

# The Matching Relationship and Formation Mechanism of Supply and Demand Space of Shadow Education: A Case Study of the Main Urban Area of Lanzhou City

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**Abstract:** Shadow education is an unofficial educational form with specific tutoring groups formed outside the mainstream education system. This study takes the main urban area of Lanzhou City as the research object and uses mathematical modeling methods to specifically identify the supply and demand relationship of shadow education space and analyze its formation mechanism. The results show that: 1) In terms of demand space, the residential space basically presents a continuous patchy distribution, the mainstream education space presents an approximately balanced "point-like" distribution, and the comprehensive demand space presents a distribution trend where continuous residential space and point-like mainstream education space are superimposed. The supply space of shadow education shows an aggregated distribution in the central business district, a transitional distribution in the transition zone, and a scattered distribution in the peripheral zone. 2) The over-supply areas of shadow education are mostly distributed in the prosperous commercial areas of each group, the under-supply areas are mainly distributed in the development zones, shantytowns and other areas with relatively sparse population in the peripheral zone, and the supply balance areas are mainly distributed in the relatively less populated Anning, Xigu and the transitional zones between the central business districts and peripheral zones of each group. 3) The matching relationship between the supply and demand spaces of shadow education is the result of the consideration of two factors in the site selection process of shadow institutions: the dependence on the source of students and the externalities generated by the agglomeration effect.

**Keywords:** Shadow Education; POI; Supply and Demand Relationship; Formation Mechanism; Main Urban Area of Lanzhou City.

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## 1. Introduction

The interplay between rapid economic development and social cultural transformation has led to the infiltration of market consumption behavior into traditional educational models, with educational activities increasingly trending towards externalization, diversification, and complexity. The inward-looking campus teaching model with gates and walls can no longer meet the increasingly fierce competition for social knowledge. Against this backdrop, shadow education, a new type of educational consumption product, has emerged. Alongside the long-term, continuous, and intense competition for knowledge and talent in modern society, the low-competition model of traditional education has created a sustained driving force for the market vitality of shadow education. From the perspective of the demand side of shadow education, family income and the stock of family cultural capital also provide economic and cultural capital for the consumption of shadow education products. This has led to the continuous expansion of the economic scale and social influence of shadow education in recent years, with the proportion and expenditure of families purchasing shadow education products constantly increasing[2][3]. However, while its quantity and social recognition are on the rise, the contradiction of supply and demand mismatch among cities, between urban and rural areas, and within cities is also intensifying. This market-driven educational consumer product has created an unresolvable order conflict with the fair enrollment educational system. Therefore, identifying the spatial supply and demand relationship of this consumer product and analyzing the formation mechanism of this

relationship is particularly important and urgent for effectively regulating the market order of shadow education and maintaining the fairness of resource enjoyment.

Shadow education is also called remedial education, extra-curricular education, and its institutions are called remedial institutions, shadow institutions or shadow schools[4]. Since Stevenson and Baker proposed the concept of shadow education in 1992[5], scholars have conducted in-depth research on this educational phenomenon from the interdisciplinary perspectives of economics, sociology and pedagogy. In recent years, its research scale has shifted from micro to meso and macro, and its research content has shifted from the causes of shadow education and its impact on students and families[6] to the influence and governance of the country and society[7]. Among them, social and educational equity issues caused by the difference in supply and demand of shadow education are the focus of scholars' attention. Kang Yueying et al pointed out that the imbalance in the supply of shadow education between urban and rural areas widened the education gap between urban and rural areas[8]. Mei Hong et al found that the participation rate of students in rural poor areas in basic education was only 37.5%[9]. The national average is as high as 66.1%-82.8%[10]. Yang Polonik pointed out that shadow education has led to the transformation of basic education from a low-level equilibrium of "competition within universities, low competition outside universities, and low participation in tutoring" to a high-level equilibrium of "low competition inside universities, competition outside universities, and high participation in tutoring", and such educational activities in the era of economic inequality have even gradually become

the main tool of social stratification and mobility[11]. The imbalance between supply and demand caused by shadow education between urban and rural areas and within cities has seriously impacted the fairness of educational resources, and this educational consumer goods under special social background has even become a status symbol of social class differentiation. However, limited to the disciplinary perspective, relevant studies only focus on the social causes of the imbalance between supply and demand of shadow education and its social impact.

