., 2020). Commuting distance, coverage radius, and number of pupils, subject to limiting factors such as population density and age structure, are normally measured and allocated by the Planning Department in the selection of primary school sites. In the operation management of school facilities, the Education Department has responsibility for maintaining an equal and effective learning environment by adjusting the school districts on an ongoing basis as required. The separate management of school resources by distinct government departments in China further strengthens this classification of school-resource types. However, such a fragmented system of school-resource management by separate authorities has exacerbated the urban–rural differences in primary schools to a certain extent.

3. Research methods

3.1. Quantifying resources in each primary school using entropy-based TOPSIS

An analytical framework is developed to explore the urban–rural differences in primary school resources in China by analyzing the resource differences between urban and rural primary schools, and identifying the resource-poor and resource-rich areas in a given study area, as shown in Figure 1. After determining the resource indicators, the resources occupied by each primary school are quantified as the relative proximities using entropy-based TOPSIS. The relative proximities of all primary schools and their kernel density estimations are calculated and presented in a thematic map to identify the resource-poor and resource-rich areas. Subsequently, descriptive statistics and two-sample Kolmogorov–Smirnov tests are employed to compare and verify resource differences between urban and rural primary schools.

In order to determine the contribution of each school-resource indicator to the relative proximity, information entropy is used to determine the entropy weights of the school-resource indicators based on the sample data.

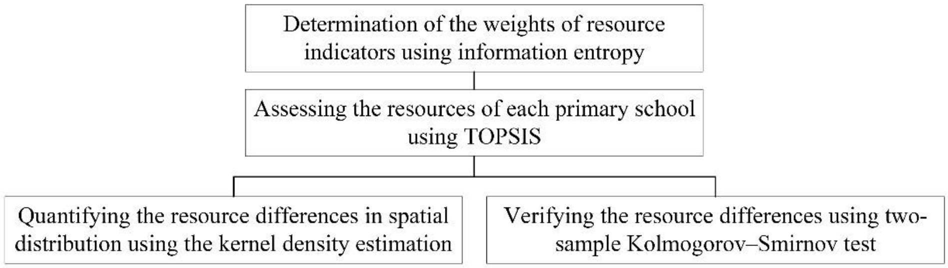

Figure 1. Procedure of analytical framework

To eliminate the differences between attributes in dimension and order of magnitude, so as not to change the diversity of the attribute data, a vector normalization method is applied to the school-resource indicators (Chen, 2019), normalizing r_{ij} to a_{ij} according to the following equation:

$$a_{ij} = r_{ij} / \sum_{i=1}^{m} r_{ij}. \quad (1)$$

The value of the j^{th} school-resource indicator of the i^{th} primary school is expressed as a_{ij}, where $i = 1,2,\cdots,m; j = 1,2,\cdots,n$; m is the number of primary schools in the study area; and n is the number of school-resource indicators.

The information entropy E_j of the j^{th} school-resource indicator is calculated by the following equation:

$$E_j = \frac{-\sum_{i=1}^{m} a_{ij} ln a_{ij}}{lnm}, \quad (2)$$

when $a_{ij} = 0, a_{ij} ln a_{ij} = 0$ is taken as convention (Cabrales et al., 2013).

The entropy weight of the j^{th} school-resource indicator is calculated by:

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{n} \left(1 - E_j\right)}. \quad (3)$$

The relative proximity characterizing the total resources of primary schools can be calculated and sorted according to the relative distances of the school-resource indicators from two ideal solutions. The weighted value of the j^{th} school-resource indicator of the i^{th} primary school v_{ij} can be obtained by integrating the normalized data and the entropy weights as follows:

$$v_{ij} = w_j a_{ij}. \quad (4)$$

The TOPSIS approach sets two ideal solutions for sample data with specific school-resource indicators. The value of a school-resource indicator expresses the amount of this school resource in a primary school. For the school-resource indicators with the–larger–the–richer attribute within a given monotonic interval, $max_i v_{ij}$ is selected as one component of the positive ideal solution, $v_j^+ = max_i v_{ij}$; while $min_i v_{ij}$ is selected as one component of the negative ideal solution, $v_j^- = min_i v_{ij}$. For the school-resource indicators with the–smaller–the–richer attribute within a given monotonic interval, $min_i v_{ij}$ is selected as one component of the positive solution, $v_j^+ = min_i v_{ij}$; while $max_i v_{ij}$ is selected as one component of the negative ideal solution, $v_j^- = max_i v_{ij}$. The positive ideal solution $\boldsymbol{v}^+$ and the negative ideal solution $\boldsymbol{v}^-$ are determined as follows.

