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School proximity and housing price capitalization in China's secondary market: hedonic and quantile regression evidence from Xi'an and Zhengzhou

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Abstract

This paper examines how proximity to key middle schools is capitalized into housing prices in urban China and whether the magnitude of this effect is associated with differences in the broader educational environment of the city. The study addresses the question of whether school-related housing premiums differ between otherwise comparable cities with distinct higher education ecosystems. Using micro-level data on secondary housing sale listings from the Lianjia platform (February 2022), we estimate hedonic price models separately for Xi'an and Zhengzhou, two second-tier Chinese cities similar in economic scale but differing substantially in higher education resources. Ordinary least squares models with heteroskedasticity-robust standard errors are complemented by quantile regressions to assess heterogeneity across price segments. Distance to the nearest key middle school is negatively and statistically significantly associated with housing prices in both cities. However, the magnitude of capitalization differs markedly: a one-kilometer increase in distance reduces prices by approximately 3.5% in Xi'an compared to 1.2% in Zhengzhou. Quantile regressions reveal moderate heterogeneity in Zhengzhou, where the school premium is stronger in the lower price segment, while in Xi'an the effect remains relatively stable across quantiles. The study contributes to the literature by demonstrating that school-related housing premiums may be associated not only with assignment rules but also with broader differences in the urban educational ecosystem. By combining a cross-city comparative design with quantile analysis, the paper provides new

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evidence on how educational resource concentration may be related to housing market outcomes.

Keywords
educational inequality, educational resources, hedonic pricing model, quantile regression, school district housing (xuequfang), spatial accessibility, urban development.

JEL: R31, R21, I24, C21.

Introduction

As China's market economy has continued to develop, substantial institutional changes have also occurred in the education sector. In 2014, the Ministry of Education introduced the "Work Plan for Further Enrollment in Primary and Junior Secondary Schools without Examinations" (Ministry of Education of the People's Republic of China, 2014), aimed at improving equal access to educational resources. Despite these reforms, there is still a significant disparity between 'key' and 'ordinary' schools, particularly with regard to teaching quality and material resources. This disparity is unlikely to be eliminated in the short term, so demand from parents for places at "key" primary and secondary schools will remain high. In most Chinese cities, students enrolled in key secondary schools account for only around 15% of the total, and even in education-rich cities such as Shanghai the share does not exceed 25%.

This paper defines "key secondary schools" as those with an officially recognized status and perceived by families as offering better education than ordinary schools, rather than based on subjective assessments of school quality.

Education functions as both a public policy domain and a vital household resource. The limited supply of high-quality schools combined with strong parental demand creates a structural imbalance in access to educational resources. Under these conditions, a specific housing segment has emerged in China – commonly referred to as school district housing (xuequfang).

In a narrow sense, school district housing refers to residential property that, under local education regulations and the principle of residence-based enrollment, entitles a child to attend a designated primary or secondary school without examinations. Urban territories are divided into "school catchment areas", and each residential building is assigned to a particular school providing access to compulsory education.

In practice, however, the term 'school district housing' is employed in both academic research and everyday communication to denote properties assigned to key (high-quality) schools. As key schools differ substantially from ordinary schools in terms of teacher quality, resource allocation, and student outcomes, housing in their catchment areas is usually more expensive than comparable properties in areas with ordinary schools. Such housing offers households access to better educational opportunities, superior urban infrastructure and often stronger investment potential.

The value of housing in key school districts is largely determined by the access it provides to high-quality education. Educational resources are not only a concern for families but also for developers and real estate agents, who seek to capitalize on this demand. Since 2014, when the 'key school' concept was formalized, housing prices in key school districts have increased rapidly and remain consistently higher than comparable properties elsewhere in the city. Part of this demand is speculative: properties near high-performing schools are purchased not only for residence or children's education but also as assets expected to appreciate. Empirical research has widely documented the fact that school quality and school district prestige are reflected in housing prices. Properties in areas with higher-performing schools tend to sell at a premium relative to otherwise comparable housing (see, e.g., Black, 1999; Fack & Grenet, 2010; Gibbons & Machin, 2008; Nguyen-Hoang & Yinger, 2011). Similar evidence has been found for Russian cities, including Moscow and regional centers (Chugunov, 2013; Mishura et al., 2019; Roshchina & Vashchenko, 2020). However, less attention has been paid to the magnitude of this premium and to whether it differs across cities with varying levels of educational resources.

The present study addresses this gap by conducting an intercity comparative analysis. From the twenty largest Chinese cities, we selected a pair of cities similar in their economic, political, geographic, and institutional characteristics but differ markedly in terms of the level of educational resources available. Using micro-level housing sale listings data from the Lianjia Real Estate online platform, we estimate hedonic price models for each city and complement the analysis with quantile regressions to examine heterogeneity across the price distribution. This approach allows us to compare the degree to which housing prices are influenced by proximity to key schools, and to evaluate the impact of the overall level of urban educational development on the housing premium in school districts.

This study aims to estimate the extent to which proximity to key secondary schools is reflected in housing prices, and how this premium varies depending on the overall development of the city's urban education system. The following hypotheses are tested:

- **Hypothesis 1.** In both cities, housing prices are statistically significantly related to the distance from the nearest key secondary school: *ceteris paribus*, a shorter distance is associated with higher housing prices.
- **Hypothesis 2.** The premium for proximity to a key school is higher in the city with a more developed education system (Xi'an) than in the city with a lower level of educational resources (Zhengzhou).
- **Hypothesis 3.** The effect of proximity to a key school varies across price segments of the housing market and differs across quantiles of the price distribution.

The relevance of this study is based on several considerations. First, as the demand for high-quality education increases, school district housing is becoming more and more important in second-tier cities, whose housing markets remain relatively understudied. Second, comparative analyses of housing in school districts

across multiple comparable Chinese cities are scarce, despite their importance for understanding price formation mechanisms. This is especially true of analyses focusing on differences in the magnitude of the proximity premium. Third, in most large cities, economic development and educational resource endowment are positively correlated, which makes it difficult to isolate the effect of educational development itself on housing prices. Yet in several rapidly growing large cities, such as Shenzhen, economic growth has outpaced the development of educational infrastructure, creating a divergence that makes the interaction between housing markets and educational resources especially important.