Shadow education is a new type of consumption space under the background of modern society and education. At present, few articles discuss the spatial supply and demand relationship and its formation mechanism based on the geographical perspective, and actively carry out research on shadow education space based on different scales. This paper discusses the optimal location range of education and training institutions[12] the differences in accessibility of extracurricular education and guidance[13] the spatial pattern and influencing factors of shadow education[14][15], the spatial agglomeration characteristics of different sizes of guidance institutions[16], the territorialization characteristics of shadow education institutions that are highly clustered around famous school districts[17], and the differences of shadow education institutions. In terms of scale, the spatial differentiation of economic capital, cultural capital and social capital[18], the urban-rural difference of shadow educational institutions and the phenomenon of ranking-scale[19] and other problems. In contrast, there are relatively more researches on the supply and demand space of mainstream education resources, which also belong to social education resources. For example, Han Yanhong et al. used the programming language Delphi system to evaluate the spatial accessibility of senior high schools and put forward adjustment plans[20]. Based on fractal theory and accessibility theory, Lu Xiaoxu et al. analyzed the characteristics of spatial evolution of ordinary senior high schools in Nanjing and their adjusted distribution pattern. Deitqi et al. optimized the educational service space in Shijingshan District of Beijing from the perspective of educational equity[21]. In addition, the research results on the supply and demand relationship of traditional urban consumption space are also relatively rich, such as policy-configured facilities focusing on medical and health care[22][23], park and green space[24][25], transportation [26] [27] and comprehensive service convenience[28]. And research on the supply-demand relationship of market-based facilities, such as commercial square[29][29], department store[30], catering service[31], hypermarket[32] and hotel service[33], has become increasingly mature. Shadow education, as the third type of urban consumer goods under

the dual order control of market orientation and policy intervention, it is of great practical and theoretical significance to study the relationship between supply and demand and its formation mechanism.

Based on this, this study studies the supply-demand matching relationship and its formation mechanism of this new educational consumer goods from a spatial perspective. At present, two-step mobile search method (2SFCA) is used in most researches on spatial supply and demand matching relationship[34]. Therefore, this study draws on the modeling idea of 2SFCA and uses ARCGIS network analysis tool to estimate the O-D distance cost from shadow education to residential areas and middle schools, and then uses the constructed mathematical model to calculate the output of middle school students in 1756 residential areas and 101 middle schools. The potential number of supplementary students obtained by 352 shadow institutions from residential areas and middle schools was accurately identified by the law of distance decline. Finally, the matching type of supply and demand relationship was specifically identified by kernel density analysis method and the formation mechanism of supply and demand space was analyzed accordingly.

## 2. Overview of the Study Area

The main urban area of Lanzhou City is located in the Yellow River Valley, showing a narrow east-west strip distribution characteristic, the main urban area mainly includes Chengguan, Qilihe, Xigu and Anning four districts, a total of 49 street offices and a high-tech zone. From the inter-district comparison of the main urban area, the development of the four groups is not sexually balanced. In terms of the spatial distribution of population, by 2019, the household population in Chengguan District of Lanzhou City accounted for 49% of the total urban population, Qilihe District accounted for 24%, Xigu District and Anning District only 16% and 11% respectively. Therefore, the spatial distribution of the population in the main urban area has the characteristics of more in the east and less in the west. From the perspective of the development of middle school education, the proportion of middle school teachers in Chengguan District is as high as 49%, 19% and 21% in Qilihe and Xigu, respectively, and 12% in Anning. In terms of the number of middle school students, Chengguan District accounted for 50%, Qilihe and Xigu 19% and 18%, respectively, and Anning district accounted for 13%; From the perspective of teacher allocation, the average number of middle school students assigned by teachers in Chengguan, Qilihe, Xigu and Anning groups is 10.93, 10.47, 9.20 and 11.88.

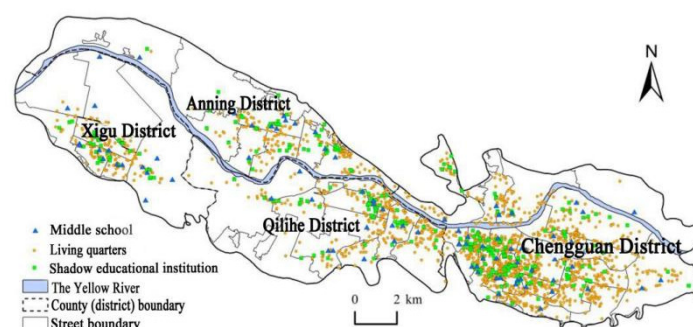


Fig 1. Research area and research object

### 3. Research Methods and Data Sources

#### 3.1. Research Methods

##### 3.1.1. Student Quantity Acquisition Model of Shadow Agency under Single Travel Mode

This study uses the distance as the output weight of the number of middle school students through mathematical processing method to accurately calculate the number of

$$P_{r,j} = \sum_{i=0}^n P_{r,ij} w_{r,ij}, w_{r,ij} = \frac{w_{r,ij}'}{\sum w_{r,ij}'}, w_{r,ij}' = 1 - \frac{d_{r,ij}}{\sum_{j \in \{d_{r,j} \leq d_{r,0}\}} d_{r,ij}} \quad (1)$$