$$\boldsymbol{v}^+ = \left\{ v_1^+, v_2^+, \cdots, v_j^+ \cdots, v_n^+ \right\}; \quad (5)$$

$$\boldsymbol{v}^- = \left\{ v_1^-, v_2^-, \cdots, v_j^- \cdots, v_n^- \right\}. \quad (6)$$

The relative distance D_i^+ of the resources for the i^{th} primary school from the positive ideal solution $\boldsymbol{v}^+$ and the relative distance D_i^- of the resources for the i^{th} primary school from the negative ideal solution $\boldsymbol{v}^-$ can respectively be calculated by:

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2}; \quad (7)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}. \quad (8)$$

The relative proximity S_i. of the total resources in the i^{th} primary school can be calculated by the following equation:

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-}. \quad (9)$$

The relative proximity of the total resources in a primary school reflects the relative distances from the two ideal solutions. The smaller the distance to the negative ideal solution (D_i^-), the smaller the value of S_i and the lower the relative proximity of the total resources in primary school i. On the contrary, the greater the distance from the negative ideal solution (D_i^-), the greater the value of S_i and the higher the relative proximity of the total resources in the i^{th} primary school. The primary school with the highest relative proximity is the one whose indicators have the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution.

The normalized campus-resource, teaching-resource, and community-resource indicators, with their entropy weights, are respectively taken into Equations (5)–(9) to calculate the relative proximities for the three types of school resources. The relative proximities for the total resources and the three types of school resources associated with the geographical location of all primary schools are represented by four variables.

3.2. Spatial and statistical analysis of resource equity in primary schools

The urban–rural differences in school resources involve an aggregation process of school resources in geographical space; then antitative evaluation of this process using spatial analysis becomes the key to revealing the urban–rural differences. Kernel density estimation considers the decay impact of school facilities and allows enrichment of the information from a spatial scatter plot of primary schools to a smooth density surface covering all geographical locations incope of this study. Kernel density estimation has frequently been employed to estimate the probability density function of a random variable and form a geographical map. For example, a map was generated to express the popularity of the cultural ecosystem services of urban and peri-urban forests (Beckmann-Wübbelt et al., 2021). Kernel density estimation requires two parameters, namely, the bandwidth and the kernel function. The bandwidth is determined rding to the densities of primary-school points and the spatial scale of the research, and kernel density estimation adopts a quartic kernel function, which is one of the most commonly used functions (Sheather, 2004). The kernel density estimate is given by:

$$\lambda(s)=\sum_{i=1}^{n}\frac{1}{\pi r^2}k\left(\frac{d_{is}}{r}\right), \quad (10)$$

where: $\lambda(s)$ is the density at location s; r is the bandwidth of the kernel density estimation; and only points within r are used to $\lambda(s)$. $k\left(\frac{d_{is}}{r}\right)$ is the kernel function of the ratio between d_{is} and r. The quartic kernel function applied in this study is expressed as follows:

$$k(\frac{d_{is}}{r})=K(1-\frac{d_{is}^2}{r^2}), 0<d_{is}\le r; \quad (11)$$

$$k(\frac{d_{is}}{r})=0, d_{is}>r, \quad (12)$$

where $K=\frac{3}{\pi}$ is a scaling factor and its purpose is to ensure the total volume under the quartic curve is 1.

Geographical locations with a higher density denote the resource-rich areas. Density maps are generated to illustrate the urban–rural differences in primary schools by identifying the resource-rich areas using kernel density estimation in ArcGIS10.7.1 (Esri, 2018). The geographical maps of the kernel density estimation of the four sets of relative proximities clearly illustrate the status quo of the total resources and the three types of school resources.

