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How Much Is a Good School Worth in Beijing? Identifying Price Premium with Paired Resale and Rental Data

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Abstract A neighborhood school policy is implemented in Beijing, where public education dominates. But only home owners, rather than renters are entitled to enroll in a local public school, even when both live in a school's attendance zone. We estimate the implicit price of school quality in Beijing's housing market by comparing within- and out-of-zone home values in adjacent buildings. Enabled by the "renter discrimination policy," this study further controls for the difference in unobserved neighborhood traits using the rental differentials between paired observations. School quality has been capitalized in home values in Beijing. A within-zone housing unit is sold RMB 2,266 yuan per square meter more than if it were outside the attendance zone of a Key Primary School.

Keywords Home price premium · Key Primary School · Paired data · Rent · Beijing

Introduction

China is experiencing an unprecedented wave of urbanization. The urbanization rate rose from under 20 % in 1980 to 50 % in 2011. Since two decades ago, urban land and housing markets have been gradually replacing state administrative land allocation and

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housing provision. Today, the most valuable private property of an urban household is often their home. Studying what affects housing market values is vital to understanding urban household location choice and consumption patterns, which in turn, allows for better design of urban plans and policies.

When the quality of school education and other public services a household receives depends on where the household is located, they are capitalized into home value. As with many other countries, China implements a neighborhood school policy to allocate urban households to different public schools[1] based on the school attendance zones they live in. In Beijing, primary schools and to some extent middle schools are supposed to enroll students who live within their attendance zones. Required by the Beijing Municipal Government, schools publish their enrollment brochures, which specify their attendance zones by naming exact residential buildings or building complexes (instead of by drawing a spatially closed boundary), almost all of which contain multi-household mid- to high-rise towers. Needless to say, if a household cares about the quality of public education, the neighborhood school policy provides an incentive for it to move to attendance zones of good schools.

Compared to typical public education systems in Western countries such as the U.S., Beijing's school system and admission rules have important differences. First, there is no local property tax in Chinese cities, and the funding of public education is from the municipal general fund.[2] As a result, Chinese cities have no corresponding concept of "school district", which links the local property tax a homeowner pays to the funding of local public schools. Second, in many Chinese cities, including Beijing, where this study is carried out, only property owners are guaranteed to enroll in the local public school.

In this study, we test whether and the extent to which school quality is capitalized in home value. More specifically, we compare the average housing prices per square meter of out-of-zone housing complexes to those of nearby within-zone housing complexes. Taking advantage of the unique "renter discrimination" education policy in Beijing, we further control for the difference in unobserved neighborhood traits using the rental differentials of housing complexes in and out of the attendance zones of the "Key Primary Schools". This innovative approach enables a more robust identification of the home value impact of school quality.

The rest of the paper is as follows. We first review existing studies on the capitalization of school quality in home values. We then describe our data and method, followed by the results of analyses. The final section concludes the paper with policy implications, limitations, and future research needs.

Literature Review

The capitalization of school quality in home value is an important question in the broader literature on the impact of public services (e.g., education, neighborhood safety and physical infrastructures) on housing market outcomes, starting with the seminal

[1] The vast majority of children in Chinese cities go to public schools. Private schools are very small in number and often considered less attractive compared to good public schools.

[2] See http://www.gov.cn/flfg/2006-06/30/content_323302.htm.

work of Oates (1969). Earlier studies, such as Rosen and Fullerton (1977) and Judd and Watts (1981), apply the hedonic technique to empirically confirm the positive and statistically significant relationship between home value and school quality, measured by educational spending and/or student test scores. It is very difficult for traditional hedonic models to include all possible characteristics of homes, households, and neighborhoods. Hence the estimation of school quality's effect on home value is likely biased due to omitted variables that are correlated with school quality. To address this issue, more recent studies have relied on various sorts of identification strategies. Some studies employ instrumental variables (IVs) that presumably induce exogenous differences in school quality. For example, using the recent occurrences of an external school inspection as the instrument for school quality change, Rosenthal (2003) finds an elasticity of dwelling purchase price with respect to exam performance by schools at around +0.05 in the UK. Gibbons and Machin (2006) rely on salient school characteristics such as institutional age to generate such exogenous differences in school quality. The majority of such IV-based studies, however, were found to be less compelling, as questions can be raised about the validity of the IVs (Nguyen-Hoang and Yinger, 2011).

An innovative and more popular strategy to control for unobserved jurisdiction and neighborhood characteristics is the use of the boundary fixed effect or spatial discontinuity. By comparing the values of houses on opposite sides of attendance-zone boundaries in the same school district, Black (1999) finds a positive impact of school quality on home value. But the magnitude of this impact is substantially smaller compared to the results of a hedonic model including samples far away from the boundaries. This strategy has been subsequently extended by studies such as Fack and Grenet (2010) and Gibbons et al. (2013). Fack and Grenet (2010) match a house sale value to a reference home value computed from all housing sale transactions that took place in the same year, but on the other side of the common attendance boundary. They find a standard deviation increase in the average exam score at the school level raises housing prices by 1.4 to 2.4 %, roughly 5 % of the observed differences in housing prices between adjacent school zones. By matching identical properties across attendance boundaries, incorporating within-boundary variation, and controlling for distance-to-boundary trends, Gibbons et al. (2013) show that a one-standard deviation change in school performance raises prices by around 3 %.

