Journal of Housing Economics 22 (2013) 291–307

Contents lists available at ScienceDirect

Journal of Housing Economics

journal homepage: www.elsevier.com/locate/jhec

School quality and housing prices: Empirical evidence from a natural experiment in Shanghai, China

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ARTICLE INFO

Article history:
Received 29 January 2011
Available online 6 November 2013

JEL classification:
H44
I28
R21

Keywords:
Education
Housing market
Capitalization
Public goods
Natural experiment

ABSTRACT

The endogeneity of education quality and quantity accounts for difficulties in appropriately identifying the causal relationship between education and housing prices. To determine how education quality is capitalized into housing prices, we deal with endogeneity bias by employing a natural experiment occasioned by China's education reforms. Based on monthly panel data for 52 residential areas in Shanghai, we conducted a natural experiment based on the exogenous designation of specific high-quality schools as Experimental Model Senior High Schools (EMSHS). Our natural experiment proved useful in analyzing how new information affected housing prices in China's developing housing market. We found evidence that housing prices included allowances for these new EMSHS designations. In general, the presence of an additional EMSHS (of the best quality) per square kilometer increases housing prices by 17.1%. If one additional, previously non-designated high school is designated as EMSHS in a residential area, housing prices will be 6.9% higher.

1. Introduction

The extent to which access to quality education is capitalized into housing prices is crucial for understanding housing price formation and education resource allocation. However, when we observe a correlation between education quality and housing prices, this does not necessarily imply a causal relationship. Higher-income parents can both afford more expensive housing options and be willing to pay for higher-quality education. Therefore, when estimating the relationship between education quality and housing prices, there is typically an upward bias in the capitalization of education since the endogeneity of education is not considered.

Parents who purchase a home based in part on where they want their children to attend school affect housing prices. When information relating to school quality is imperfect in the quasi-market for education, the disclosure of additional information can be utilized to identify the effects of school quality on housing prices if that information is exogenous to the housing market. We therefore designed an empirical strategy to empirically test the effects of new exogenous school quality information on housing prices. Education reform and the development of China's housing markets provide a natural experiment to trace the causality from school quality to housing prices. In the case of Shanghai, 50 quality schools were designated Experimental Model Senior High Schools (EMSHS) during the 2005 and 2007 education reforms. There had been no prior disclosure of the schools' quality rankings. The designation of schools as EMSHS, a movement that took place

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1051-1377/$ - see front matter
http://dx.doi.org/10.1016/j.jhe.2013.10.003

over several waves, therefore revealed information about school quality, a disclosure that potentially affected housing prices.

Given the exogenous EMSHS information, we can draw on a natural experiment to determine the degree to which education quality is reflected in housing prices. Compared with a traditional analysis on the effects school quality on housing prices, our natural experiment provides a superior method for analyzing how new information released through designating quality-based grades on schools affects housing prices in China's developing housing market. In addition, the experiment can provide evidence of imperfect information in the education market; had the information been complete, the designations would not have had a significant effect on school choices and, consequently, housing prices.

Studies taking into consideration the capitalization of education quality into housing prices exist in a strand of literature that can be traced back at least half a century to Tiebout (1956) and his theoretical analysis of how residents take advantage of the provision of public goods by "voting with their feet" in the presence of intergovernmental competition. Subsequently, Oates (1969) and others studied the relationship between housing prices and the level of local public expenditure and taxation. Nearly all of the early studies using traditional multivariate regression methodology have found that differences in school quality between local administrative districts are capitalized into housing prices. However, the endogeneity of education quality and quantity remains an obstacle in empirical studies attempting to quantify the causal relationship between education and housing prices. In particular, regression discontinuity design (RDD), based on administrative boundaries, and difference-in-difference (DID) estimations address the endogeneity problems more rigorously. Black and Machin (2010) provide a detailed review of this literature.

We thus employed a natural experiment to estimate the education-housing relationship using data from a transitional and developing country, China. Our estimation strategy involves a natural experiment arising during a period of reform in education and the emerging development of China's housing markets. Along with an estimation of the relationship between education quality and housing prices using a full sample of monthly panel data from 52 residential areas in Shanghai, we considered the effects of the EMSHS designation on housing prices as a means of alleviating any endogeneity bias. We found that housing prices already included an allowance for access to quality education, and especially included an allowance for new information released through the EMSHS designation system when a neighborhood-based school admissions system was used.