The two-sample Kolmogorov–Smirnov test calculates the distance between the two empirical distribution functions formed by the relative proximities of the school resources for UPSs and RPSs, which is named the Kolmogorov–Smirnov statistic. The two-sample Kolmogorov–Smirnov test has been widely used to test whether two one-dimensional probability distributions differ, such as a comparison of mean suggested hospital travel times and distributions between two patterns (Olivier et al., 2022). The resource differences between UPSs and RPSs are verified by determining that the Kolmogorov–Smirnov statistics are beyond a threshold corresponding to an expected probability value. The Kolmogorov–Smirnov statistic takes the largest absolute difference between the empirical distribution functions of the first and second samples (Frey, 2012). The empirical cumulative distribution functions $F(x)$ and $G(x)$ are computed as follows:

$$F(X^1) = \mathrm{P}\ (X_i^1 \le \mathrm{x}) = k_1 / N_1, \ -\infty < \mathrm{x} < \infty; \quad (13)$$

$$F(X^2) = \mathrm{P}\ (X_i^2 \le \mathrm{x}) = k_2 / N_2; \quad (14)$$

where: X^1 and X^2 represent the observations from two samples; P ($X_i \le$ x) denotes the probability of observations less than or equal to X_i; k_1 and k_2 are the number of observations less than or equal to X_i^1 and X_i^2, respectively; and N_1 and N_2 are the total number of observations in the two samples.

The Kolmogorov–Smirnov statistic *KS* is calculated to validate the existence of the differences between the two empirical cumulative distribution functions $F(x)$ and $G(x)$. If the value of the Kolmogorov–Smirnov statistic exceeds the threshold at a significant level, then differences between the two functions exist. A result of above 99% probability of resource differences existing between UPSs and RPSs means the Kolmogorov–Smirnov statistic of the two samples is higher than the threshold of the Kolmogorov–Smirnov statistic corresponding to 99% probability. *KS* is defined as the maximum of the absolute difference between two empirical cumulative distribution functions, $F(x)$ and $G(x)$:

$$KS=max\left\{|F(X_i^1)-G\left(X_i^2\right)|\right\}, \quad (15)$$

where the empirical cumulative distribution functions $F(x)$ and $G(x)$ are computed for observations X_i^1 and X_i^2, respectively.

4. Case study

4.1. County selection for case study and data description

The selection of the case study county for this study mainly considered the following aspects. First, the selected county is experiencing the pressing issue of resource differences between UPSs and RPSs. Second, it is a typical area with towns of growing population and villages of declining population in the context of rapid urbanization. Third, the selection is based on a county that has a certain population size and population density, and a certain number of primary schools. Yuncheng County, located in the southwest of Shandong Province in the east coast of China, is a typical county suffering the pressing issue of resources differences between UPSs and RPSs. At the end of 2021, the urbanization rate of the permanent population was 49.1% according to the Yuncheng Bureau of Statistics (2021). By 2021, the population density was about 686 people per square kilometer and the permanent population was about 1.12 million (Yuncheng Bureau of Statistics, 2021).

Yuncheng County comprises 40 UPSs and 229 RPSs. For this study, the most important town in a county is the one where the local government is based, named the county town, while the others are called small towns. Of the 40 UPSs, 16 RPSs are in the county town of Yuncheng County, while 24 UPSs are in the 20 small towns. The 269 primary schools form a school network covering all villages and towns in Yuncheng County. The maximum average commuting distance in all the school districts is 3.4 kilometers and the maximum coverage radius is 5.2 kilometers. The data for the 10 school-resource indicators has been collected from two sources. The statistical data for primary schools has been obtained from the Education Department, while the distance data has been calculated using ArcGIS based on an overall urban–rural master planning map (2016–2030). All primary schools' attribute data is related to the geographical locations of the primary schools in ArcGIS. Figure 2 shows the geographical locations of the study area and the primary schools in Yuncheng County.

The maximum and minimum for each school-resource indicator are summarized in Table 2 as the relative standards used to calculate the relative proximities using entropy-based TOPSIS. It can be observed from the data presented in Table 2 that the maximums and minimums of the 10 school-resource indicators differ sharply. The school-resource indicators for the negative ideal solution are far lower than the lower limit of the normal size needed to maintain the operation of a primary school, while the indicators for the positive ideal solution are greater than the upper limit of the normal size (Ministry of Education, 2008). The capitals, talents, and built environment conditions are related to the level of regional socio-economic development in rapid urbanization (Hassan et al., 2019). Given the population migration from villages to towns and the influence of residents' preference for high-quality schools, the school resources between UPSs and RPSs have dramatically changed (Sun et al., 2021). The interconnection between these diverse school resources is made more complex with the differences in primary schools. The 10 school-resource indicators quantify the resources in the primary schools in Yuncheng County. For convenience of description, the indicators which have the–larger–the–richer attribute are denoted by + and the indicators which have the–smaller–the–richer attribute are expressed by – in the attribute column.