However, the use of the boundary fixed effect technique reduces but cannot eliminate the bias from all omitted variables, especially where residential sorting exists, which can lead to differences in neighborhood characteristics (Kane et al. 2006).[3] Fortunately, one may greatly relieve this concern with longitudinal data, as the identification of home value impact of school quality comes from its temporal variation. Using detailed data on repeated sales of residential properties in the state of Florida, Figlio and Lucas (2004) examine whether the housing market responds to state-administered school grades, controlling for observed school attributes, such as test

[3] An earlier remedy to school-induced sorting is to include neighborhood income and education as control variables on both sides of a boundary (e.g., Bayer et al., 2007). Unfortunately, by including demand variables like income and education, this approach introduces an endogeneity bias as households simultaneously select housing price and school quality, while both decisions are affected by income and education (Butler, 1982; Nguyen-Hoang and Yinger, 2011).

scores. They find an independent effect of these grades on house prices and residential location, but such an effect diminished over time. Taking advantage of events such as the rezoning of school districts or attendance zones, Reback (2005) and Kane et al. (2006) find that house values respond to exogenous policy changes in school boundary or admission rules. Ries and Somerville (2010) employ repeat sales data in rezoned areas and find significant impacts of secondary school performance on residential prices. But when long-run price trends are controlled, only prices of residences likely to be purchased by high-income families appear to have been affected by rezoning induced changes in school quality.[4]

Due to the short history of assigning school attendance rights based on geographic location within cities, there have been very few studies on the capitalization of school quality in China. Using individual home sales data in Beijing, Zheng and Kahn (2008) find positive correlation between distance to high-quality schools and home value. But the validity of their results seems to suffer from the classic bias due to missing variables. Observing a natural experiment similar to that in Figlio and Lucas (2004), Feng and Lu (2010) find positive changes in house values following the municipal designation of "Model High Schools" in Shanghai and the capitalization of the designation in home value decreases over time. However, this study is based on data aggregated at the "area" level that typically includes multiple high schools – school quality is measured in a noisy way. Using the same dataset as in this study, Hu et al. (2014) adopt the boundary fixed effect approach to quantify the capitalization of premium primary school in home price in Beijing. They find an 8.1 % price difference between adjacent homes on the boundary. Nevertheless, their method is still subject to Kane et al.'s (2006) critique that omitted variables, especially due to residential sorting, can lead to unobservable differences in neighborhood characteristics. This is the central issue this paper tries to resolve.

Research Context and Data

As shown in Fig. 1, the Beijing Metropolitan Area spreads out in every direction. Tian'anmen Square with the surrounding traditional hub of commercial, cultural, and administrative functions is considered as the city center. The five ring roads circling Tian'anmen Square were built successively from inside to outside, demonstrating a mono-centric urban structure (Zheng and Kahn, 2008). In the last decade, vast infrastructure investment took place in Beijing, a megacity with 15 subway lines today.

Before the late 1980s, urban housing was allocated to residents as a welfare good by their employer (work units or "*dan-wei*") through the central planning system. Most of the work-unit housing has since been gradually privatized. By the end of the 1990s, housing offered by work units for their employees officially ended and new homes would be built and sold in the market. Most urban households now choose their residential locations given market supply of housing (Zheng et al., 2006).

[4] Identification of capitalization based on changes in school quality over time, however, may suffer from several issues. First, the lack of such variation in data, second, compared to cross-sectional studies, more serious downward bias due to the more significant role of measurement errors in school quality, and third, potential bias caused by time-varying unobservable factors (Nguyen-Hoang and Yinger, 2011).

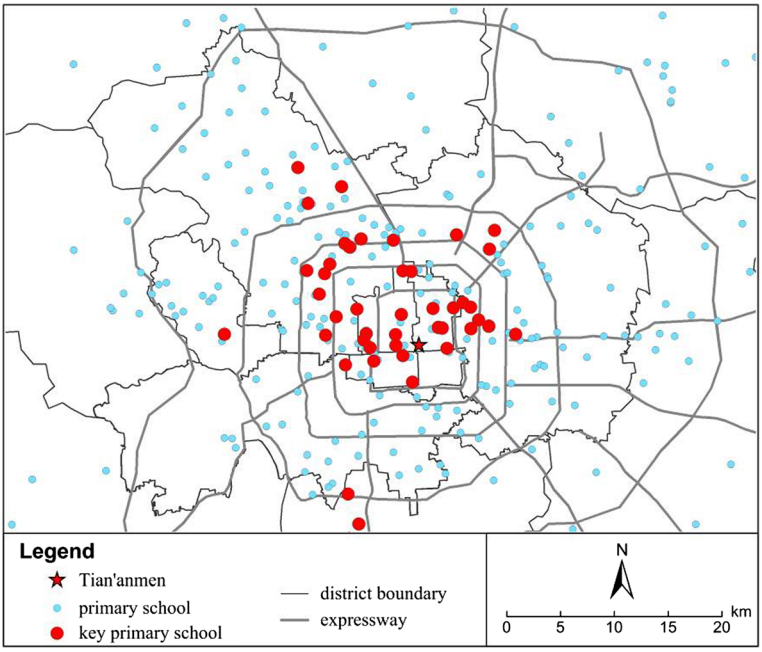

Fig. 1 Spatial distributions of primary schools in Beijing

Primary schools in Beijing

Beijing has altogether 1,160 schools, the vast majority of which are public schools.[5] The student enrollment policy during compulsory education years (primary and middle schools) is based on "attendance zone," which is implemented according to the neighborhood school policy adopted in 1986. However, only homeowners are eligible to send their children (most urban families have just one child due to China's family planning policy) to the public school that serves their zone in Beijing. Nevertheless, this system does not work rigorously. There has been a semi-official market for those who are ineligible to attend a school to be admitted by paying a high fee for many years. A report published in 2011 by the "Institute for 21st Century Education" claims that despite the neighborhood school policy, a small number of exceptions still exist, as some out-of-zone parents pay a high "extra admission fee" to send their children to a Key Primary School. The average value of this "extra admission fee" was 130 thousand Yuan in 2011. [6]