Based on the exogenous natural experiment in the EMSHS designations, we found evidence that housing prices included allowances for new information revealed by assigning quality-based grades to Shanghai schools. In general, the presence of an additional EMSHS (of the best quality) per square kilometer increases housing prices by 17.1%. If one additional, previously non-designated high school is designated as EMSHS per square kilometer in a residential area, the housing prices will be 6.9% higher. On average, the first-wave designations had no further effects on housing prices, whereas the second-wave designations had significantly positive effects on housing prices. However, the aggregate effects for the second-wave EMSHS's (8.9%) were about half of the effects for the first-wave EMSHS's (17.1%). We also found that both the first- and second-wave EMSHS's designations had significantly positive effects on marginal quality schools using the subsample estimation and a method similar to the DID estimation. The effects on housing prices as a result of increasing the number of high-quality EMSHS's per square kilometer in a residential area is equivalent to that of increasing green space in an area by 16.4 ha, or increasing per capita annual government expenditure by 19 thousand RMB, or moving the area 4.1 km closer to the metropolitan center.

Our empirical findings also present important evidence for Tiebout mobility in China's metropolitan housing market, which is a key mechanism in undertaking education policy. When education resources are effectively allocated through the housing market, regulations for seemingly equalized access to education, such as those governing the school choice and school fees, may actually enhance the education-housing price relationship. This leads to households competing for education resources through housing choices, thereby increasing the inequality of education access. Because we found that access to quality education is already capitalized into housing prices in China's emerging housing market when a neighborhood-based school admissions system is in place, our findings imply that developing countries should be prepared for similar consequences related to residential sorting in housing markets. Such sorting has the potential to affect social mobility and economic inequality in developing countries when their housing markets are in early stages of development, such as in China.

The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 introduces the compulsory-education reform's background and discusses recent housing market developments in Shanghai. Section 4 presents the data and econometric specification used in the analysis. Section 5 provides the empirical results, and Section 6 describes the results for several checks of robustness. Section 7 presents conclusions.

2. Literature review

The relationship between the local provision of public goods and housing prices is a classic concern in public and urban economics. In his early work, Tiebout (1956) argued that if households were mobile and could choose a community providing local public goods for which they were willing to pay, then local governments would provide these local public goods more efficiently as a result of intergovernmental competition. Subsequent studies showed that if Tiebout's theory held, housing prices would incorporate capitalization of the quality and quantity of local public goods, such as education (Oates, 1969; Yinger, 1982). In the general equilibrium analysis of local public goods and residential choice, paying different housing prices causes people to sort themselves spatially into diverse residential communities according to their preferences for public goods consumption. When incorporating peer effects into education, the fact that some parents have the means to pay for better neighborhoods and better schools enhances this sorting process (Epple and Romano, 1998; Epple and Sieg, 1999; Rothstein, 2006).

Since Oates (1969) empirical analysis on the effects of property taxes and local public spending on property value, numerous empirical studies have examined the relationship between the provision of public goods and housing prices in both the United States and Europe. Most commonly, the econometric specification of housing prices consists of a hedonic pricing model that includes both structural characteristics and housing location characteristics as explanatory variables (Rosen, 1974; Anderson, 1985; Epple, 1987). As shown in Black and Machin (2010) survey, most of the early research using a traditional multivariate regression methodology found that housing prices reflect differences in public goods, such as education, across local administrative districts. In developed housing markets, these findings are consistent with the Tiebout model (Rubinfield, 1987; Rubinfield et al., 1987; Epple and Sieg, 1999), although the question still remains whether the relationship between public goods and housing prices is causal.

One problem with early empirical studies on the education-housing price relationship is that there may be endogeneity problems arising from both missing variable bias and two-way causality. Additionally, unobservable neighborhood attributes and housing characteristics may affect both local education and housing prices. More to the point, the availability of quality schools may be a function of housing prices; those who can afford more expensive homes are also more likely to be able to afford a higher quality education for their children. To control for these potential endogeneity biases, recent studies have attempted to implement new methodologies aimed at rigorously addressing these problems, including regression discontinuity desigen (RDD) using administrative boundaries and difference-in-difference (DID) estimations (Black and Machin, 2010). RDD using administrative boundaries—or boundary discontinuity design (BDD)—is derived from a crucial assumption that while school quality changes discontinuously, other characteristics of neighborhoods and housing change smoothly along the boundaries of the school districts.