Where: variable  $P_{r,j}$  represents the total number of students obtained by shadow agency  $j$  under the  $r$  TH travel mode, variable  $P_{r,ij}$  represents the number of students output from residential area  $i$  to shadow agency  $j$  under the  $r$  TH travel mode, and  $n$  represents the total number of residential areas within the farthest travel range. Variable  $w_{r,ij}$  represents the student output weight of residential area  $i$  to shadow mechanism  $j$  under the  $r$  TH travel mode; variable  $w$  represents the intermediate processing variable of calculating  $w_{r,ij}$ : it is used to deal with the problem that the greater the distance divided by the sum of distances, the greater the value, but the smaller the student output; variable  $d_{r,ij}$  represents the distance between residential area  $i$  and shadow mechanism  $j$  under the  $r$  TH travel mode, and  $d_{r,0}$  represents the scope of the  $r$  TH travel mode.

##### 3.1.2. Student Quantity Acquisition Model of Shadow Agency under Comprehensive Travel Mode

(1) The scope of different travel modes and their demand output weights

This study chooses walking, cycling and public

students output to the shadow institution in a residential area. This method firstly uses the O-D distance cost in ARCIS network analysis tool to calculate the distance between each residential area and the shadow mechanism in its scope, then calculates the distance weight, and finally calculates the total number of people obtained by the shadow mechanism from the residential area under a certain travel mode based on the output weight of student volume.

transportation as the main ways for students to participate in shadow education. Relevant studies show that the average walking speed of people is about 5km/h, the average cycling speed is 20km/h, and the average bus speed is 30km/h. Therefore, this study takes 30 minutes as the upper limit of walking travel[35], and 20 minutes as the upper limit of cycling and bus travel. It can be concluded that the scope of students' participation in shadow education under different travel modes is 2.5km, 6.67km and 10km respectively (Table 1). Considering that the choice of transportation modes is nested under different travel distances, for example, the travel modes that can be taken within the range of 2.5km include walking, cycling and transportation, and the travel modes beyond 2.5km can only be taken by cycling and public transport, while the travel scope beyond 6.67km can only be taken by public transport, that is, the travel scope of public transport includes cycling and walking. The cycling range includes the walking range, and the number of riders has the relationship of "2.5km ∈ range 6.67km ∈ range 10km". This indicates that there is redundancy in the process of calculating the comprehensive output of students under the three modes of occurrence. Therefore, distance weight is used to eliminate the influence of calculation redundancy. Based on this, objective weights are constructed for the output of students under different travel modes by using the scope.

**Table 1.** Scope of different travel modes

Travel mode	Travel cost			Full range travel	Number of students output weight
	Average velocity(km/h)	Time (min)	Distance (km)		
Walk	4.8	30	2.5	Walk, cycling, public transport	0.126
Cycling	20	20	6.67	Cycling, public transportation	0.35
Public transportation	30	15	10	Public transportation	0.524

(2) The demand acquisition model of shadow institutions (suppliers of shadow education) under comprehensive travel mode

Based on the total number of students obtained by the shadow agency from the residential area under a single travel

$$P_j = \sum_{r=0}^m P_{r,j} W_r, W_r = \frac{D_r}{\sum_{r=1}^m D_r} \quad (2)$$

Where: Variable  $P_j$  represents the total number of

mode and the weight of the number of students obtained by different travel modes, the total number of people obtained by the shadow agency under the comprehensive travel mode is obtained.

students obtained by shadow institution  $j$ ; The variable  $W_r$  represents the weight of the  $r$  type of travel mode,  $D_r$

represents the scope of the  $i$  type of travel mode, and  $m$  represents the type of travel mode, which is 3 in this study.

### 3.2. Data Source and Processing

The data required for this study include POI data of secondary schools, secondary school shadow institutions and residential areas; The number of middle school students and the number of middle school students in residential areas; Lanzhou city main city road network and administrative zoning map. Among them, the POI data of middle schools and shadow institutions were obtained through web crawler on Baidu Map open platform, and a total of 101 middle schools were obtained. Non-further education or vaguely defined parts such as child care, vocational training and art training were deleted from the 1,621 shadow institutions, and 355 shadow institutions targeted at secondary school students' further education were selected (identified through Dianping). The acquisition time is January 2019; Residential area of POI

data and residence number information through to the guest's official website (<https://lanzhou.anjuke.com>) crawl, for residential 1756, access time is September 2020; The number of middle school students can be obtained by visiting the "School Profile" column of the official website of the school, and the number of middle school students in the residential area can be obtained by converting the proportion of middle school students in the country in 2019. The conversion formula is as follows: Number of middle school students in residential areas = number of residential households  $\times 2.725 \times 5.48\%$  (2.725 is the average population number of a household in Lanzhou in 2019, 5.48% is the proportion of middle school students in the total population of Lanzhou in 2019 (Table 2)); The urban road network in the main urban area of Lanzhou city can be downloaded through the electronic map of the water channel. The administrative data of the main urban area are from Lanzhou Land Use Planning Database (2009-2020).