Different from a simple geographical boundary of each school zone in countries such as the U.S., a public school's attendance zone in Beijing is usually defined as a list of residential complexes, each including one to several buildings that are typically mid-

[5] According to the Beijing Municipal Commission of Education, there were only 24 private schools out of a total of 1,160 schools in Beijing. Those private schools are regarded as a different "animal" from public schools – private schools often place less emphasize on academic grades and frequently serve expats and households considering sending their children overseas for high school and/or college. See http://www.bjedu.gov.cn/publish/main/269/2010/20100120150130185385604/20100120150130185385604_.html and http://www.bjedu.gov.cn/publish/main/269/2010/20100120145833218227393/20100120145833218227393_.html.

[6] see http://www.21cedu.org/index.php?m=special&c=index&a=show&id=150.

to high-rise towers. Due to the construction of new complexes, demolishing of old ones, as well as other adjustments by the local education authority, an attendance zone may adjust slightly each year. Unlike school districts in the US, in the absence of local property taxes, such "local" schools are funded by the centralized municipal government, instead of "school districts".

This paper focuses on primary schools in Beijing because evidence shows that despite the fact that the attendance-zone based enrollment policy has been implemented quite consistently for primary schools, this has not been the case for middle schools (Feng and Lu, 2010).[7] There are altogether 652 primary schools in the Beijing Metropolitan Area.[8] Each residential complex is assigned to one school attendance zone.[9] The quality of these schools obviously varies. However, detailed school quality data, such as spending per student, student-teacher ratio, or standard exam score, are not publicly available. Nonetheless, a consensus among the public about which primary schools are the best seems to exist based on the list of "Key Primary Schools," which was created by the Beijing Municipal Commission of Education beginning in the late 1950s. There are 40 former Key Primary Schools in Beijing, accounting for a small share (6.13 %) of all primary schools (See Fig. 1). The "Key Primary School" received more resources from the Beijing Municipal Government until the year 2000, when the title of "Key Primary School" was no longer used by the government. Until today, the former "Key Primary Schools", with their legacy of superior quality thanks to the long-term capital and human resource investments and reputation among parents, are still considered by most as the best.[10] Without other school quality measures, when parents compare primary schools, this list remains the most important source of information. In this study, we use this list of "Key Primary Schools" as a discrete indicator of good schools and explore whether and the extent to which such a school quality advantage translates into home value premium.

The building complexes on the attendance zone list are usually close to the Key Primary School, but there may be some out-of-zone complexes at the same distance or even closer to the school[11] because an attendance zone is often not contiguous in Beijing. Figure 2 shows the spatial distribution of residential complexes around Key Primary Schools in our sample. The enlarged shadowed part of Fig. 2 demonstrates the typical situation. Within-zone complexes are overall but not always closer to the school

[7] Middle schools often enroll students outside of their attendance zones through a number of other procedures, such as admitting "especially talented" students, students from "Experimental Primary Schools (or Classes)," students whose parents' employer is affiliated with the school in various ways, and students who pay a considerable amount of "extra admission fee." The share of students enrolled in middle schools by attendance zone is less than 50 % in general and only about 10 % for good schools in Beijing, according to the 21st Century Education Research Institute.See http://finance.sina.com.cn/review/sbzt/20110901/165010418693.shtml.

[8] Number obtained from the website of the Beijing Municipal Commission of Education.

[9] Informal urban settlements, such as "urban villages", are mainly occupied by rural migrants and temporal labor. Those communities are not eligible for public schools in most cities including Beijing.

[10] See, e.g., http://www.ah.xinhuanet.com/news/2012-01/19/content_24574617.htm ("Over RMB 250,000 yuan Entrance Fee for Key Elementary School in Beijing - Competition of Parents to Obtain Admission," Jan 19th, 2012), and http://www.bj.xinhuanet.com/bjpd_sdzx/2009-07/20/content_17147367.htm ("The unjustifiable allocation of educational resources lead to parents' competition over within-zone housing," July 20th,2009).

[11] This group mainly comprises in-filled new residential estates that are not assigned to the Key Primary School yet, most likely due to the capacity limit of premium schools.

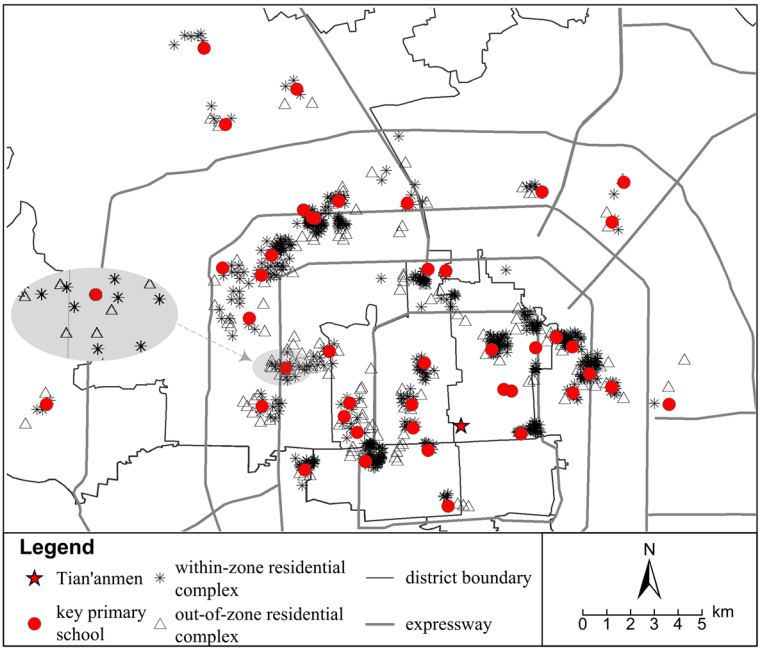

Fig. 2 An illustration of within-zone and out-of-zone residential complexes around Key Primary Schools

than out-of-zone complexes. Such a spatial "mix" of within-zone and out-of-zone complexes enables a more robust paired data regression strategy discussed in Section "Method".