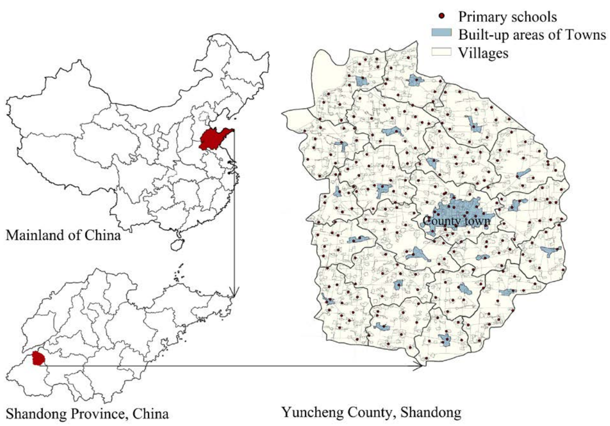

Figure 2. Location of study areas and geographical locations of primary schools in Yuncheng County

4.2. Measurement of resources in primary schools in Yuncheng County

The information entropy $\boldsymbol{E_j}$, the entropy weights $\boldsymbol{w_j}$, the positive ideal solution $\boldsymbol{v}^+$, and the negative ideal solution $\boldsymbol{v}^-$ for each school-resource indicator are calculated and shown in Table 3. Information entropy measures the expected overall events, so the larger the information entropy, the less information it contains and the smaller the entropy weight is. Among all the school-resource indicators, the entropy weight for the cost of furniture and equipment is the largest, followed by the number of pupils, the number of reading books, the number of teachers, and the amount of green space in turn, which are the five indicators with entropy weights over 0.1. Their high entropy weights indicate that the values for these five school-resource indicators vary substantially between the 269 primary schools. On the contrary, the commuting distance and the coverage radius are the only two indicators

Table 2. Maximum and minimum of each school-resource indicator

Type	Indicator	Maximum	Minimum	Attribute
Campus resources	School land area (m^2)	55575	1200	+
	Building area (m^2)	27002	250	+
	Playground area (m^2)	18784	300	+
	Green space area (m^2)	21202	50	+
Teaching resources	Number of fixed assets (furniture and equipment) (yuan)	6961200	12000	+
	Number of teachers (persons)	199	2	+
	Number of reading books (books)	111785	220	+
Community resources	Commuting distance (m)	3388	245	–
	Coverage radius (m)	5190	497	–
	Number of pupils (persons)	4338	20	+

Table 3. Key parameters of school-resource indicators

Type	Indicator	E_j	w_j	v^+ (10^{-5})	v^- (10^{-5})
Campus resources	School land area (m^2)	0.9720	0.0565	94.26	2.04
	Building area (m^2)	0.9523	0.0961	327.34	3.03
	Playground area (m^2)	0.9670	0.0665	103.34	1.65
	Green space area (m^2)	0.9401	0.1206	476.05	1.12
Teaching resources	Cost of furniture and equipment (yuan)	0.9150	0.1712	925.10	1.59
	Number of teachers (persons)	0.9367	0.1276	452.38	4.55
	Number of reading books (books)	0.9362	0.1286	450.90	8.87
Community resources	Commuting distance (m)	0.9798	0.0468	4.58	47.51
	Coverage radius (m)	0.9768	0.0408	2.56	55.61
	Number of pupils (persons)	0.9279	0.1452	57.00	4.12

with entropy weights lower than 0.05, which indicates that the values for primary schools in these two indicators are relatively similar. The entropy weight of school land area is slightly higher than for these two. The sum of the entropy weights for the indicators in the three school-resource types ranked in descending order are: teaching resources, campus resources, and community resources, whose values are 0.4274, 0.3398, and 0.2328, respectively. The difference between the positive and negative ideal solutions, after normalization and weighting, determines the scale of the metric, which can be compared between indicators. The larger the range, the better the discrimination between primary schools. Sorted by the difference from large to small, the top three indicators are the cost of furniture and equipment, the number of pupils, and the number of reading books.

Figure 3 reflects both the relative proximities of each primary school and their kernel density estimation in the geographical location of Yuncheng County. Four geographical maps of the relative proximities of the total resources and the three types of school resources are generated in ArcGIS to reflect the status quo of school resources, as shown in Figure 3(a–d). A bandwidth of 4,709 meters is proposed for the calculations to consider the distance between primary schools. The points with different colors indicate the primary schools with relative proximities of 10 intervals using ArcGIS10.7.1 (Esri, 2018). The density value at each location, which is estimated based on the relative proximities of all primary schools, is also shown in Figure 3. The continuous surfaces of the density are generated to clearly identify the resource-rich areas using ArcGIS10.7.1 (Esri, 2018).