Literature review

School quality and housing prices

A substantial body of literature has examined the relationship between the quality of public services and housing prices. In the classical framework of capitalization of public goods into property values, the starting point is the "voting with one's feet" hypothesis (Tiebout, 1956), which posits that the differentiated provision of public goods encourages households to move to areas where the balance of taxes and services more closely aligns with their preferences. Oates (1969) provided empirical evidence that local property taxes and public expenditure are reflected in housing prices. Building on this, Ross and Yinger (1999) modelled household location choice as a function of sets of local public goods, with willingness to pay for housing reflecting the valuation of these sets.

An important development in this field of study is the hedonic pricing framework, which models housing prices as a function of structural and locational attributes, including the characteristics of local public services. Many studies (Bayer et al., 2007; Cheshire & Sheppard, 2004; Downes & Zabel, 2002; Reback, 2005; Rosen & Fullerton, 1977) show that housing prices depend not only on structural features of the property (type, size, layout, floor level, condition) but also on neighborhood characteristics, such as transport accessibility, infrastructure, environmental quality and social environment. In these models, school quality is measured using various indicators, including test scores, per-pupil expenditures and student–teacher ratios.

For the United States and Europe, studies show that the quality of schools is capitalized in housing prices. Properties in areas with better schools are sold at a premium compared to similar properties in other districts (Black, 1999; Fack & Grenet, 2010; Gibbons & Machin, 2008; Nguyen-Hoang & Yinger, 2011). The magnitude of this effect may be weaker where households have broader educational choices and school assignment is less strictly tied to residential location (Cheshire & Sheppard, 2004). Some researchers also highlight the differences in the capitalization of public

and private schools and the specific roles of selective or elite schools, whose catchment rules may be less strict (Bae & Chung, 2013).

Similar patterns have been observed in Russian cities. Using housing listings from Moscow and official data on school assignments, Roshchina and Vashchenko (2020) show that a higher quality of assigned schools, as measured by official rankings, is associated with higher apartment prices. The effect sizes are comparable to those reported in the international literature. Chugunov (2013) found that educational quality and social environment characteristics were positively capitalized in Moscow housing prices. Mishura et al. (2019) analyzed data from a regional Russian city and demonstrated that school quality is significantly associated with housing prices, and that the magnitude of this association may vary across market segments. These findings suggest that the relationship between educational quality and housing prices is not limited to developed economies, but also exists in large cities in transition economies.

In the Chinese context, the institutional structure of compulsory education and the residence-based admissions policy make the analysis of school district housing particularly important. Several studies have shown that educational resources have a positive impact on housing prices in major Chinese cities. The empirical evidence indicates that the impact of educational infrastructure on property prices is mediated by the capitalization of the accessibility and quality of educational facilities, as well as spatial proximity to them (Wen et al., 2014). Using secondary housing market data from Beijing, Han et al. (2021) demonstrate that properties associated with prestige educational resources are priced significantly higher than comparable housing. However, most existing studies focus on a single city or area and do not examine how the magnitude of the school district housing premium relates to the overall level of educational development. Moreover, relatively few studies in the Chinese literature employ micro-level housing data and compare multiple economically similar cities that differ in educational resource endowment. These gaps motivate our comparative analysis.

Empirical approaches

A common strategy for dealing with endogeneity in housing price models is using instrumental variables. Because of data limitations and institutional complexity in local education systems, it is difficult to find appropriate instruments, so this method is rarely used in empirical studies of school quality and housing prices.

Another method widely used in the literature for controlling unobserved factors is the boundary fixed effects (BFE) approach. In a pioneering study, Black (1999) compared housing prices of properties located on either side of school attendance boundaries and showed that higher school quality leads to higher housing prices. This approach was later developed by Gibbons et al. (2009), Fack and Grenet (2010), and other authors, who refined the specification, controlled for distance to the boundary and aggregated observations within narrow bands along school district borders.

Overall, these studies confirm that differences in school quality generate statistically significant differences in housing prices.

However, the boundary-based approach has significant limitations when applied to Chinese school district housing markets. Formally, the school district premium can be defined as the price difference between properties located on opposite sides of a district boundary. However, in large Chinese cities, such an approach may underestimate the effect because, firstly, a significant proportion of the demand for housing in school districts is concentrated in small apartments, which are primarily purchased to gain access to high-quality schools. Empirical evidence from Shanghai shows that a premium is paid for high-quality schools, particularly for small properties, whereas the premium is weaker for larger ones (Liu et al., 2022). Secondly, in practice, school district apartments often serve as a formal "entry ticket" to a desirable school. Families may purchase a small apartment within the catchment area to register their child while living in a larger dwelling outside the formal boundary. Similar practices have also been described in journalistic and popular analytical sources. For example, a report by *Sixth Tone* discusses a family that purchased an approximately 30-square-meter apartment in a prestige district of Shanghai solely to secure access to a high-performing school (Sixth Tone, 2018). Likewise, a review by *China Educational Tours* analyzes the phenomenon of *xuequfang* ("school district housing") as a distinct category within the Chinese housing market (China Educational Tours, n.d.). As a result, the influence of a key school may extend beyond the administratively defined catchment area. Therefore, estimating the premium using only observations located within narrow boundary bands is likely to produce an estimate that is lower than the true effect.

Against this background, hedonic housing price models remain the primary analytical tool. In these models, housing prices are expressed as a function of structural attributes (type, size, layout, floor level, condition) and locational characteristics (transport accessibility, infrastructure, environmental quality). For Chinese cities, this framework is particularly suitable because many public services are provided by the state, and intra-city variation in some services may be limited compared to cross-city differences.

In addition to the traditional ordinary least squares (OLS) estimation, recent studies increasingly use methods that allow for heterogeneous effects and nonlinear relationships, including quantile regression and various machine learning techniques. Quantile regression makes it possible to examine how the effect of a key explanatory variable, such as distance to the nearest key school, varies across the distribution of housing prices, thereby comparing lower- and higher-priced segments. In this study, we take the following approach: we estimate hedonic price models for two Chinese cities at different stages of educational development using OLS, and then use quantile regressions to assess the robustness and heterogeneity of the results.

Methods

Study context and city selection

In order to empirically test our hypotheses, we need to compare two cities that are as similar as possible in terms of their key socio-economic characteristics, but which differ substantially in terms of their educational resources. Initially, we considered the twenty largest Chinese cities for which comparable indicators of economic development and global competitiveness are available.