**Table 2.** Population and number of students in Lanzhou in 2019

	Chengguan District	Qilihe District	Xigu District	Anning District	Municipal district
Number of households (10,000)	35.46	17.27	11.89	7.93	72.55
Household population (10,000 people per household)	96.19	47.5	32.29	21.72	197.7
Junior high school enrollment	35092	14350	10416	8684	68542
High school enrollment	19360	6017	9017	5355	39749
Middle school enrollment	54452	20367	19433	14039	108291

## 4. Analysis of Spatial Characteristics of Supply and Demand of Shadow Education

### 4.1. Spatial Analysis of Demand for Shadow Education

From the perspective of demand space, the spatial demand of middle school students for shadow education presents a distribution pattern of "high in the east and low in the west". As a typical valley city, the development of Lanzhou is restricted by the shape of the valley, and the population has formed a spatial distribution pattern. By 2019, the urban population of Chengguan District reached 961,900, while that of Xigu District was only 322,900. In terms of the number of middle school students, Chengguan District (54,000) > Qilihe District (20,000) > Xigu District (19,000) > Anning District (14,000), the demand of Chengguan District is much higher than that of the other three regions (Figure 2-a). Therefore, the spatial demand of middle school students for shadow education is low in the west and high in the east. From the perspective of living space, mainstream education space and comprehensive space, the living space basically presents a continuous sheet-like distribution, the mainstream education space presents an approximate balanced "point-like" distribution, and the comprehensive demand space presents a superposition of continuous living space and point-like mainstream education space.

From the internal relationship of different demand Spaces, different demand Spaces still show different spatial differences. Among them, there are still high core residential areas in the residential space, mainly including Xigucheng - Fui Road - Xianfeng Road group, Shilidian - Dunhuang Road

- West Railway Station group, Zhangye Road - Gaolan Road - Tuanjie New Village group, Yanchang - Caochang Group and Yantan Group, etc. (Figure 2-a); There are also some "core points" in the mainstream education space, which are mainly distributed in Xigucheng, Fui Road, Jianlan Road, grass yard, Guangwumen, Gaolan Road, East Railway Village, Yanbei Street and Jiayuguan Road (Figure 2-b). The core areas of the two comprehensive demand Spaces are mainly distributed in the bustling business districts of their respective groups, which presents a multi-core distribution pattern of "Xigucheng - Anning Science and Education City - Qilihe West Station - Chengguan Xiguan Cross" (Figure 2-c).

### 4.2. Supply Space Analysis of Shadow Education

The supply space of shadow education presents a concentrated distribution pattern. From the number of shadow institutions in each group, Chengguan District (183) > Qilihe District (58) > Anning District (55) > Xigu District (51), it can be seen that the number difference between Anning District, Qilihe District and Xigu District is not obvious, but the supply of shadow education in Chengguan District is much larger than that in the other three regions, which shows a corresponding trend with the spatial pattern of demand. From the perspective of the shadow agencies assigned per thousand (middle school students), Anning District (3.92) > Chengguan District (3.36) > Qilihe District (2.85) > Xigu District (2.62). According to the distribution of shadow agencies per thousand (middle school students), Anning District is the highest among the four groups, followed by Chengguan District, and the gap between Qilihe District and Xigu District is not obvious (Figure 2-d).

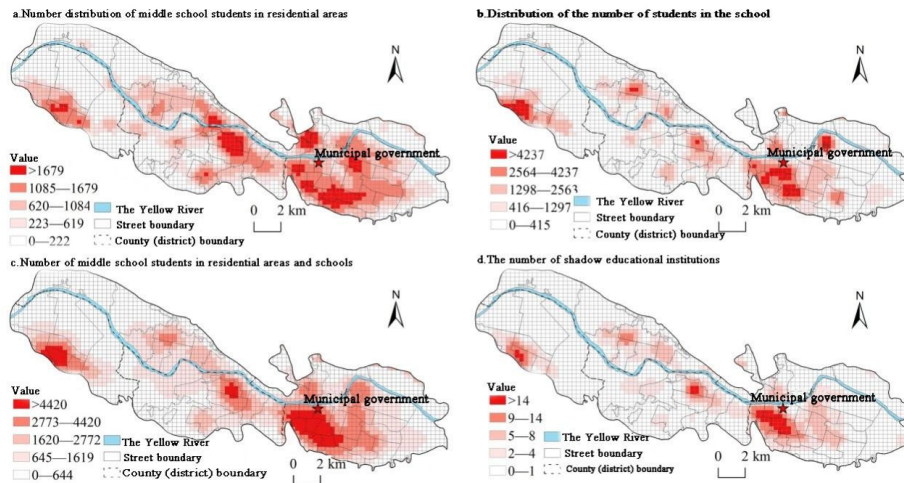


Fig 2. Supply and demand space of shadow education based on kernel density analysis