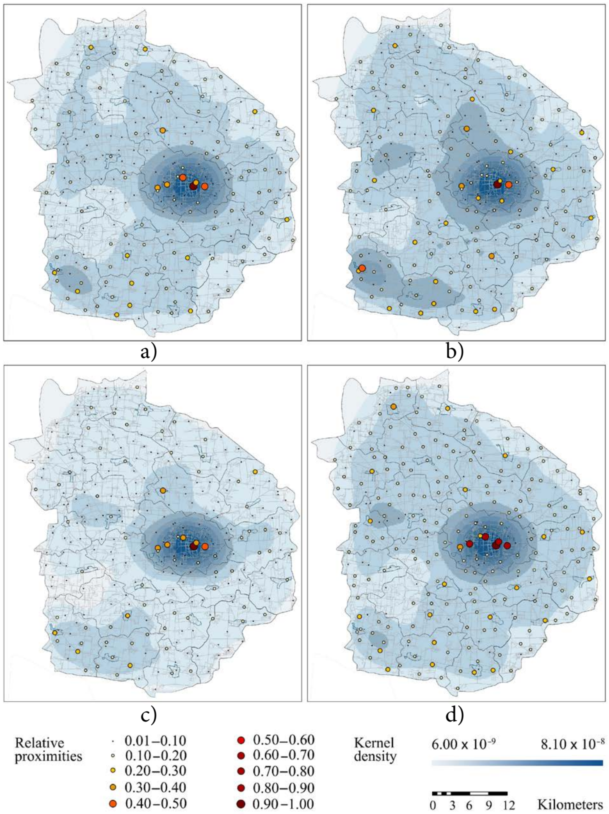

Figure 3. Geographical locations of primary schools with concentration of school resources: a) Total resources; b) Campus resources; c) Teaching resources; d) Community resources

The geographical locations of primary school points with different relative proximities are clearly illustrated in Figure 3. There are 164, 146, 195, and 67 primary schools with relative proximities below 0.1 in Figures 3(a–d), respectively. Associated with the relative standard, these primary schools with relative proximity below 0.1 are all small primary schools. There are 19, 26, 12, and 28 primary schools with relative proximities above 0.2, of which 6, 4, 6, and 7 are in the county town, 7, 9, 3, and 13 are in small towns, and 6, 13, 3, and 8 are in villages. Most importantly, the peak points of the three sets of relative proximities overlap at one school in the county town. In addition, five primary schools for community resources but only one primary school for campus resources have relative proximities above 0.5 in the county town. This indicates, to some extent, how the investment in campus resources for primary schools in the county town has begun to fall short.

Figures 3(a–d) show the county town contains the resource-rich areas. Although some small towns have a few advantages in school resources over most villages, especially in terms of the value of their relative proximities, according to the kernel density estimation no obvious sub-centers of the total resources or the three types of school resources appear in small towns. As indicated in the figure, the school resource gradients decrease from the center to the periphery. Teaching resources have the largest decreasing gradient, followed by campus resources and community resources. The geographical locations of all small primary schools show a lower density value. The villages near the administrative border are the areas with the most severe decline in school resources.

4.3. Comparison of urban–rural differences in school resources in Yuncheng County

The relative proximities of the four variables are respectively grouped in pairs in terms of UPSs and RPSs to form eight sets of relative proximities. A scattered boxplot for the eight sets of relative proximities of school resources is developed using R studio to illustrate the resource differences between UPSs and RPSs by a pairwise comparison of the four variables, as shown in Figure 4. The eight sets of relative proximities are sorted in descending order to represent the resources of UPSs and RPSs more clearly. The relative proximities of school resources for UPSs and RPSs are divided into four intervals, where the interval value is 0.25. The boxplots (Figure 4) reflect the distribution of the relative resource proximities based on five statistics: maximum value, first quartile, median, third quartile, and minimum value.