Housing data

Based on the 40 Key Primary Schools' 2011 enrollment brochures, we collect housing price and rent data surrounding each Key Primary School in fall 2011, around the time the new school year started. As individual real estate transaction record is unavailable, we obtain average resale price and rent at the residential complex level from the internal transaction data of Soufun.com, a market leading listed online real estate portal.[12]

For each of the Key Primary Schools, we collected resale and rental transaction records from as many "within-zone vs. out-of-zone" housing complex pairs as possible in Soufun's database. We set the maximum distance allowed between the two complexes in each pair at 0.75 km (0.47 mile).[13] 113 pairs (226 complexes) are identified.

[12] As the largest real estate information company in China, Soufun.com reports monthly and quarterly average first-sale prices (newly-built complexes sold by developers), resale prices (existing units sold by households) and rents (existing units leased by households) at the complex-level for a large number of residential complexes in Beijing.

[13] The maximum within-pair distance of 0.75 km (2,461 ft) used by this study is a little over half of those adopted by most boundary fixed effect studies. According to Nguyen-Hoang and Yinger (2011), the maximum distance to the closest boundary adopted by most studies between 1999 and 2011 is 2,000 ft, indicating a 4,000 f. inter-property maximum distance. We believe our choice of shorter maximum inter-property distance is necessary given the much higher density of Beijing.

All complexes have average resale price (*HP*) information as of fall 2011, but the average rent (*HR*) information of 12 complexes is missing.

For each complex, we collect its physical and locational attributes, including straight-line distance to the city center (Tian'anmen Square) (*D_CENTER*), floor-to-area ratio (*FAR*), age of housing (*HAGE*, 2011 minus its construction year, in years), green space ratio within complex (*GREEN*), straight-line distance to the closest subway stop (*D_SUBWAY*), straight-line distance to the closest comprehensive hospital (*D_HOSPITAL*), and a Key Primary School attendance zone dummy (*SCHOOL*), which equals one if the complex is in any of the 40 Key Primary Schools' enrollment brochures, and zero otherwise. We also measure in each pair, two complexes' straight-line distances to the Key Primary School that the within-zone complex belongs to (*D_SCHOOL*). Table 1 provides summary statistics of our data set with a comparison of within- and out-of-zone subsamples. No notable multicollinearity issue among the variables is detected in the regressions of this paper (explained in Section "Method").

The average housing complex is 13.6 years old, eight kilometers to city center, 1.1 km to the closest subway stop, and 0.7 km to the Key Primary School. The units in this average complex were sold at 33.4 thousand yuan per square meter and were leased at four thousand yuan monthly per two-bedroom unit as of fall 2011. The average resale price of within-zone complexes is higher than that of out-of-zone complexes (a difference of 2,100 yuan/m^2 or 6.3 %), while the relative rent gap is smaller (a difference of RMB 131 yuan per unit-month or 3.3 %). The within-zone complexes are on average 2.6 years older than the out-of-zone ones (14.9 vs. 12.3 years), which is not surprising as the 40 Key Schools were all established before the 1980s and most of the nearby, older residential buildings were included in their attendance zones.

Method

To compare the price difference between homes within and out of the attendance zone of a Key Primary School, this study focuses on the absolute rather than relative difference in home value for two reasons. First, the "extra admission fee" does not vary according to a household's home price. Thus it is the absolute price difference that is directly linked to the shadow price of school quality. Second, this study measures the home price premium due to a discrete change in school quality, which means estimating a school quality elasticity of home price less meaningful. To provide a baseline for the estimates of school quality's capitalization in home value, we first run standard hedonic regressions with sale price (*HP*) and as comparison, rent (*HR*) as dependent variables. In this step we pool within- and out-of-zone observations together and estimate Eqs. (1) and (2) below:

$$HP_i = \alpha_0 + \alpha_1 \cdot X_{1i} + \alpha_2 \cdot X_{2i} + \alpha_3 \cdot SCHOOL_i + \alpha_4 \cdot D_i + \eta_i + \varepsilon_i; \quad (1)$$

$$HR_i = \beta_0 + \beta_1 \cdot X_{1i} + \beta_2 \cdot X_{2i} + \beta_3 \cdot SCHOOL_i + \beta_4 \cdot D_i + \lambda_i + \delta_i, \quad (2)$$

where HP_i and HR_i are average resale price and rent of residential complex i in fall 2011, respectively. X_{1i} is a vector of complex i's physical attributes, including *FAR*,