To position cities within the national and global urban hierarchy, we used the 2021 edition of the City Comprehensive Economic Competitiveness Index developed by the Chinese Academy of Social Sciences (CASS). The index aggregates indicators across ten broad dimensions, including financial services, technological innovation, industrial structure, human capital, domestic demand, fiscal and financial conditions, the institutional and business environment, physical infrastructure, the quality of the urban living environment, and global connectivity. The indicator system, normalization procedures and the weighting scheme are documented in the *Global Urban Competitiveness Report 2017–2018: House Prices: Changing the City World* (Ni et al., 2019) and subsequent GUCR volumes issued jointly by CASS and UN-Habitat. In this paper, however, we rely only on the composite scores for 2021. We used the index exclusively to classify the twenty largest Chinese cities into broad tiers. It is not employed as an explanatory variable in the econometric analysis, but rather to justify our selection of Xi'an and Zhengzhou as comparable cases. Given the relative stability of the ranking of major Chinese cities over time, the 2021 scores are sufficient for our purposes (see Table 1).

According to this ranking, four first-tier cities are identified in China: Beijing, Shanghai, Shenzhen and Guangzhou (with normalized index values ranging from 0.8 to 1.0). The next group consists of major second-tier cities: Nanjing, Wuhan, Hangzhou, Chengdu, Ningbo, Changsha, Xiamen, Qingdao, Zhengzhou, Hefei, Fuzhou, Chongqing, Jinan, and Xi'an (with index values from 0.5 to 0.8).

For the purposes of our study, first-tier cities are not suitable candidates for comparison because they differ substantially from one another in their economic structure, degree of integration into global networks and administrative status (e.g. capital city, city directly under central government, provincial capital, special economic zone). In the analysis of housing prices, this heterogeneity makes it difficult to separate the influence of educational factors from broader differences in urban status and functions. We therefore focused on selecting a pair of comparable cities from among the second-tier group.

Table 1. City competitiveness ranking in China, 2021

Rank	City	Weighted score
1	Shanghai	1.000
2	Shenzhen	0.975
3	Beijing	0.896
4	Guangzhou	0.817
5	Nanjing	0.715
6	Wuhan	0.704
7	Hangzhou	0.688
8	Chengdu	0.671
9	Ningbo	0.659
10	Changsha	0.635
11	Xiamen	0.624
12	Qingdao	0.619
13	**Zhengzhou**	0.614
14	Hefei	0.597
15	Fuzhou	0.583
16	Chongqing	0.577
17	Jinan	0.567
18	**Xian**	0.552
19	Nanchang	0.497
20	Taiyuan	0.441

Source: Authors' calculations based on the 2021 CASS City Competitiveness Index.

We first excluded Ningbo, Xiamen, Qingdao, Fuzhou and Chongqing from this group, as they are not provincial capitals and are located in different parts of the country, primarily in coastal areas or geographically distinctive regions. It would be difficult to form a homogeneous subgroup from these cities, whereas our aim is to compare provincial capitals with broadly similar economic structures. Chengdu was also excluded, as it functions as a major economic center of Southwest China and stands out markedly from other second-tier cities in terms of its characteristics.

The remaining cities can be divided into two relatively homogeneous subgroups. The first subgroup (Nanjing, Hangzhou, and Jinan) consists of eastern provincial capitals with developed economies and convenient access to maritime routes. The second subgroup (Wuhan, Zhengzhou, Xi'an, Changsha, and Hefei) includes inland provincial capitals located in the Yangtze and Yellow River basins. These cities are generally less developed than those in coastal areas but are comparable to one another in terms of economic structure and spatial position.

Within this second subgroup, we selected Xi'an and Zhengzhou for comparative analysis. While these two cities are similar in terms of economic scale, geographic location and administrative status, they differ substantially in terms of the level and concentration of higher education resources. This combination of similarity in key economic and infrastructural characteristics alongside a pronounced gap in educational resources makes Xi'an and Zhengzhou a suitable pair for examining the effect of the level of urban educational development on the school district housing premium. The following subsection provides a more detailed comparison of the socio-economic and educational characteristics of these two cities.

Comparison of Xi'an and Zhengzhou

In this subsection, we demonstrate that Xi'an and Zhengzhou are comparable in key economic and infrastructural characteristics, yet differ substantially in their level of educational resources.

- **Urban development and metro system.** The built-up area of Xi'an covers 546 square kilometers, with a metro network of 92 km (as of 2021). In Zhengzhou, the built-up area amounts to 437 square kilometers, while the metro network extends over 95 km (as of 2021). Thus, both cities are comparable in terms of urban scale and metro development.
- **Economy.** In 2021, GDP per capita in Xi'an was 78,346 yuan, and per capita disposable income reached 32,597 yuan (38,539 yuan for urban residents and 16,522 yuan for rural residents). In Zhengzhou, GDP per capita was 93,143 yuan, and per capita disposable income amounted to 30,556 yuan (36,050 yuan for urban residents and 19,974 yuan for rural residents). Overall, Zhengzhou slightly outperforms Xi'an in GDP per capita, while household income differences are relatively modest.
- **Transport and mobility.** In 2021, total freight volume in Xi'an reached 254.97 million tons, including 9.94 million tons by rail and 260 thousand tons by air. Passenger traffic totaled 242.87 million passengers, including 45.0 million by rail and 41.86 million by air. By year-end, the city had 2.89 million registered vehicles, including 2.47 million passenger cars. In Zhengzhou, freight volume amounted to 251.57 million tons, including 30.34 million tons by rail and 229 thousand tons by air. Passenger traffic totaled 166.64 million passengers, including 54.18 million by rail and 5.19 million by air. The number of registered vehicles reached 3.13 million, including 2.85 million passenger cars. Overall, freight volumes in the two cities are comparable. Zhengzhou demonstrates stronger rail and air freight performance, while Xi'an shows higher overall passenger traffic, partly due to its tourism sector. Taking population and territory differences into account, vehicle density is broadly similar.
- **Financial sector.** In 2021, total deposits in financial institutions in Xi'an amounted to 2,037.81 billion yuan (including 749.73 billion yuan in household

deposits), while total loans reached 1,715.51 billion yuan. In Zhengzhou, the corresponding figures were 2,034.96 billion yuan in deposits (653.82 billion yuan household deposits) and 1,799.24 billion yuan in loans. The scale of the financial sector is therefore nearly identical in both cities.