For instance, Black (1999) used housing data for areas near the borders of neighboring school districts in Massachusetts to compare housing prices and school quality on different sides of the shared border. The core explanatory variable was each school's average test score for statewide assessment (the Massachusetts Educational Assessment Program). Using a hedonic pricing model, Black (1999) concluded that a 5% increase in elementary school test scores led to an increase of approximately 2.1% in a resident's willingness to pay. Following Black's (1999) use of the BDD method, Weimer and Wolkoff (2001), Leech and Campos (2003), Gibbons and Machin (2003, 2006), Davidoff and Leigh (2008), Fiva (2008), Gibbons et al. (2009) and Fack and Grenet (2010) employed data from many different countries; they all found significant effects of school quality on housing prices. BDD was also incorporated in the structural two-stage approach based upon residential sorting developed by Bayer et al. (2007); they used this approach and found that a 5% increase in school quality led to a 1% increase in housing prices. Nonetheless, Kane et al. (2006) suggested there might be differences in neighborhood and housing characteristics on either side of a school district boundary which could lead to bias when using the BDD method.

In this study, we adopted a method similar to DID estimation to deal with the endogeneity problem. Using the DID method, Bogart and Cromwell (2000) measured the changes in school quality by observing the redistricting of the high-quality Shaker Heights schools in Cleveland, Ohio, concluding that the loss of one quality school reduced housing prices by 9.9%. As school relocation also occurs in our sample, we attributed the estimated effects of our fixed-effects (FE) model to similar changes in the gain and loss of quality schools. Exogenous changes in education expenditures (Dee, 2000; Cellini et al., 2008) also help gauge the changes in school quality, given that both of these studies found significant effects on housing prices. Similarly, Kane et al. (2006) used differences in housing prices along boundaries and changes following modifications in school assignments to determine that a one standard deviation increase in school quality increases housing prices by 10%.

Several studies used changes in test scores to measure alterations in school quality. Of these studies, some found significant effects on housing prices (Brunner et al., 2002; Clapp et al., 2008; Caetano, 2009), whereas others did not (Clapp and Ross, 2004). As reviewed by Black and Machin (2010), one potential limitation of the simple test scores in a DID-type estimation is that the changes in test scores may be coincident with unobserved changes in neighborhood characteristics. To overcome this kind of endogeneity bias, some studies employed exogenous policy changes as natural experiments. For example, Reback (2005) found that housing values rose in school districts where students were able to transfer to preferred school districts under a new policy; however, housing values were generally lower in districts accepting transfer students. Machin and Salvanes (2010) likewise focused on policy reform in Oslo, Norway; their study focused on the switch from zone-based enrollment to open enrollment, finding that the effects of school performance on housing prices declined following the reform.

In this study, we adopted a different DID-type empirical strategy based on the government's release of new information on school quality. At the time of release, information regarding school quality in Shanghai was imperfect because there had been no official disclosure of school quality rankings since the announcement of a group of core high schools (CHS) decades earlier. We used panel data for 52 residential areas in Shanghai that spanned a period of 48 months, and utilized a natural experiment where the government allocated grades to schools. During this education reform, 50 quality schools in Shanghai were designated as EMSHS's in waves. As the designation related only to school quality and not to other characteristics of the communities in which the schools were located, the designation offers a natural experiment for investigating whether presence of quality schools affects housing prices.

Our approach parallels the work by Figlio and Lucas (2004), who compared housing prices before and after Florida began to assign grades to schools based on test scores. They found that housing prices generally increased in areas with higher-grade schools compared to areas with lower-grade schools, although the estimated effect diminished over time. In our investigation, however, the effect on housing prices persisted after the designation of a school as an EMSHS. This may imply that information about school quality and accessibility has a deeper impact on prices in developing housing markets.

A few empirical studies have already examined the correlation between the provision of public goods and housing prices in China. However, compared with the present study, the previous studies' capitalization estimation of local education quantity and quality into housing prices is inadequate. For example, Wang et al. (2007) found that Beijing housing prices, but not land prices, capitalized access to subway stations, bus stops and parks. Zheng and Kahn (2008) also used Beijing housing data and found that houses closer to high-quality schools had higher prices. However, those studies suffered from potential endogeneity. Especially when compared to the existing Chinese literature, the natural experiment in the present analysis is more effective in controlling for endogeneity when estimating how the quality and quantity of schools influence housing prices and how this influence changes over time.