As shown in Figure 4, compared with the relative proximities of school resources for RPSs, the relative proximities of school resources for UPSs cover a wider distribution range, which indicates that the differences between the 40 UPSs are significant. Specifically, the relative proximities of the total resources for UPSs are spread over 0.042–0.979, while those for RPSs are concentrated over 0.028–0.279. Figure 4 also illustrates that the relative proximities of the campus, teaching, and community resources for RPSs are concentrated over 0.010–0.286, 0.005–0.282, and 0.054–0.294, respectively, all on the side of the negative ideal solution. The intervals of the relative proximities for the campus, teaching, and community resources for UPSs are 0.029–0.962, 0.005–1, and 0.078–0.967, respectively. In addition, the relative proximities of all RPSs in Yuncheng County are below 0.3. There are significant differences between UPSs. Notably, the relative proximities of the total resources and the three types of school resources in the first place are much larger than those in the second place. The maximum value, first quartile, median, third quartile, and minimum value of the relative proximities of UPSs are higher than those of the relative proximities of RPSs for the total resources and the three types of resources. The five statistics indicate that teaching resources have the lowest value for relative proximity of the three types of resources. Specifically, teaching resources of RPSs have the lowest value of all the five statistics in the eight sets of relative proximities. Of the 164 primary schools with relative proximities of total resources below 0.1, 10 are UPSs, accounting for 25% of the 40 UPSs. The remaining 154 are all RPSs, accounting for 67% of the 229 RPSs. There are 146, 195, and 67 primary schools with relative proximities of campus, teaching, and community resource below 0.1, respectively, of which 11, 11, and 6 are UPSs, respectively. Compared with the three types of school resources, the relative proximities of teaching resources cover the widest distribution range and have the highest median.

Although the scatter plot illustrates the characteristics of school resources in UPSs and RPSs, there is still insufficient evidence to verify whether there is a significant resource difference between UPSs and RPSs. The two-sample Kolmogorov–Smirnov test is adopted to analyze the resource differences between UPSs and RPSs in the total resources and the three types of school resources from the perspective of a cumulative distribution function. Figure 5 illustrates the Kolmogorov–Smirnov statistic for the relative proximities of school resources between UPSs and RPSs, as the largest absolute difference between the two distribution functions. The red and blue lines correspond to a cumulative distribution function for the relative proximities of school resources in UPSs and RPSs, respectively, and the black line segment is the Kolmogorov–Smirnov statistic. For the two samples consisting of 40 UPSs and 229 RPSs, the statistical probability of a different functional distribution existing between UPSs and RPSs is above 99%, which means the threshold of the Kolmogorov–Smirnov statistic is above 0.28. Figure 5 shows that the four Kolmogorov–Smirnov statistics of total, campus, teaching, and community resources are much larger than 0.28, which indicates that the relative proximities of school resources for UPSs and RPSs have significant differences in functional distribution. The Kolmogorov–Smirnov statistic for teaching resources is the largest, followed by community resources, and then campus resources. Interestingly, after integrating the three types of school resources, the difference between UPSs and RPSs for the total resources increases.