- **Geographic position.** Both cities are located within inland China and function as major regional centers, without direct advantages from coastal economic integration. Situated within the Yellow River basin and its tributaries, Xi'an and Zhengzhou have historically developed as key nodes in transport corridors linking eastern and western China. As provincial capitals and major transport and logistics hubs, they have a similar metropolitan scale and level of internal mobility. This is important when making meaningful comparisons between housing markets.

We now turn to educational resources. In China's higher education system, university status has traditionally been defined through large-scale national support initiatives. In the 1990s, two major programs were launched: "Project 211", aimed at strengthening approximately one hundred leading universities and key disciplines, and more selective "Project 985", designed to develop world-class research universities (39 institutions, all also included in Project 211). The nine strongest universities within Project 985 form the C9 League. Broadly speaking, C9 universities can be regarded as the top nine institutions in the country. The entire 985 group includes around the top 40 universities, and the group of 211 universities includes approximately 120 leading higher education institutions.

In recent years, both programs have been incorporated into the 'Double First-Class' initiative, which aims to develop world-class universities and disciplines. The official lists of participating institutions were updated in 2022. Nevertheless, the labels '211' and '985' remain widely used in academic and public discourse. For this reason, when describing the spatial distribution of elite universities, we primarily rely on the historical '211' and '985' classifications, supplementing them with reference to 'Double First-Class' status where relevant.

From this perspective, the differences between Xi'an and Zhengzhou are substantial (see Table 2).

Table 2. Number of top universities in Xi'an and Zhengzhou

City	C9	Project 985	Project 211
Xi'an	1	1	7
Zhengzhou	0	0	1

Source: Authors' compilation based on data from the official website of China's Ministry of Education.

In addition to the number of elite universities, we also consider a comprehensive higher education competitiveness index for mainland China (Southern Plus, 2025). At the beginning of 2022, when our housing dataset was formed, Xi'an was ranked

6th among provincial capitals for higher education competitiveness, with 32 points. Meanwhile, Zhengzhou was ranked 24th, with fewer than 8 points. In a more recent 2025 ranking covering 1,072 universities across 267 cities, Xi'an was among the top five university centers nationwide (after Beijing, Shanghai, Nanjing, and Wuhan), while Zhengzhou ranked 16th. Although Zhengzhou's position has improved somewhat, the gap in higher education development remains significant, confirming Xi'an's status as a much stronger university center.

Official statistics from the Ministry of Education (Ministry of Education of the People's Republic of China, 2024) indicate structural differences. Although the total number of higher education institutions is comparable (97 in Xi'an and 71 in Zhengzhou), their internal composition differs markedly. Zhengzhou has a larger overall student population (approximately 1.35 million versus 1.03 million in Xi'an), with a significant share enrolled in colleges and applied institutions. By contrast, Xi'an has more than 2.7 times as many master's and doctoral students (approximately 183,000 compared to 67,000), accounting for 18% of total enrolment, compared to 5% in Zhengzhou. This suggests that Xi'an's higher education institutions are substantially more research-oriented. Thus, the structural data are consistent with Xi'an's higher positions in rankings of higher education competitiveness.

In China, higher education resources are traditionally seen as an important measure of a city's overall educational development. Inequality in these resources also influences perceptions of the quality of secondary education. In both cities, a significant proportion of high school graduates enroll in universities within their home province. According to reports from the provincial education departments for 2023, this proportion consistently exceeds 70% in both Shaanxi (Xi'an) and Henan (Zhengzhou).

However, the competitiveness of leading local universities differs far more than suggested by the total number of institutions. According to official *gaokao*[1] admission thresholds for 2023, key engineering programs at Xi'an Jiaotong University (historically part of Project 985 and included in Double First-Class) require substantially higher entrance scores for applicants from Shaanxi than comparable programs at Zhengzhou University (Project 211 and Double First-Class participant) require for applicants from Henan. This gap is widening due to significant demographic differences: in 2023, over 1.3 million candidates registered for the Gaokao in Henan Province, which has only one Double First-Class university, Zhengzhou University. By contrast, the number of Gaokao candidates in Shaanxi was nearly four times smaller (around 330,000), yet the province is home to six Double First-Class universities, including Xi'an Jiaotong University.

Taken together, these differences imply that for families in Xi'an, admission to a strong local secondary school is perceived as a more direct and realistic pathway

[1] The *gaokao* is China's national college entrance examination and the main mechanism of admission to higher education institutions

to a prestige university than in Zhengzhou, where even very high gaokao scores do not guarantee admission to a top-tier institution because of intense competition. Research in the sociology of education in China shows that, in large cities with a high concentration of prestigious universities and intense competition for places, parents tend to start planning their children's educational journeys from primary and secondary school onwards. This involves choosing a school district and making investments in extracurricular activities and other educational opportunities (Shi et al., 2020; Liu & Qiao, 2024). It is therefore reasonable to expect that, on average, parents in Xi'an are more sensitive to school quality and more attentive to the school selection process than parents in Zhengzhou.

We argue that these differences have deep historical roots.

First, Xi'an has a long history as a former capital of China and repeatedly served as a political, cultural, and educational center. Zhengzhou, by contrast, remained largely a regional trade and transport hub until the 20th century, while Luoyang long functioned as the historical center of Henan Province and had previously served as a Chinese capital. Around two thousand years ago, Xi'an and Luoyang were the western and eastern capitals respectively, forming the heart of ancient Chinese civilization. Although the centers of political and economic gravity later shifted northwards and southeastwards, Xi'an accumulated and preserved educational and research institutions to a much greater extent than Zhengzhou.

Second, events in the 20th century played a decisive role. Before World War II, most Chinese universities were concentrated in Beijing and Shanghai. During the war, many eastern cities (including Beijing, Shanghai, Nanjing, and Zhengzhou) were occupied by Japan. Consequently, many leading universities were moved to safer areas in the west, such as Xi'an and Chongqing, and some did not return after the war. For example, Northwestern Polytechnical University in Xi'an was established in 1938 based on several institutions relocated from Beijing. Similarly, Jiaotong University, originally based in Shanghai, was evacuated to Chongqing and later transferred to Xi'an, which thus inherited a stronger university base. Today, these institutions form the backbone of Xi'an's scientific and educational capabilities.