## 5. Study on the Spatial Matching Relationship Between Supply and Demand of Shadow Education

### 5.1. Analysis of Spatial Matching Relationship Between Supply and Demand of Shadow Education

According to the student volume acquisition model under the three travel modes, the shadow institutions were measured from the residential space, mainstream education space, residential and mainstream education comprehensive space (the number of students obtained from the comprehensive space is the number of students in the residential space (0.633 (junior high school students, most of them are students in general school)) and the number of students in the mainstream education space (0.367 (high school students)). The weight of high school students is mostly residential students), the number of students obtained by three demand Spaces, and the Kriging difference is used to visualize the number of students obtained by shadow institutions. Then, the kernel density analysis results of the three demand Spaces of residence, school, residence and school are used to identify the demand

area (assigned as 1) and the low demand area (assigned as -1), and then the product operation of the two is carried out to identify the specific matching relation area of the shadow education supply and demand space. Assuming that all middle school students participate in shadow education, based on the number of middle school students and the corresponding number of shadow institutions in Lanzhou in 2019, the average number of shadow institutions is about 300 ( $108291/355=305$ ). Therefore,  $<-400$  is identified as low-demand and low-supply area,  $-400-(-200)$  is identified as low-demand and low-supply area, and  $-200-0$  is identified as low-demand and low-supply area (considering the profitability of shadow mechanism location selection, "low-demand and high-supply area" is not identified),  $0-200$  is high-demand and oversupply area, and  $200-400$  is high-demand and high-supply area.  $400-600$  high demand and low supply zone,  $>600$  is high demand and thin supply zone (Table 3), because the low demand and high supply type does not conform to the market behavior, this paper focuses on the identification and analysis of high demand and oversupply type and high demand and low supply type imbalance zone. In order to ensure the accuracy of the zoning results, this paper analyzes the fishing net types of  $30 \times 30$  and  $50 \times 50$  scales.

Table 3. The identification of the spatial relationship between supply and demand in shadow education

Access to shadow educational institutions (A)	The fuzzy relationship between supply and demand		Demand space (B)	A×B product operation	The specific relationship between supply and demand	Degree of imbalance
0-200	Low demand	High supply	Low demand area (-1)	-200-0	Low demand and high supply area	1
	High demand	Oversupply	High demand area (1)	0-200	High demand and oversupply area	1
200-400	Low demand	Low supply	Low demand area (-1)	$(-400) - (-200)$	Low demand and low supply area	0
	High demand	High supply	High demand area (1)	200-400	High demand and high supply area	0
>400	Low demand	Lack of supply	Low demand area (-1)	$< -400$	Low demand and lack of supply area	1
	High demand	Low supply	High demand area (1)	400-600	High demand and low supply area	1
				$>600$	High demand and lack of supply area	2



### 5.1.1. Matching Relationship Between Supply and Demand of Shadow Institutions and Living Space

The supply-demand relationship between shadow institutions and residential space presents a spatial heterogeneity with a small difference in the west and a large difference in the east. The shortage and undersupply areas are mainly distributed in Xiyuan, Yanjiaping, Yantan Qingbaishi and high-tech District streets in the east of the river valley, where the number of students available to shadow institutions is more than 600. On the contrary, the phenomenon of oversupply of space appeared in the central districts of Jiuquan Road, Gaolan Road and Guangwumen, the Shilidian of Anning and Peili Street, etc. Although these areas have a large output of student demand, the large number of shadow agencies still creates fierce competitive pressure among shadow agencies. Relatively speaking, the central streets of Xigu District, central streets of Anning District, western streets of Qilihe and the caochang and salt fields in the north of Chengguan show a matching relationship between supply and demand. The low-demand and low-supply areas are mainly found in the marginal areas with sparse population distribution such as development zones, unused land, and shantytowns (Figure 3-a, 3-b).