Table 1 Descriptive statistics

Variables	Definition	Num. of Obs.	Mean	Std. Dev.	Min	Max	Mean	
							Within-school zone	Out-of-School zone
HP	A complex's average resale price in fall 2011 (yuan/m^2)	226	33438.1	7110.9	16006	62212	34488.4	32387.9
HR	A complex's average rent for a two-bedroom unit in fall 2011 (yuan/unit-month)	202	4016.8	1159.7	1500	8715	4082.4	3951.2
HAGE	Housing age (year)	226	13.59	5.77	1.00	39.00	14.88	12.30
GREEN	Green space ratio (%)	226	0.32	0.07	0.10	0.64	0.32	0.31
FAR	Floor-to-area ratio	226	2.47	1.41	0.30	9.70	2.40	2.54
SCHOOL	Binary, 1=within a Key School's attendance zone, 0=otherwise	226	0.50	0.50	0.00	1.00	1.00	0.00
D_CENTER	Straight-line distance to city center (kilometers)	226	8.02	3.50	1.36	18.33	8.00	8.04
ln(*D_SUBWAY*)	The natural logarithm of straight-line distance to the closest subway stop (kilometers)	226	−0.17	0.80	−2.96	1.81	−0.14	−0.20
ln(*D_HOSPITAL*)	The natural logarithm of straight-line distance to the closest first rank hospital (kilometers)	226	0.25	0.80	−2.19	2.41	0.25	0.26
ln(*D_SCHOOL*)	The natural logarithm of straight-line distance to the Key School (kilometers)	226	−0.66	0.74	−3.29	0.69	−0.92	−0.41

GREEN and *HAGE*. X_{2i} is a vector of complex i's locational attributes, including *D_CENTER*, *D_SUBWAY*, *D_HOSPITAL, and D_SCHOOL* (the latter three in natural logarithm[14]). The variable of interest is the coefficients of dummy variable *SCHOOL*, which equals one if a home is in the attendance zone of a Key Primary School and zero otherwise. To control for unobservable factors at the urban district level (there are a total of seven districts, or lower-level municipal governance units in our sample), we also include district fixed effects (D_i) in some model specifications. η_i and λ_i are unobserved variables. ε_i and δ_i are independent and identically distributed error terms.

As discussed in our review of the literature, the unobserved variables (η_i and λ_i) are likely correlated with school quality, which biases the coefficients of *SCHOOL*. We address the omitted variables issue with two strategies. First, we pair a within-zone building complex with the most adjacent out-of-zone complex so that other location differences of the two complexes in a pair are tiny, except for the school attendance zone difference. By doing this, we are able to mitigate the problem of certain omitted local characteristics such as local amenities like parks and food outlets. By differencing the dependent and independent variables of the two complexes in a pair, the above mentioned unobserved location characteristics can be cancelled out, enabling a more reliable estimate of the capitalization effect of school quality ($\alpha_3^{'}$) as in Eq. (3). For the purpose of comparison, we also implement a similar rent regression (omitted here).

$$\Delta HP_i = \alpha_1^{'} \cdot \Delta X_{1i} + \alpha_2^{'} \cdot \Delta X_{2i} + \alpha_3^{'} \cdot \Delta SCHOOL_i + \Delta\eta_i + \varepsilon_i^{'}. \quad (3)$$

However, the above paired data regression approach cannot fully address the unobserved difference between the paired housing complexes due to residential sorting potentially related to households' preference of education quality. So $\Delta\eta_i$ may still be different from zero, as pointed out by Kane et al. (2006). Our second strategy addresses this concern by taking advantage of the unique enrollment policy that discriminates against renters in Beijing. If renters do not compete against buyers for the occupancy of within-zone housing units (we will turn to this assumption below), any rental value difference attributed to *SCHOOL* should be considered not directly due to school quality difference, but due to unobserved neighborhood differences that are correlated with *SCHOOL*, but not eliminated by the paired data regression strategy above.[15] So we add ΔHR_i to the right hand side of Eq. (3) to control for unobserved factors captured by rent differences between in-zone and out-of-zone housing complexes.[16] This produces Eq. (4) below:

$$\Delta HP_i = \omega_1^{'} \cdot \Delta X_{1i} + \omega_2^{'} \cdot \Delta X_{2i} + \omega_3^{'} \cdot \Delta SCHOOL_i + \omega_4^{'} \cdot \Delta HR_i + \Delta\gamma_i + \theta_i^{'}. \quad (4)$$

[14] We choose to not use logarithm of D_CENTER since we believe D_CENTER indicates accessibility at the metro area level instead of local level, the pattern of distance gradient would be different from distances to local (dis)amenities such as subway stations and hospitals. Nevertheless, we have also tested by using the logarithm of D_CENTER in our regressions. The results are very similar to those reported in the paper.

[15] We acknowledge that the spatial proximity to a nearby good school is also preferred by a renter if he/she has a child and already obtains the right of school attendance through other means (for instance, pay the very high school attendance fee) rather than buying a within-school housing unit. We address this concern by including *ln*(D_SCHOOL) in the price/rent regressions as a control variable.

[16] Hu et al. (2014) use a model similar to Equation (3) to infer the home value premium of education quality. As discussed earlier, they do not include rent differential as an explanatory variable in the price differential equation. So their work fails to control for the omitted neighborhood attributes due to school quality-related residential sorting, which are captured by rent differentials in this study.