3. Compulsory education and the housing market in Shanghai

Education reform and housing market development in Shanghai, Mainland China's most populous city, comprise a representative case for China. Since the 1990s, Shanghai's compulsory education and its housing market have changed significantly because of the country's movement toward a market economy. In 1997, a policy indicating that students would attend the schools nearest to them replaced junior high school entrance examinations. This enrollment practice is similar to the neighborhood-based school admissions system prevalent in the United States and some European countries, and effectively strengthens the relationship between the housing market and access to quality education. Private schools also developed rapidly during the early years of China's education and market reforms, even though most students continued to attend public schools during this time.

In October 2003, private elementary schools accounted for only 4.9% of all elementary school students in Shanghai, while private junior high schools enrolled 7.4% of all junior high school students.[1] The mid-1990s witnessed the partial privatization of some elementary and high schools (usually the better ones).[2] Several years later, following criticism stating that the education reform process had created unequal access to education, most of these partially privatized schools were reverted to public schools once again. However, the change in ownership structure did not greatly affect the quality and reputation of these schools; teacher mobility is very low in China's traditional state-controlled education system, even after the reforms Shanghai saw in the 1990s and early 2000. As public schools play a major role in Shanghai's education system by continuing to admit most elementary and junior high school students who live within a certain radius of a certain school, our empirical analysis focused on the housing effects of these quality public schools.

Before introducing several key points concerning the history and current situation of Shanghai's education system as a means of obtaining the detailed understanding necessary for our empirical strategy, we must first examine Shanghai's housing market. In line with other reforms that transformed the public housing system to private housing, Shanghai's housing market has grown rapidly in recent years. Nowadays, housing provisions are less frequently included in employee welfare, and therefore most people buy and sell housing using market transactions. Housing that was formerly public housing but has since been privatized can also be traded in the market.[3] The development of a housing market enables people to choose schools by purchasing an apartment in a particular location. More importantly, the rapid increase in housing prices since 2003 provides a unique opportunity to study the geographic and chronological capitalization of education.

3.1. The "Attending Nearby Schools" system

China's traditional compulsory education system was elitist, comprised of "core" elementary, junior high, and senior high schools at different societal levels. These core schools commanded the best education resources and admitted students based on entrance examinations. Following reforms in the mid-1990s that completely removed entrance examinations for junior high schools, the enrollment practice under the current system, referred to as "Attending Nearby Schools," is based on parental *hukou* (household registration) and housing ownership. If parents do not have *hukou* where they reside, or do not own housing in the area, their children can attend only ordinary public or private schools, but not any quality public schools nearby. In the early stages of the Attending Nearby Schools reform, students from other districts were able to enroll in private schools and partially privatized schools, all of which used a variety of methods to select students and charge fees. For example, some former CHS's offered "special classes," "artist classes" or "experimental classes" to attract students that performed well in their examinations.[4]

[1] Shanghai Municipal Commission on Education (SMCE): www.shmec.gov.cn/web/concept/show_article.php?article_id=17787.

[2] Known as *Minban Zhuanzhi Xuexiao* ("schools with transformed ownership and run by the private sector"). Similarly, private schools are usually referred to as *Minban Xuexiao* ("schools run by the private sector").

[3] See Sato (2006) for details on the housing system reforms of the late 1990s and empirical evidence on housing inequality in post-reform urban China.

[4] Some of the best Shanghai schools kept one third of their enrollment open for specially selected students.

In the past decade, education reform has further reinforced the policy stating students would attend nearby schools, and therefore the link between school quality and housing prices likewise strengthened. Since 2003 and following reconsideration of education system's structure as a market, school choice has been viewed as hindering the equality of education opportunity. In the name of promoting education equity, the Attending Nearby Schools location-based system has been strengthened even further. For instance, since 2005, regulations have not permitted academic competition at the elementary school level in any Chinese province, an important tool for selecting students based on ability. Other regulations prohibit elementary and junior high schools from vying for excellent students.

In terms of the experience in Shanghai, in 2006 the Shanghai Municipal Commission on Education (SMCE) prohibited public schools from enrolling students based on test scores and private schools from interviewing potential students prior to enrollment. In 2007, the Shanghai government further regulated the attempts of private schools to enroll students across districts; it was interpreted that this policy's implementation meant private schools would also have to abide by the location-based policies. However, despite the apparent strengthening of the Attending Nearby Schools system and its policies, the government cannot control a parent or student's school choice via the housing market. In effect, policies stating that a student must attend a nearby school mean that parents can choose a school by choosing their residence. Thus, if anything, the system has strengthened the relationship between housing prices, access to education and school quality.