### 5.1.2. Supply-demand Matching Relationship Between Shadow Institutions and Mainstream Education Space

The supply and demand relationship between shadow institutions and mainstream education space presents a large spatial difference. Compared with residential space, the east and west of shadow institutions show a large difference. The areas of shortage and oversupply are mainly distributed in Xigu City, Fui Road, Xianfeng Road and Chenping Street in Xigu District, Tumendun, Xihu and Xiyuan streets in Qilihe District, Zhangye Road, Guangwumen, Jingyuan Road, Wuquan, Tuanjie New Village, Jiayuguan Pass, Railway Station, Yantan and Donggang streets in Chengguan District, which indicates that there are a large number of school students in this area. However, the number of shadow institutions is relatively small, showing a spatial phenomenon

of short supply. Compared with the residential space, the area of the oversupply area is relatively small, mainly distributed in some streets such as Donggang West Road and Gaolan Road in the center of the city pass, Jianlan Road in Qilihe and Shilidian in Anning, etc., which indicates that there are relatively more shadow agencies and strong competition in these areas. The areas with low demand and low supply are mainly distributed in the areas with insufficient urban renewal or development, such as the west of Anning, the west of Qilihe, the east of Xigu and the east of Chengguan (Figure 3-c, 3-d).

### 5.1.3. The Supply-Demand Matching Relationship Between Shadow Institutions, Residential and Mainstream Education Comprehensive Space

The supply and demand relationship between shadow education, residential and mainstream education shows a spatial pattern with little difference in the west and big difference in the east. The areas of shortage and oversupply are mainly distributed in Xiyuan, Yanjiaping, West Railway Station, Dunhuang Road, West Lake, Jianlan Road and Gongjiawan Street in the east of Qilihe River, Wuquan, Railway West Village, Railway Station, Jiayuguan Street in the south of Chengguan, and Yantan, high-tech Zone and Yanchang Road street in the northeast. Its oversupply areas are mainly distributed in Gaolan Road, Jiuquan Road and Donggang West Road in Chengguan, and Shilidian street in Anning, which are relatively concentrated and small in area. Compared with a single living space and mainstream education space, the supply and demand balance area of its comprehensive space is larger, which is mainly distributed in Xigu Central Street, Anning Central Street, Qilihe West Street, Chengguan West Street and Jingyuan, Caochang and Yanchang streets in the north. The large area of supply and demand balance indicates that the location of shadow institutions tends to consider the demand space under the combination of the two. The distribution of low-demand and low-supply areas is consistent with unilateral residential space and mainstream education space, mainly concentrated in urban fringe areas (Figure 3-e, 3-f).

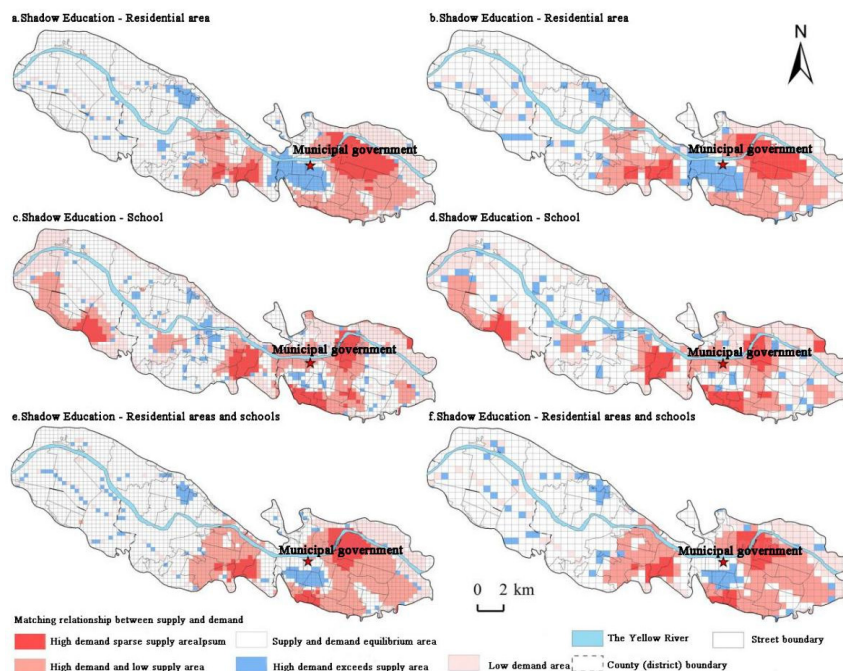


Fig 3. The spatial matching relationship between supply and demand of shadow education

## 5.2. Analysis of the Formation Mechanism of The Supply-Demand Relationship of Shadow Education

### 5.2.1. The Spatial Dependence of the Shadow Mechanism on the Source is the Basis of the Supply and Demand Balance Zone

In order to scientifically and accurately analyze the spatial dependence of the shadow mechanism on the source area, this study created two scales of 50×100 and 30×60 fishing nets as statistical units, analyzed the nuclear density of the middle school student field in the residential area, the middle school student field in the school, the middle school student field under the combination of the two, and the shadow mechanism, and then counted the average nuclear density value in the grid. Finally, a linear regression analysis of the supply and demand in the grid is made to judge the correlation of supply and demand space.