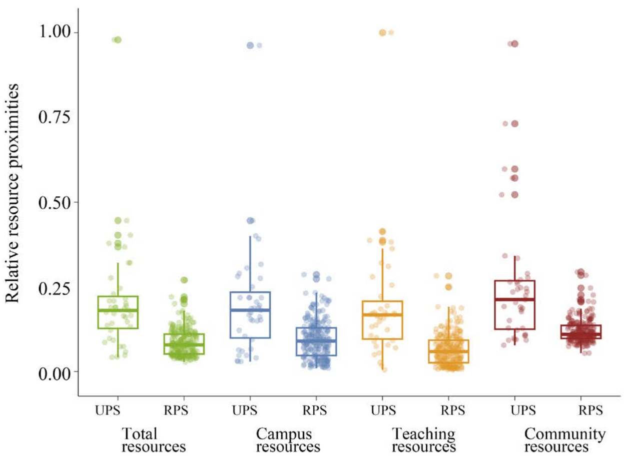

Figure 4. Scattered boxplots of relative resource proximities

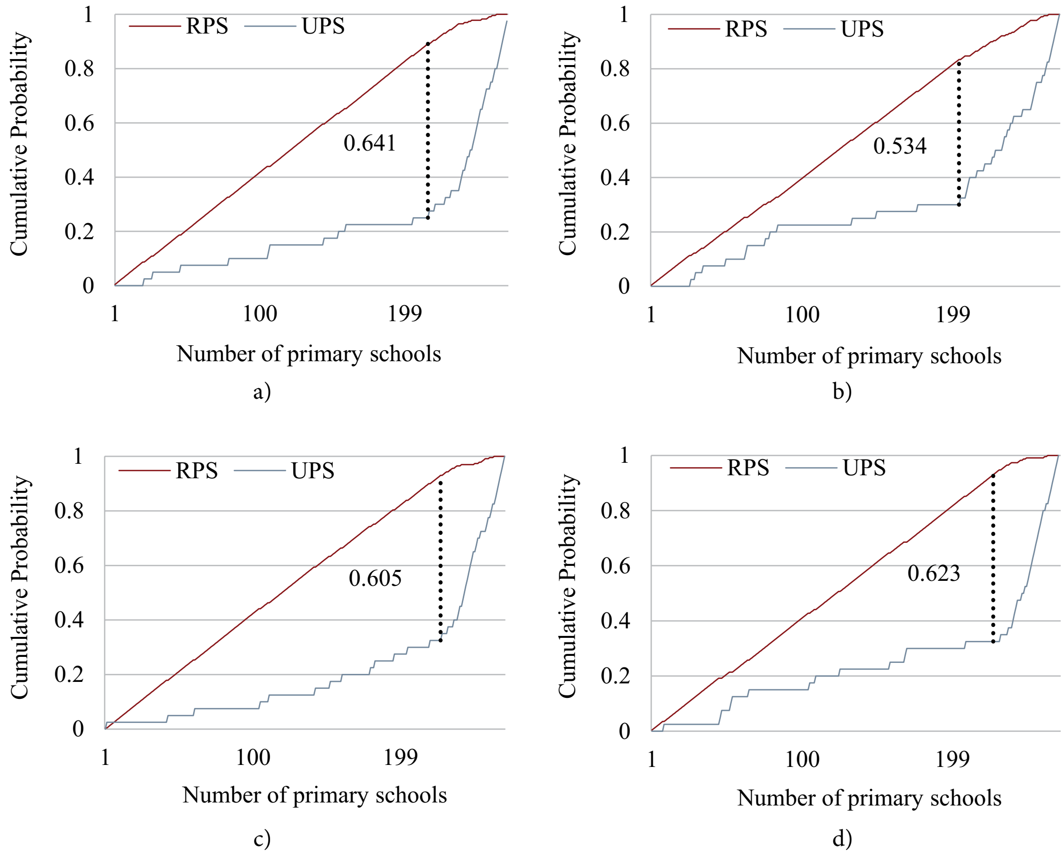

Figure 5. Kolmogorov–Smirnov statistic corresponding to two empirical distribution functions: a) Total resources; b) Campus resources; c) Teaching resources; d) Community resources

5. Discussion

The aggregation of school resources in primary schools in Yuncheng County is illustrated by the geographical maps of relative proximities and their kernel density estimations in Figure 3. The urban–rural differences in primary schools are further analyzed through the descriptive statistics in Figure 4 and the two-sample Kolmogorov–Smirnov test statistics in Figure 5. This study proposes that the nature of the differences in school resources lies in the resource differences between UPSs and RPSs. From these results, the study concludes that the hierarchical administrative system of a geographical county is essential, with the need for a hierarchical structure of urban–rural systems to be established given the rapid urbanization of counties (Cui et al., 2022). Generally, small towns are marginally better than villages but much poorer than county towns in terms of economic development level, living environment quality, and public service performance. County towns, small towns, and villages form an invisibly stratified system of school resources in a county (Cui et al., 2022). In this stratified system, there is notable polarization of both the total resources and the three types of school resources, which presents as differences between the large number of RPSs and the small number of UPSs in the county town. Unlike the RPSs, there are still differences between the school resources of the UPSs in Yuncheng County. School resources are concentrated in a few primary schools in the county town, which indicates that school resources tend to gather in well-developed county towns rather than in small towns in the hierarchical administrative system (Yin et al., 2021). In addition, primary schools in small towns cannot form a clustering distribution as small towns are evenly scattered across the county and usually have only one or two primary schools. Therefore, no obvious resource-rich areas emerge in small towns.