The key assumption of our above second empirical strategy is that renters do not compete against buyers for the occupancy of within-zone housing units, because otherwise one would expect that rent will reflect the competition for school.[17] We believe our assumption is valid in this particular study for the following reasons. As the right to attend primary school is only bundled with homeownership (rather than leasehold) in Beijing, a rational renter will not pay any price premium for a within-zone unit given the choice of an all-else-equal nearby out-of-zone unit, unless the supply of out-of-zone rental units is less elastic than that of within-zone rental units. Due to the scarcity of premium schools in Beijing (6.13 % of all primary schools, as mentioned earlier), it is much more likely that a renter will have more choices of out-of-zone units than within-zone units in any housing submarket, and perhaps even more so in the areas where our sample housing complexes are located (fringe instead of central areas of the premium schools' attendance zones). Moreover, buyers' purchase of within-zone properties does not necessarily deprive renters' occupancy of the same properties because school attendance right only requires proof of ownership, not residence in Beijing. It is common that households purchase or keep within-zone units for their own kids' education but rent the units out because they do not have to physically live in it. This is in fact an important reason that we are able to observe both prices and rents of the within-zone housing complexes.

Results

Home price and rent hedonics

Table 2 presents the regression results of the basic home price and rent hedonics. The first two columns are regression results of home prices. Depending on whether the urban district fixed effect is controlled for, a residential complex's unit resale price drops by 225–230 yuan (roughly 0.7 % of sample mean) as its age increases by one year. Green space contributes to a complex's value – a 10 % increase in green ratio results in a price increase of about 1,240-1,525 yuan/m^2 or 3.7-4.6 % of sample mean. As a complex moves away from the city center by one kilometer, its price drops by 1,082 to 1,203 yuan/m^2 (3.2-3.6 % of sample mean), a negative price gradient significant at the 0.1 % level. Subway accessibility has a positive effect on resale prices. The floor-to-area ratio of a building (complex) site and the variable hospital accessibility, however, have insignificant effects on price. Our main interest is the extent of school quality capitalization, the coefficient of *SCHOOL*. In column (1), a price premium of 2,405 yuan/m^2 is statistically significant at the 1 % level. In column (2) we include urban district fixed effects and the price premium shrinks to 2,048 yuan/m^2, or about 6.1 % of the sample mean.

[17] We thank an anonymous referee for pointing this out.

Table 2 Home price and rent hedonic regressions

Dependent Variable	(1) *HP*	(2) *HP*	(3) *HR*	(4) *HR*
HAGE	−230.3**	−225.4**	−44.09***	−46.04***
	(−2.79)	(−2.91)	(−3.58)	(−3.63)
GREEN	15249.1*	12409.3*	2509.8	2619.3*
	(2.44)	(2.34)	(1.94)	(2.29)
FAR	−174.8	3.512	60.75	94.52
	(−0.70)	(0.02)	(1.02)	(1.67)
SCHOOL	**2405.1****	**2047.8****	**154.2**	**212.5**
	(2.94)	**(2.93)**	**(0.99)**	**(1.29)**
D_CENTER	−1082.1***	−1203.2***	−41.08	−129.4***
	(−5.91)	(−5.60)	(−1.31)	(−3.79)
Log(*D_SUBWAY*)	−1261.7*	−728.5	−200.5*	−103.1
	(−2.56)	(−1.54)	(−2.15)	(−1.10)
Log(*D_HOSPITAL*)	−362.7	398.7	117.3	299.3*
	(−0.55)	(0.64)	(1.08)	(2.25)
Log(*D_SCHOOL*)	−335.5	−1038.2	108.8	59.03
	(−0.51)	(−1.65)	(1.09)	(0.54)
Fixed urban district effect	NO	YES	NO	YES
Constant	39307.0***	31947.5***	3895.2***	4362.4***
	(13.25)	(9.12)	(7.25)	(8.33)
Observations	226	226	200	202
R-squared	0.340	0.480	0.104	0.216

(a) robust t-statistics in parentheses. (b) ***, **, *: significant at the 0.1 %, 1 %, and 5 % levels, respectively. (c) two significant outliers are excluded from the sample regressed in Model 3. Results are largely consistent with those when the two outliers are included, in which the estimated *SCHOOL* coefficient (246.9) is slight larger with a bigger but still insignificant t-statistic (1.47)

Columns (3) and (4) report rent hedonic regression results. Rents are more sensitive to housing age – older buildings have larger rent discounts of roughly 45 yuan per month (1.1 % of sample mean). The rent gradient with respect to the distance to the city center is flatter than that of resale price – 129 yuan/month (or 3.2 % of sample mean) every kilometer away, but this effect is only significant when the urban district fixed effect is controlled for. The *SCHOOL* dummy has a positive coefficient that in relative term (as percentage of sample mean) is smaller than in the price regression and is statistically insignificant in both columns (3) and (4). This is not a surprise given the crucial role that ownership plays in accessing high-quality primary school education in Beijing. The r-squares of the rent regressions are significantly lower than those of the price regressions. This may be partially a result of the less precise measurement of rent (per two-bedroom house unit instead of per square meter).

Our sample is a selective (only those within-zone and out-of-zone residential complexes close to each other are chosen) and relatively small one, so we consider

the hedonic regression results as suggestive evidence and a baseline for comparison against our results from the paired data regressions below.

Paired data regression results

We re-organize our sample and run paired data regressions using the 113 pairs of residential complexes. Table 3 reports the results. Column (1) has the difference of home price as the dependent variable. The differences or log differences of all independent variables in the baseline hedonic equation are included as regressors. The within-pair distance between the two complexes is so close that all distance differentials lose their significance with very small t values. Similar to the hedonic regression results in Table 2, housing age and green space ratio differences can explain part of the within-pair price differential. Controlling for other within-pair differences, a within-school zone housing complex claims a 2,623.5 yuan/m^2 (or 7.8 % of sample mean) price premium compared to an otherwise identical complex outside the attendance zone of a Key Primary School. This difference is statistically significant at the 0.1 % level. Such a price premium implies a total additional housing cost that is quite consistent with the typical "extra admission fee" of 130,000 yuan suggested in Section "Primary schools in Beijing" given the average size of roughly 50–60 m^2 for a typical two-bedroom home in Beijing's resale market.