The correlation between the distribution of shadow institutions and the three types of student source space shows the relationship of comprehensive space > mainstream education space > residential space. According to the analysis results of 50×100 and 30×60, the spatial correlation between the distribution of shadow institutions and the number of students in residential space is 0.622 and 0.632 respectively. It is generally believed that the correlation coefficient below 0.3 has no correlation, 0.3-0.8 is a weak correlation, and above 0.8 is a strong correlation. This indicates that there is a

weak correlation between the two. The attraction of residential areas to the spatial distribution of shadow institutions mainly comes from the group of school students, who complete shadow education activities in the path of "residential area - shadow institution - residential area". Some shadow institutions choose to distribute around residential areas with large student population to obtain more students. The correlation between the distribution of shadow institutions and the mainstream education space is 0.791 and 0.803 on the scales of 50×100 and 30×60 respectively, which indicates that shadow institutions have a strong dependence on the mainstream education space. Considering the impact of distance cost on students' participation in shadow education, some shadow institutions choose to distribute around mainstream schools with large student population or areas with dense school distribution to obtain more students. The correlation between the distribution of shadow institutions and the comprehensive space is 0.816 and 0.822 on the two scales respectively. Among them, the simulation effect of residential space is not as good as that of mainstream education space and comprehensive space, but both of them pass the confidence level of 0.05. From the two scales, the simulation results of 30×60 are better than those of 50×100 (Table 4), but both scales are correlated. Therefore, it is concluded that there is a strong spatial dependence of shadow institutions on the source area, and this correlation is the basis of the supply and demand balance of shadow education supply and demand space.

**Table 4.** The test of spatial regression analysis of supply and demand of shadow education

	Regression analysis under 50×100			Regression analysis under 30×60		
	Living quarters	Middle school	Synthesis	Living quarters	Middle school	Synthesis
Pearson correlation coefficient	0.622	0.791	0.816	0.632	0.803	0.822
Adjusted R <sup>2</sup>	0.387	0.625	0.666	0.399	0.645	0.675
Significance F test	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

### 5.2.2. The Spatial Agglomeration of Shadow Institutions is the Internal Driving Force Leading to the Imbalance between Supply and Demand

The spatial agglomeration of shadow institutions is the inner driving force that leads to the imbalance between supply and demand of shadow education consumption space. The externality caused by the spatial agglomeration of industries is also one of the important factors to be considered in the spatial location selection of shadow agencies. Under this effect, the number of shadow agencies decreases from the core area to the fringe area. The spatial phenomenon of shadow agencies gathering in various clusters of bustling commercial centers in Lanzhou's main urban area indicates the tendency of decision makers to locate in agglomeration areas. Thus, the supply space of shadow education is generated. Living space and mainstream education space are two important sources of shadow education, namely the demand space of shadow education. Among them, the residential space shows a continuous spatial distribution in the urban area. However, the mainstream education space approximately presents a balanced point distribution pattern, which is determined by the school district system implemented in China and the education policy of fair admission. When the residential area is approximately continuously distributed in space, the mainstream education institutions will be affected by the population distribution and

finally present a balanced point distribution. Therefore, the demand space of shadow education presents a superimposed distribution trend of continuous living space and point-like mainstream education space.

This study conducted modeling analysis based on the above theoretical speculation: Assuming that the total number of students in the evenly distributed residential space is A, the number of shadow institutions in the cluster area is B, the transition area is B/2, and the discrete area is B/4, the number of students obtained by the shadow institutions in the cluster area, the transition area and the discrete area is 41/18B, 8A/18B, and 12A/18B, respectively, according to the shadow institutions selected by students nearby. According to the average quantity (7.2A/18B) that can be allocated to the shadow mechanism, the supply and demand relationship of the shadow mechanism is determined as the excess region, the equilibrium region and the insufficient region of the distributed supply respectively (Figure 4). It can be seen that the agglomeration area of shadow mechanism is more likely to form the spatial phenomenon of over-supply and insufficient formation of discrete area. Based on this calculation, the number of students obtained by shadow institutions in the cluster area, transition area and discrete area under the mainstream education space is A/5B, 2A/5B and 4A/5B respectively (Figure 4-b), and the supply-demand relationship shows a similar pattern with the residential space,

with only a slight difference in the degree of supply-demand imbalance. On the whole, the spatial agglomeration phenomenon of shadow institutions is the internal driving force that leads to the imbalance of student quantity distribution.