The three types of school resources have their own characteristics and interact with each other to construct the urban–rural differences in school resources. This study reveals that the polarization of teaching resources is the most significant of the three types of school resources where these resources are sensitive to socio-economic status. For instance, due to limited financial support, the number of rural teachers has decreased substantially (Li et al., 2020). There is still a gap between the small towns and the county town, as well as the villages. Importantly, teaching resources affect the teaching quality of primary schools, which is the most referenced factor in school choice (He & Giuliano, 2018). Thus, the loss of teaching resources in RPSs influences residents' preferences and further worsens the loss of pupils. A study showed that school land is oversupplied in RPSs and undersupplied in UPSs (Sun et al., 2021). This is not completely consistent with this paper's research findings on school land, where campus resources in most RPSs are much lower than in some UPSs. The reason is that the construction of buildings, playgrounds, and green spaces in RPSs is lower than in some UPSs. Additionally, there is a shortage of campus resources in county towns. The adjustment and extension of school land in the county town involve the demolition and reconstruction of adjacent plots. It is difficult for the Public Education Finance Department to afford the costs of demolition and relocation (Sun et al., 2020). Furthermore, the distribution of community resources is the result of a trade-off between commuting distance and school quality (He & Giuliano, 2018). The findings in this study provide evidence that community resources are also concentrated in the primary schools of small towns in addition to the county town. Although many households are willing to sacrifice accessibility in exchange for high-quality education services, the closure of RPSs has caused difficulties for some other residents (Echazarra & Radinger, 2019). In the foreseeable future, it would be unrealistic to concentrate all the population and school resources of a county in the county town. It is necessary to strengthen the school resource investment of small towns, especially in teaching resources. The emergence of new digital technologies in the era of the fourth industrial revolution presents a turning point that may, to a certain extent, weaken the geospatial differences in primary school resources through blockchain and the Internet of Things (Brandín & Abrishami, 2021). However, the new digital technologies will not prevail in both urban and rural areas of China in the near future.

There is a multi-stakeholder game behind the urban–rural differences in school resources. This game is characterized by the local government, which seeks to maximize the value of public education funding and actively practices economies of scale in the operation of primary schools. However, this game ignores marginal benefits and residents' benefits (Hilber & Mayer, 2009). The consolidation of primary schools is an intervention of local government in school resources under the influence of economies of scale (Hannum & Wang, 2022). The reduced school operating costs become the increased educational costs for households (Hannum & Wang, 2022), which directly influences parents' selection of high-quality schools at an affordable cost. The uneven distribution of school resources also provides real estate developers with the opportunity to capitalize on education dividends in commercial housing (Chiang, 2019). As a result, equity in education is transformed into the privilege of the wealthy to receive high-quality education (Hutchings, 2021). Public policy intervention in allocating school resources should carefully consider the maximum social benefits rather than only meeting the needs of one type of stakeholder in advancing social sustainability. In addition, the urban–rural differences in school resources essentially result from demographic and socio-economic factors. Therefore, the fundamental solution to urban–rural differences in school resources in counties is the balanced development of demographic and socio-economic factors in villages, small towns, and county towns.

Conclusions

In this research, resource equity in primary schools is assessed and urban–rural differences in resources between primary schools have been introduced to generalize the phenomenon of resource differences between primary schools in the counties of China. Ten school-resource indicators are proposed based on the existing literature and categorized into campus, teaching, and community resources. An analytical framework for quantifying urban–rural differences is developed based on the three types of school resources and applied in a case study of primary schools in Yuncheng County to analyze and verify its feasibility. The results and outcomes provide empirical support for decision-makers in allocating school resources to achieve equity of education and social sustainability. The developed analytical framework has the potential to be used in secondary or high schools. In this case study of Yuncheng County, there are some key conclusions. Specifically, resource differences between UPSs and RPSs do exist in both the total resources and the three types of school resources from the perspective of a cumulative distribution function. These identified urban–rural differences reflect the polarization of school resources between a small number of UPSs and a large number of RPSs. The relative proximities of school resources in UPSs show great differences, while those in RPSs show homogeneity, and so reflect poverty, in Yuncheng County, where the county town contains the resource-rich areas. The study also finds that there is a shortage of campus resources in the county town. The geographical locations of all small primary schools show a lower density value. The villages near the administrative border of the county have much fewer school resources. Of all indicators, the contribution of the cost of furniture and equipment is the largest according to the entropy weight. Finally, the three types of school resources sorted in ascending order of concentration degree are: campus resources, community resources, and teaching resources. This study concludes that teaching resources contribute the most of the three school-resource types to the total resources and are an area needing further research and attention to achieve equity of education and social sustainability. Since the forms of urban–rural differences vary according to counties and time periods, the research results cannot represent all counties in China. It is worth mentioning that since the two ideal solutions comprised of the maximum and the minimum of all indicator vectors are the relative standards for calculating the relative resource proximities using the TOPSIS method, it is not possible to compare two samples from two different counties.

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