Data and variables

As a source of micro-level housing market data, we use listings of residential property sales extracted from the online platform **Lianjia (**链家**)**, one of the largest real estate brokerage companies in China. Lianjia data are widely used in academic research on housing markets in major Chinese cities (see, e.g., Li et al., 2019; Yu & Hou, 2021), which supports their suitability for empirical analysis.

To ensure comparability between the two markets, we restrict the sample to a narrow time window. The dataset includes apartment sale listings in Xi'an and Zhengzhou posted on the Lianjia platform between February 1 and February 28, 2022.

The short observation period helps minimize the influence of macroeconomic shocks and regulatory policy changes on housing price dynamics.

The dataset refers to 2022, but the institutional structure of school district housing markets in China exhibits a high degree of stability over time. In particular, the list of key secondary schools in both cities has remained unchanged in recent years, meaning that the spatial distribution of educational advantages remains largely stable.

For each city, active resale housing listings were collected from the Lianjia website using a web-scraping procedure. For each listing, the dataset includes the standard information provided by the platform: residential complex name, year of construction, total apartment area, floor level, orientation, building type, renovation level, property address and asking price. In addition, the data contain an indicator of attention to the listing (the number of views), which allows us to partially control for differences in market exposure across properties.

On the Lianjia platform, apartment orientation is reported as a categorical variable (south, north–south, east, west, and their combinations) and directly affects prices. In the empirical analysis, we aggregate these options into a binary variable *NorthSouth*, which takes the value 1 for south or north–south orientation. These directions are generally considered preferable in the Chinese housing market, reflecting both market expectations and cultural norms: southern exposure is associated with better sunlight conditions, while a north–south orientation is additionally valued because it provides natural cross-ventilation and is traditionally regarded as the most favorable layout. All other orientations are used as the baseline category.

The renovation condition is aggregated into a binary variable "Fine repair", which takes the value of 1 if the apartment has high-quality renovation and 0 otherwise (basic renovation, unfinished condition, or other states). Apartments that have been renovated to a high standard are generally perceived by the market as more attractive because they do not require any additional time or financial investment after purchase, and can be used immediately for living or rental purposes.

On the Lianjia platform, building type is specified as a categorical characteristic (*Panel type*, *Tower type*, *Mixed type*). These formats differ in structural design and, consequently, in perceived housing quality. Sectional buildings (*Panel type*) typically have a shallower building depth, provide better sunlight exposure, and allow more effective natural ventilation. This makes them more desirable from residential comfort perspective. Tower buildings (*Tower type*), by contrast, are characterized by higher density and often less favorable apartment orientation. The *Mixed type* combines elements of both formats and occupies an intermediate position in terms of market perception. The *Tower type* is used as the baseline; so positive coefficients are expected for the *Panel* and *Mixed types*, reflecting a price premium for more desirable formats.

From the initial dataset, we excluded villas, luxury residences and various subsidized or affordable housing formats, focusing instead on typical urban apartments in the secondary housing market. After data cleaning and removing

observations with missing values for key variables, the final sample consists of 1,118 observations for Xi'an and 1,269 observations for Zhengzhou. In both samples, several dozen observations still had missing information on floor level. To avoid losing these observations, such apartments were assigned to the middle floor category (Mid floor = 1; Low floor = High floor = 0). When the total number of floors in a building was missing, we substituted the median value for the respective city.

To measure the spatial accessibility of schools, we additionally used the Gaode (Amap) mapping API, which is part of the Alibaba ecosystem. Based on the address of each residential complex, every observation was geocoded into geographic coordinates (latitude and longitude). Using these coordinates, we calculated the distance to the city center and the distance to each key secondary school in the city. The variable *Distance to key school* is defined as the minimum of the distances between the property and all key secondary schools. Distances were measured as the shortest distance over the Earth's surface (great-circle distance) between the property coordinates and the corresponding reference point. It is important to note that this variable captures spatial proximity to the nearest key secondary school rather than formal admission eligibility. In China, the value of school-district housing may also depend on catchment boundaries, school status, residence requirements, and local admission rules. Because complete and comparable boundary-level admission data are not available for both cities, our measure should be interpreted as a proximity-based indicator of access to key educational resources.

The list of key secondary schools in Xi'an and Zhengzhou was compiled using data from the educational portal **chusan.com**, a large online resource that publishes educational materials, school information and lists of key secondary schools for Chinese cities. The list selected for the analysis is provided in **Appendix A (Tables A1–A2)**.

Based on these sources, we constructed the set of variables used in the econometric analysis (see Table 3). Descriptive statistics indicate that the housing markets in the sample are broadly comparable in terms of price levels and apartment characteristics.

Table 3. Definition of variables used in empirical analysis (with descriptive statistics)

Description (unit)	Expected sign	Xi'an (Mean / Share)	Zhengzhou (Mean / Share)
Dependent variable			
Log of total apartment price (ln(CNY))		4.771	4.771
Continuous variables			
Apartment area (m^2)	+	94.600	101.900
Distance to city center (km)	−	10.913	10.581
Distance to key school (km)	−	5.100	6.037
Attention / views index (count)	?	20.979	22.770
Number of rooms (count)	+	2.433	2.656
Number of halls (count)	+	1.579	1.602
Total floors in building (count)	?	21.460	18.170
Orientation dummy (share) (base category in regressions: not North-South, not South)			
NorthSouth (=1)	+	0.420	0.423
Floor group dummies (share) (base category in regressions: mid floor)			
Low floor (=1)	?	0.245	0.258
Mid floor (=1)	base	0.452	0.446
High floor (=1)	?	0.303	0.296
Building type dummies (share) (base category in regressions: mixed)			
Panel type	+	0.322	0.549
Tower type	base	0.185	0.193
Mixed type	+	0.493	0.258
Renovation dummy (share) (base category in regressions: not fine)			
Fine repair	+	0.521	0.452
Simple repair	base	0.334	0.391
Unfinished repair		0.089	0.079
Other		0.057	0.079

Source: Authors' compilation.

Hedonic pricing model

The hedonic pricing model treats housing prices as a function of a set of property characteristics (attributes). In real estate markets, housing units represent differentiated products: apartments differ in size, layout, renovation quality, building type and location. Therefore, the observed listing price reflects the market valuation of this set of

characteristics at the time the listing is posted, including the accessibility of local public goods – in our case, access to a key secondary school.