In order to examine the "bandwidth" effect as in the boundary fixed effect literature, we divide the paired sample into two groups – those with a within-pair distance less than 300 m and those between 300 and 750 m apart in columns (2) and (3), respectively. The former subsample has a smaller price premium than the latter (2,400 vs. 3,234 yuan/m^2). One possible reason for this difference is omitted variables because the remaining unobserved difference between paired properties should be larger when they are further apart. A second explanation is related to the possibility of changes in attendance zone. The within-zone complexes in the pairs 0-300 m apart are closer to the fringe of the attendance zone than the within-zone complex in the pairs that are 300-750 m apart (see Table 1). So households living closer to the fringe of attendance zone (farther from the school) may place a lower value on school quality because they believe that the boundary of attendance zone might change, as discussed by Cheshire and Sheppard (2004) and Zahirovic-Herbert and Turnbull (2009).

Serving as a comparison, we run a full-sample regression on rent differentials and report results in column (4). Similar to what we find in Table 2's hedonic regressions, the relative rent premium of within-zone properties (6.9 % of sample mean) is smaller in magnitude compared to the price premium in columns (1), (3) and (4) and statistically insignificant. This suggests that rental value difference of homes within and out of school attendance zone is both weaker and less robust compared to the difference in ownership cost.

Finally, to control for unobservable factors (e.g., related to residential sorting) captured by the rent difference between in-zone and out-of-zone homes, we include within-pair rent difference in the price difference regression (Eq. 4). Results are presented in column (5). After controlling for rent differences, we obtain a school price premium of 2,265.8 yuan/m^2 (significant at the 1 % level). This estimate is smaller than the 2,623.5 yuan/m^2 obtained in column

Table 3 Paired data regressions of home price and rent differentials

Dependent Variable	(1) ΔHP	(2) ΔHP (0, 300 m]	(3) ΔHP (300 m, 750 m]	(4) ΔHR	(5) ΔHP
$\Delta HAGE$	265.3***	294.8**	164.2	42.71*	189.0**
	(3.88)	(3.20)	(1.96)	(2.54)	(2.82)
$\Delta GREEN$	12270.7*	14541.8*	10895.5	1862.4	12162.0*
	(2.58)	(2.20)	(1.47)	(1.29)	(2.57)
ΔFAR	−181.8	−63.13	−531.8	257.2*	−361.8
	(−0.51)	(−0.15)	(−0.98)	(2.51)	(−0.91)
$\Delta SCHOOL$	**2623.5*** **	**2400.3** **	**3233.9*** **	**278.7**	**2265.8*** **
	(5.30)	**(3.37)**	**(4.47)**	**(1.53)**	**(3.72)**
ΔD_CENTER	−276.7	−520.4	30.72	−260.6*	627.3
	(−0.53)	(−0.61)	(0.03)	(−2.33)	(1.35)
$\Delta \ln(D\_SUBWAY)$	−328.6	−66.12	−18.91	−137.8	−1351.4
	(−0.39)	(−0.07)	(−0.01)	(−0.70)	(−1.18)
$\Delta \ln(D\_HOSPITAL)$	−792.1	97.66	−3063.3	29.59	−2538.0**
	(−0.88)	(0.06)	(−1.78)	(0.11)	(−3.04)
$\Delta \ln(D\_SCHOOL)$	−81.32	−968.5	944.8	118.0	−342.6
	(−0.14)	(−0.94)	(0.93)	(0.65)	(−0.54)
ΔHR					0.672
					(1.33)
Observations	113	67	46	99	91
R-squared	0.252	0.281	0.283	0.187	0.297

(a) robust t-statistics in parentheses. (b) ***, **, *: significant at the 0.1 %, 1 %, and 5 % levels, respectively. (c) Model 4's sample is reduced from 101 pairs to 99 pairs after excluding two significant outliers. R^2 improves from 0.154 to 0.187 and results are qualitatively unchanged (ΔHAGE and ΔD_CENTER become statistically significant at 5 %; the coefficient of ΔSCHOOL changes from 273 to 278.7, with an improvement in robust t-statistic from 1.45 to 1.53

(1), suggesting that rent differential helps further control for unobserved within-pair difference. Nevertheless, a large share (86 %) of the price premium estimated in column (1) is due to school quality itself, as suggested in column (5). Similar as in column (1), the location differentials (to city center, subway, hospital and school) remain largely insignificant except the negative effect of hospital on home value. The coefficient of rent difference, while positive (suggesting the co-movement of price and rent), is statistically insignificant. Comparing results of Tables 3 and 2, we find that the estimated price premium of Key Primary Schools in the paired data regression (2,265.8 yuan/m^2, column (5) in Table 3) is smaller than that in the hedonic regression results (2,405.1 yuan/m^2, column (1)[18] in Table 2). This is consistent with the existing literature. That is, controlling for unobservable neighborhood characteristics

[18] We compare to column (1) instead of (2) in Table 2 because both column (1) in Table 2 and column (5) in Table 3 do not control for the urban district fixed effect.

(other than those due to residential sorting), home value premium of school quality is smaller than the estimated premium when such controls are absent.