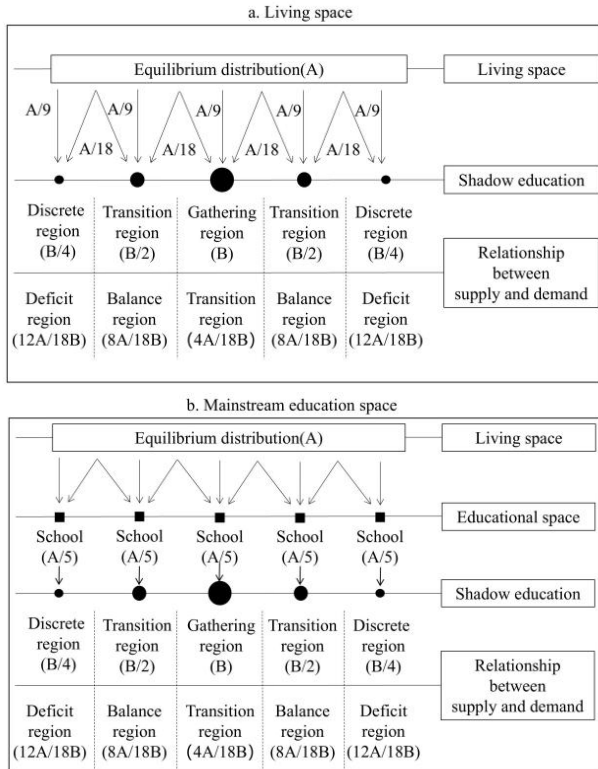


Fig 4. The spatial matching relationship between supply and demand of shadow education

## 6. Conclusion and Discussion

### 6.1. Conclusion

Shadow education consumption space is a new type of consumption space created under the social background of education competition and education reform, which is composed of multiple levels, such as physical layer (location, buildings, teaching facilities, etc.), social layer (relationship between training team, family, students and teachers) and power layer (market rules, institutions and legal constraints, etc.)[36][37]. The significance and connotation of its consumption space cannot only be concentrated on the buildings that carry out teaching or profit activities or fall on the shadow education team, parents and students, which has both location and other spatial relations of location load[38]. Therefore, this study takes the main urban area of Lanzhou city as the research object, and studies the spatial supply and demand relationship of shadow education from the perspective of location and formation mechanism. The conclusions are as follows:

(1) The spatial distribution pattern of shadow education supply and demand is "high in the east and low in the west". In terms of demand space, the living space basically presents a continuous sheet-like distribution, the mainstream education space presents an approximate balanced "point-like" distribution, and the comprehensive demand space presents a superposition of continuous living space and point-like mainstream education space. From the internal relationship of different demand Spaces, different demand Spaces still present different core areas. From the perspective of supply space, the supply space of shadow education

presents agglomeration, transition and discrete distribution in the central business district, transition area and marginal area respectively.

(2) The spatial relationship between supply and demand of shadow education presents a large spatial difference, and the oversupply areas are mostly distributed in the bustling business districts of various groups, among which Chengguan district is the most obvious; The areas with insufficient supply are mainly distributed in the marginal areas with sparse population distribution such as development zones and shantytowns. The supply balance area is mainly distributed in the relatively small population of Anning, Xigu and the transition zone between the central business district and the fringe area of each group.

(3) The matching relationship between the supply and demand space of shadow education is the result of the two factors of the shadow institution's dependence on the source of origin in the process of location selection and the externality caused by the agglomeration effect. In terms of the degree of dependence on the source area, the degree of dependence of shadow institutions on the comprehensive space of residence and mainstream education is higher than that of the mainstream education space, and the dependence on the residential space is the weakest.

### 6.2. Discussion

The generation of demand space is subject to the influence of China's current urban residence mode and education policies under the school district system, while the supply space is generated based on the joint effect of student origin and agglomeration effect. The opposition of order and rules caused by the policy constraint of demand space and the market rules of supply space will inevitably lead to differences in the spatial matching relationship between supply and demand. And then lead to the shadow education supply and distribution space imbalance problem. As can be seen from the research results, there is a serious shortage of supply in emerging regions and marginal regions, which easily leads to the relative lack of students' enjoyment of learning resources in these regions, thus causing the implicit deprivation of educational resources. In addition, from the perspective of the relationship between students and shadow education, shadow education has the characteristics of discipline, complementary habits and compensation[38][39], which helps to improve students' competitiveness in education, but this "high-pressure" form of education is also a potential negative force that stifles students' interest in learning and even causes students' physical and mental health problems[39][40]. From the perspective of the relationship between urban and rural areas, students' demand for further education, as the interest driver in shadow education, will attract shadow institutions to focus more on cities for the optimal location choice, which will inevitably cause the Matthew effect in the competition between urban and rural students for further education, thus breaking the balance in the utilization of educational resources and causing educational injustice. Therefore, reasonable policy control of shadow education is an important link to maintain educational equity and an important way to promote the healthy development of education.

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