In the empirical part of the study, we estimate a hedonic model for each city using secondary housing market data (February 2022). The dependent variable is the logarithm of the apartment price. Taking the logarithm allows the coefficients on continuous regressors to be interpreted as semi-elasticities, partially reduces the right-skewness of the price distribution, and decreases the sensitivity of estimates to outliers. The baseline specification for city c ∈ {Xi'an, Zhengzhou} is as follows:

$$ln(price_{ic}) = \alpha_c + \beta_c dist_to_school_{ic} + \gamma_c dist_to_center_{ic} + X'_{ic}\vec{\delta}_c + \varepsilon_{ic},$$

where *dist_to_school* denotes the distance to the nearest key secondary school (km), *dist_to_center* is the distance to the city center (km), and *X* is a vector of structural and quality housing characteristics (control variables listed in Table 3). Estimation is performed using ordinary least squares (OLS) separately for each city. As an additional cross-city test, we estimate a pooled specification combining observations from Xi'an and Zhengzhou. The model includes a Xi'an city dummy and interactions between this dummy and regressors. This specification allows the coefficients of the control variables to differ between the two cities, while the interaction between the Xi'an dummy and *Distance to key school* provides a formal test of whether the school-distance gradient differs across cities.

We estimate the models using heteroskedasticity-robust standard errors. As an additional robustness check, we also compute standard errors clustered at the residential complex level (xiaoqu_id), which accounts for possible correlation of unobserved factors within the same complex. We further conduct diagnostic checks for multicollinearity, model specification and influential observations. The estimated coefficients are broadly robust to the choice of standard error specification. What follows reports results using heteroskedasticity-robust standard errors (also known as White-type robust standard errors). The key parameter of interest is β_c, which shows how housing prices change with increasing distance from the nearest key secondary school. In line with the hypotheses formulated in the introduction, this forms the basis for testing the following:

- **H1:** $\beta_c < 0$ and statistically significant in both cities (i.e., the closer a property is to a key secondary school, the higher its price).
- **H2:** $|\beta_{Xi'an}| > |\beta_{Zhengzhou}|$, meaning that the proximity premium associated with key secondary schools is larger in Xi'an.

The test of **H3** (heterogeneity of the effect) is presented in the next section.

Endogeneity and identification. Interpreting the estimate of β_c as the effect of proximity to a key secondary school requires caution. Endogeneity may arise if unobserved neighborhood characteristics, such as the quality of infrastructure, the composition of the population, or the overall prestige of the location, are correlated with distance to a key school. The literature commonly mitigates this concern using instrumental variables and/or boundary fixed effects at school-district borders. In our

setting, however, a full implementation of these approaches is problematic. First, it is difficult to justify a strong and valid instrument for *Distance to school*: possible sources of variation, such as the historical location of schools, administrative decisions granting 'key' status, or local infrastructure projects, are likely to be related to neighborhood quality and buyers' expectations. This would violate the assumption of exogeneity. Second, boundary-based designs are constrained by features of China's school-district housing market: demand often extends beyond formal catchment boundaries (e.g., purchases of small units as a "ticket" to school admission and investment demand), which reduces the informativeness of comparisons within a narrow band around the boundary. Therefore, our baseline approach is to use a hedonic model with controls for property attributes and overall accessibility (distance to the city center). We then assess the robustness of our main conclusions using quantile regression, a method that accounts for heterogeneity across price segments. For this reason, throughout the empirical interpretation we treat the coefficient on distance to the key school as a conditional association, or price gradient related to proximity to the school, rather than as a fully identified causal effect.

Quantile regression

The OLS model estimates the effect of covariates on the conditional mean of *ln*(*price*). However, the proximity premium associated with key secondary schools may vary across market segments. It may be stronger in lower-priced segments if access to better schools is especially valued by households on tighter budgets. Alternatively, it may be stronger in higher-priced segments. To test for such heterogeneity, we use quantile regression (QR), estimating the impact of the regressors at different conditional quantiles of the distribution of *ln*(*price*). For a chosen quantile $\tau \in (0,1)$, we estimate the following specification: the conditional quantile model

$$Q_\tau\left(ln(price_{ic}) \mid Z_{ic}\right) = \alpha_{c,\tau} + \beta_{c,\tau} dist_to_school_{ic} + \gamma_{c,\tau} dist_to_center_{ic} + X'_{ic}\vec{\delta}_{c,\tau}$$

where Z = (*dist_to_school*, *dist_to_center*, X) includes the same regressors as in the baseline hedonic model. Estimation is carried out by minimizing an asymmetric loss function (the check function), which makes QR less sensitive to outliers and allows for a direct comparison of effects in the lower and upper parts of the housing price distribution. Bootstrap standard errors were additionally computed as a robustness check for the quantile regression estimates. Quantile regression is used to test the following hypothesis:

- **H3:** $\beta_{c,\tau}$ differs across quantiles of the conditional *ln*(*price*) distribution (i.e., $\beta_{c,\tau_1} \neq \beta_{c,\tau_2}$ for some $\tau_1 \neq \tau_2$, meaning that the capitalization effect of proximity to a key school is heterogeneous across housing price segments.

Thus, the combination of OLS and QR provides two complementary tests: the presence of the "average" effect and its cross-city differences (**H1–H2**), and the heterogeneity of this effect across market segments (**H3**).

Results

To ensure comparability, we report estimates from the baseline hedonic (OLS) model separately for Xi'an and Zhengzhou in the comparative Table 4. The coefficients are interpreted as semi-elasticities, since the dependent variable is specified in logarithms.

Table 4. OLS hedonic price model estimates for Xi'an and Zhengzhou

Variable	Xi'an	Zhengzhou
Intercept	3.249***	3.138***
	(0.0510)	(0.0486)
Area	0.0086***	0.0097***
	(0.0005)	(0.0005)
Distance to city center	0.0073	−0.0079***
	(0.0054)	(0.0028)
Distance to key school	−0.0354***	−0.0123***
	(0.0046)	(0.0039)
Attention	−0.0011***	−0.0001
	(0.0003)	(0.0003)
Room	0.1064***	−0.008
	(0.0180)	(0.0206)
Hall	0.0891***	0.0946***
	(0.0169)	(0.0241)
Total floors	0.0121***	0.0135***
	(0.0008)	(0.0010)
NorthSouth	0.0809***	0.2300***
	(0.0214)	(0.0315)
Low floor	−0.0271	0.0136
	(0.0192)	(0.0254)
High floor	−0.0493***	−0.0105
	(0.0171)	(0.0243)
Panel type	0.0859***	0.1932***
	(0.0228)	(0.0272)
Mixed type	0.0833***	0.1176***
	(0.0204)	(0.0304)
Fine repair	0.1049***	0.2116***
	(0.0158)	(0.0213)
Observations	1118	1269
R^2	0.783	0.636
Adjusted R^2	0.780	0.632
Prob > F	0.000	0.000

Notes: Standard errors in parentheses are heteroskedasticity-robust (HC/White). *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Source: Authors' calculations (R).