Conclusion

This study provides one of the first pieces of evidence on the capitalization of school quality in home values in China, the world's largest emerging economy. Using a paired data regression strategy, and with the help of the "renter discrimination policy" that is rarely seen in the US or other western countries, this study is able to control for many, if not all unobserved neighborhood traits. We find robust evidence that school quality has been capitalized in home values in Beijing. As of fall 2011, a within-zone complex claimed on average a 2,265.8 yuan/m^2 (6.8 % of sample mean) price premium over those outside the attendance zone of a Key Primary School in Beijing. We also find evidence of unobserved neighborhood characteristics that bias the estimates of not only a traditional hedonic regression, but also a boundary fixed effect model that does not control for unobserved differences due to residential sorting.

An important limitation of this study is the lack of precise measurement of school quality. Our results can only be interpreted as the average home value difference between housing units in attendance zones of two groups of schools (premium vs. ordinary) with possibly non-negligible within-group quality heterogeneity. It limits our estimated price premium from being quantitatively compared to other studies in the literature that often reports home value premium associated with a standard deviation in test scores. In an effort to better measure school quality, we have tried to include in the regressions proxies of the quality of Key Primary Schools using either a continuous measure (number of internet search engine results when searching "school name+Key Primary School") or a discrete measure (whether a Key Primary School is considered as "Top-10 primary schools" in a popular unofficial ranking). However, such differentiated quality measures of the Key Primary Schools result in little statistically significant price or rent effects. In the future, more accurate and objective school quality measures and larger sample size would greatly benefit research on this topic.

One concern of our empirical strategy is the possible difference between homeowners and renters, which is an inherent issue when using market price and rent in the same regression. If renters value housing attributes and neighborhood amenities in a systematically different way from owners (e.g., renters may care less about who their neighbors are), one may be less confident to conclude that the home value difference we find represents solely the premium of school quality. We cannot preclude such a possibility. Nevertheless, unlike situations in countries such as the U.S., the relatively short history of setting school attendance zones in Chinese cities may have resulted in limited neighborhood changes associated with school quality and residential sorting (e.g. crime rate, environmental quality, and proximity to employment or to shopping). The lack of fiscal relationship between local property value and school spending also reduces the potential bias from omitted neighborhood or service variables.

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References

Bayer, P., Ferreira, F., & McMillan, R. (2007). A Unified Framework for Measuring Preferences for Schools and Neighborhoods. *NBER Working Paper,*No.13236.

Black, S. E. (1999). Do Better Schools Matter? Parental Valuation of Elementary Education. *The Quarterly Journal of Economics, 114*(2), 577–599.

Butler, R. V. (1982). The specification of hedonic indexes for urban housing. *Land Economics, 58*(1), 96–108.

Cheshire, P., & Sheppard, S. (2004). Capitalising the value of free schools: the impact of supply characteristics and uncertainty. *Economic Journal, 114*(499), 397–424.

Fack, G., & Grenet, J. (2010). When do better schools raise housing prices? Evidence from Paris public and private schools. *Journal of Public Economics, 94*(1), 59–77.

Feng, H., & Lu, M. (2010). School quality and housing prices: Empirical evidence based on a natural experiment in Shanghai, China. *The Journal of World Economy, 12*, 89–104 (**in Chinese**).

Figlio, D. N., & Lucas, M. E. (2004). What's in a grade? School report cards and the housing market. *American Economic Review, 94*(3), 591–604.

Gibbons, S., & Machin, S. (2006). Paying for primary schools: admission constraints, school popularity or congestion? *Economic Journal, 116*(510), 77–92.

Gibbons, S., Machin, S., & Silva, O. (2013). Valuing school quality using boundary discontinuities. *Journal of Urban Economics, 75*, 15–28.

Hu, W., Zheng, S., & Wang, R. (2014). The capitalization of school quality in home value: A matching regression approach with housing price-rent comparison. *China Economic Quarterly, 13*(3), 1195–1214 (**in Chinese**).

Judd, G. D., & Watts, J. M. (1981). Schools and housing values. *Land Economics, 57*, 459–470.

Kane, T. J., Riegg, S. K., & Staiger, D. O. (2006). School quality, neighborhoods, and housing prices. *American Law and Economics Review, 8*(2), 183–212.

Nguyen-Hoang, P., & Yinger, J. (2011). The capitalization of school quality into house values. *A Review Journal of Housing Economics, 20*, 30–48.

Oates, W. E. (1969). The effects of property taxes and local public spending on property values: an empirical study of tax capitalization and the Tiebout hypothesis. *Journal of Political Economy, 77*(6), 957–971.

Reback, R. (2005). House prices and the provision of local public services: capitalization under school choice programs. *Journal of Urban Economics, 57*(2), 275–301.

Ries, J., & Somerville, T. (2010). School quality and residential values: evidence from Vancouver zoning. *Review of Economics and Statistics, 92*(4), 928–944.

Rosen, H. S., & Fullerton, D. J. (1977). A not on local tax rates, public benefit levels and property values. *Journal of Political Economy, 85*(2), 433–440.

Rosenthal, L. (2003). The value of secondary school quality. *Oxford Bulletin of Economics and Statistics, 65*(3), 329–355.

Zahirovic-Herbert, V., & Turnbull, G. (2009). Public school reform, expectations, and capitalization: what signals quality to homebuyers? *Southern Economic Journal, 75*(4), 1094–1113.

Zheng, S., Fu, Y., & Liu, H. (2006) Housing-choice hindrances and urban spatial structure: evidence from matched location and location-preference data in Chinese cities. *Journal of Urban Economics, 60*, 535–557.

Zheng, S., & Kahn, M. E. (2008). Land and residential property markets in a booming economy: New evidence from Beijing. *Journal of Urban Economics, 63*, 743–757.