Both models are statistically significant overall, and the adjusted R^2 indicates a higher explanatory power for Xi'an than for Zhengzhou.

The main result concerns distance to a key secondary school: the coefficient on *Distance to school* is negative and statistically significant in both models. This implies that, conditional on observed property and location characteristics, a greater distance to the nearest key middle school is associated with a lower listing price, which is consistent with **H1**. A comparison of the estimates shows that the effect is substantially larger in Xi'an than in Zhengzhou in absolute terms: a 1 km increase in distance to a key school is associated with an approximately 3.5% decrease in price in Xi'an and a 1.2% decrease in Zhengzhou. Thus, the magnitude of the coefficient in Xi'an is almost three times greater than that in Zhengzhou. The 95% confidence interval for the coefficient on *Distance to key school* is approximately [−0.044; −0.026] in Xi'an and [−0.020; −0.005] in Zhengzhou. To formally test this cross-city difference, we estimated a pooled model with a Xi'an dummy and interactions between the city dummy and the regressors. The interaction between the Xi'an dummy and *Distance to key school* is negative and statistically significant (coefficient = −0.023, $P < 0.001$), confirming that the school-distance gradient is significantly stronger in Xi'an. Taken together, the city-specific estimates, confidence intervals, and the pooled interaction test support H2: the proximity premium associated with key secondary schools is higher in Xi'an than in Zhengzhou.

Additional diagnostic checks support the robustness of the main result. The VIF values do not indicate severe multicollinearity: the highest values are observed for the spatial variables but remain below the conventional threshold of 10. The influential-observation check also shows that the result is not driven by a small number of influential observations. After excluding the top 1% observations by Cook's distance, the coefficient on *Distance to key school* remains negative and statistically significant in both cities.

To compare effect magnitudes, note that in Xi'an a 1 km increase in distance to a key secondary school would need to be offset by an increase in apartment size of about 4 m² to keep the price unchanged. In Zhengzhou, the same increase in distance corresponds to roughly 1.3 m² of additional area. This indicates that the education-related factor is comparable in magnitude to changes in one of the key housing attributes.

The control variables generally have expected signs. Apartment size, the number of halls, total building floors, building type and high-quality renovation are statistically significant and positively associated with prices in both models. In Xi'an, a broader set of housing attributes is significant (including the number of rooms and the high-floor dummy), whereas in Zhengzhou proximity to the city center is significant. These differences probably reflect the specific features of the secondary housing market in each city and the varying sensitivity to property characteristics. They also point to a more pronounced monocentric structure in Zhengzhou. In contrast, the emergence of multiple development zones and new clusters outside the historical core in Xi'an (including the High-Tech Zone, Qujiang New District and the Chanba Ecological

Area, among others) weakens the relationship between property prices and distance from the administratively defined center (World Bank, 2023). Notably, the key finding regarding proximity to the nearest key secondary school remains robust.

We also present the results for apartment orientation. The NorthSouth variable is positive and statistically significant in both models, confirming a price premium for south-facing or north–south exposure. These orientations are traditionally favoured in China because they allow for better sunlight and natural ventilation, and align with long-standing cultural norms regarding the 'proper' orientation of a dwelling. The effect is stronger in Zhengzhou, indicating that these preferences play an important role even in a more modern city with a less historically structured urban layout.

Finally, to test Hypothesis H3 on the heterogeneity of the proximity effect across housing price segments, we estimate quantile regressions. This approach allows us to assess whether the impact of *Distance to school* differs between higher-priced and more affordable market segments, thereby complementing the OLS results, which relate to the conditional mean.

The results for Zhengzhou indicate moderate heterogeneity. The coefficient on *Distance to key school* is negative and statistically significant at all considered quantiles; however, its magnitude is larger in absolute value in the lower segment ($\tau = 0.25$) and declines somewhat in the median and upper segments of the price distribution. This suggests a tendency toward a more pronounced "school premium" in the more affordable part of the market, although the confidence intervals partially overlap and the differences across quantiles are not sharp. In this sense, **H3** receives partial support for Zhengzhou.

For Xi'an, the coefficients on *Distance to key school* are also consistently negative and statistically significant across all quantiles, but their magnitude changes very little over the price distribution. This points to a fairly uniform capitalization of proximity to key secondary schools across housing price segments and, accordingly, does not support **H3** for Xi'an.

The quantile regression results are also robust to the use of bootstrap standard errors. The coefficient on *Distance to key school* remains negative and statistically significant across all considered quantiles in both cities.

The remaining coefficients are generally highly stable across quantiles: floor area, high-quality renovation and building type retain positive and significant effects in all segments. The most notable differentiation is observed for apartment orientation and building type in Zhengzhou, where the corresponding premia increase in the upper segment, whereas in Xi'an the contribution of these characteristics is more stable across the entire price distribution.

Discussion

The results confirm that access to key secondary schools is capitalized into housing listing prices in the secondary market in both cities. The negative relationship between

price and distance to the nearest key middle school is consistent with the logic of the "school-district housing" (*xuequfang*) market: under a residence-based enrollment system, proximity to a high-quality school becomes a valuable advantage and is reflected in higher housing prices.

A comparison of the estimates shows that the proximity premium is higher in Xi'an than in Zhengzhou. This is consistent with differences in the educational environment: in a city with a higher concentration of educational resources, households' expectations and their willingness to pay for access to high-quality schooling may be stronger.

At the same time, this cross-city comparison should not be interpreted as isolating the effect of the educational ecosystem alone. Xi'an and Zhengzhou may also differ in demand structure, district prestige, spatial organization, market segmentation and local institutional arrangements. Therefore, we interpret the stronger school proximity premium in Xi'an as being consistent with differences in the wider educational environment, while acknowledging that other city-specific factors may also contribute to the observed gap.

We also clarify that the higher education environment is not used as a direct measure of household motivation. Instead, it is seen as part of the broader educational context that can influence expectations regarding educational pathways. The link between university resources and secondary-school housing demand is therefore interpreted cautiously and not as a standalone causal mechanism. In order to establish this mechanism in a more direct manner, it would be necessary to obtain household-level data on school choice and expectations, richer neighborhood-level controls, or a larger multi-city design.

More generally, it is important to note that the estimated coefficients capture the statistical associations within our empirical framework. Interpreting them as causal effects of school proximity would require a separate identification strategy capable of isolating the school effect from other unobserved neighborhood characteristics.

Quantile regression complements the OLS analysis by enabling us to examine potential heterogeneity in the relationship between covariates and prices across market segments, thereby clarifying the interpretation of **H3**. The results indicate that the nature of heterogeneity differs across the two cities. In Xi'an, the effect of proximity to a key school remains statistically significant and nearly constant across quantiles, suggesting a fairly uniform capitalization of the "school premium" throughout the price distribution. In Zhengzhou, by contrast, we observe moderate differentiation: the effect is stronger in the lower-priced segment and weakens toward the middle and upper parts of the distribution.

In theory, proximity to a key school can have a different impact on property prices in different segments of the market. In the more affordable segment, this school attribute may play a more important role as a channel for upward mobility and human-capital accumulation. In contrast, in the upper segment, housing prices may be more influenced by factors such as location prestige, construction quality, and

other property characteristics. In this context, the results for Zhengzhou are consistent with this logic; in Xi'an, however, the school factor appears to be more universal across segments.

There are several limitations that should be noted. First, the analysis is based on listing prices, which may differ from final transaction prices. Second, endogeneity remains a concern, as proximity to key schools may correlate with unobserved neighborhood attributes, such as infrastructure quality and prestige, implying that the coefficient on *Distance to school* should be interpreted with caution in causal terms. Given the complexity of housing price formation, the baseline linear hedonic model should be viewed as a simplified approximation; for this reason, we complement it with quantile regressions and additional robustness checks. In addition, buyers' expectations about the future development of specific neighborhoods may also affect housing prices and residential choices. Although we control for general accessibility using distance to the city center and include a set of property-level characteristics, such expectations cannot be fully accounted for in our data and therefore remain a limitation. Third, spatial dependence in the error terms is possible in housing data. Using robust standard errors (and, for an additional check, standard errors clustered at the level of residential complexes) helps to reduce the risk of erroneous inferences being made. Finally, our sample was limited to the secondary market data from a single platform and one observation period. The short observation window helps reduce the influence of macroeconomic and regulatory changes, but it does not allow us to test for seasonal patterns in the school-district housing market. Although the school year in China usually begins in September, housing decisions related to school access may be made several months earlier, when families prepare documents and secure residence-based eligibility. Therefore, the February window may capture part of this pre-enrollment planning, but we cannot rule out seasonal fluctuations. Future research could expand the dataset to include other months, such as those in autumn, in order to test the temporal stability of the results.

Conclusions

This paper estimates the capitalization of proximity to a key secondary school in housing listing prices on the secondary market in two comparable Chinese cities: Xi'an and Zhengzhou. Despite similarities in several economic and infrastructure characteristics, the cities differ markedly in the concentration of educational resources. This enables us to interpret the differences in the cross-city estimates as reflecting differences in the educational environment.

Estimates from hedonic models show that, in both cities, housing prices are statistically significantly associated with distance to the nearest key secondary school: all else being equal, greater distance corresponds to a lower listing price. This confirms the existence of a premium for proximity to a key school. The effect is substantially stronger in Xi'an than in Zhengzhou, and the pooled interaction test confirms that this

difference between the two cities is statistically significant. These findings support the idea that the proximity premium is higher in cities with more developed educational systems.

The study contributes to the literature by showing that the magnitude and distribution of school-related housing premiums may be associated not only with institutional assignment rules but also with the broader educational ecosystem of the city.

Quantile regressions complement the OLS results by assessing heterogeneity across price segments. In this study, the heterogeneity of the effect across price segments is partially confirmed: in Zhengzhou, the effect is stronger in the lower segment of the market and weakens for more expensive housing, whereas in Xi'an the proximity premium is distributed relatively uniformly across the entire price spectrum. From a practical perspective, the findings suggest that residence-based enrollment policies and the limited supply of high-quality school places can reinforce price-based segregation in housing markets, since access to educational resources is partly reflected into property values. This emphasizes the importance of policies that equalize the quality of compulsory education and reduce dependence on place of residence for educational opportunities.

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Appendix A

List of key secondary schools used in the analysis

The list of key secondary schools was compiled using information from the educational portal **chusan.com**, which publishes city-level rankings and lists of recognized key middle schools in China. The schools included in the analysis correspond to those identified as key secondary schools in Xi'an and Zhengzhou according to these sources.

Geographic coordinates were used to compute the distance between each property and all schools in the corresponding city.

Table A1. Key secondary schools in Xi'an

School	Latitude	Longitude
西安市铁一中学	34.240467	108.973288
西安交通大学附属中学	34.224666	109.003327
西安市长安区第一中学	34.136951	108.966192
陕西省西安中学	34.331683	108.940097
陕西师范大学附属中学	34.215598	108.960128
西北工业大学附属中学	34.241871	108.919502
西安市第八十五中学	34.220741	108.956375
西安市第三中学	34.264376	108.984394
西安高新第一中学	34.178121	108.881399
周至中学	34.16186	108.242575
户县第一中学	34.111465	108.61088
西安市第八中学	34.256335	108.960421
西北大学附属中学	34.247665	108.920662
西安市第七十中学	34.258361	108.928931
西安市第一中学	34.264526	108.918606
西安市第八十三中学	34.252288	108.999445
西安市第八十九中学	34.272314	108.94976
西安思源中学	34.229633	109.077643

Table A2. Key secondary schools in Zhengzhou

School	Latitude	Longitude
郑州枫杨外国语学校	34.7604	113.5046
郑州外国语中学	34.7385	113.5168
郑州实验外国语学校	34.7009	113.6009
郑州一八联合国际学校	34.8126	113.6802
郑州市第八中学	34.7651	113.6802
郑州桐柏路一中	34.7610	113.6455
河南省实验中学	34.7907	113.6826
郑州市经纬中学	34.7610	113.6601
郑州市郑中国际学校	34.7041	113.5727
郑州一中经开区实验学校	34.7015	113.7370