3.2. The history of CHS's in Shanghai

The Shanghai CHS system has a long history. First designated in the 1950s, by 2002 there were 33 CHS's in Shanghai. However, the historically determined group of CHS's has seen no new changes in the 21st century. Under China's traditional education system, these schools enjoyed the best education resources and enrolled the best students through uniform entrance examinations. Whether because of teaching quality, school facilities or peer effects among students, the superiority of CHS's was evident in the students' college entrance examination results. During the education reforms of the 1990s, the system abandoned "core junior high schools" in favor of equal education, but the difference in quality among schools never quite disappeared; junior sections of the CHS's still retained large educational advantages over other schools. Because the Attending Nearby Schools system applies to students seeking admission to junior high schools, a student can only legally attend the junior section of a CHS by residing in the school district in which it is located.

Although enrollment in Shanghai's senior high schools is decided by a city-level uniform examination (unlike the Attending Nearby Schools system in place for junior high school enrollment), prior to the academic year 2004–05 (beginning in September of 2004 and ending in July of 2005), out of their total sixteen applications, students were permitted to apply to only one of the twelve CHS's that had the right to enroll students from other districts. The remaining fifteen applications were thus restricted to schools in their own district. Some students moved to other districts before the examination because their home location was important when applying to a CHS.

In recent years, the Shanghai government replaced the concept of CHS's with EMSHS's. Although these two types of schools overlap greatly, they are not completely the same. However, during the period of our data set (April 2003–April 2007), the 33 traditional CHS's continued to represent the top level of senior high school education in Shanghai, because there were no major changes in student enrollment and the level of teacher mobility was very low in China's public schools. From the 2004–05 academic year onward, the Shanghai government further reformed the enrollment practices of senior high schools, dictating that at least 15% of every CHS's enrollment in Shanghai must be open to students from other districts. Currently, students can include one of 50 EMSHS's (including the traditional CHS's) among their 16 admission applications. Thus, residential location has become less of a factor in senior high school enrollment.

We examined the effects of these reforms in our empirical study by including interaction terms between key explanatory variables representing access to quality education and a dummy variable indicating the periods before and after September of 2004 (the starting point of academic year 2004–05). However, the enrollment quota for the schools in each district is set before the examinations, and students from the district containing a specific core school have an additional quota to access that school than those from other districts. Therefore, parents still have an incentive to improve their children's opportunity to attend a CHS by purchasing an apartment within that school's district.

3.3. The designation of EMSHS's in Shanghai

In February 2005, September 2005 and July 2007, the government designated 50 schools as EMSHS's in three waves. According to the SMCE, "the senior high schools and senior sections of high schools within Shanghai, after being admitted by the government of their own district, can all participate in the public appraisal of EMSHS."[5] Therefore, after several rounds of appraisals and designations, the government gave the market a clear indication of which schools were considered to be high quality. Before the EMSHS designations, there had been no official disclosure of school quality rankings other than the list of CHS's announced in Shanghai several decades earlier. Most aspects of school performance, such as student academic achievements and college admissions, were not made public. Although the first-wave EMSHS's were generally those schools that already had a good reputation, the EMSHS designation produced new information regarding school quality

[5] See "The Ideas of Shanghai Municipal Commission of Education for the Appraisal of Experimental Model Senior High Schools," an official publication by the SMCE.

for the parents. The three waves of designations were released in order of school quality; additionally the first-wave EMSHS's was a smaller group than the CHS group.

However, students and parents were able to obtain informal information about school quality. When the use of the Internet became increasingly common in Chinese cities from the early 2000s, many informal school rankings became available through the Internet as a means of guiding school choice. However, these informal school rankings were usually neither accurate nor consistent because they lacked evidence to support their results, which sometimes contradicted each other. Considering these informal sources of information about school quality, we expect that the information discriminating between some marginal schools of similar quality is the real "new" information generated by the EMSHS designations; these designations are less likely to affect schools that already had a reputation for being high quality.

Although there is no evidence that designation itself improves school quality, due to the low level of teacher mobility among Chinese public schools, we cannot deny the possibility that some schools strive to improve themselves to attain the designation, especially those schools that may have just missed the cutoff. However, if the designation effect appears shortly after the designation, it is hard to believe the effect was due to a quality improvement in such a short period. Moreover, we can affirm that the designation can affect housing prices only through disseminating information on school quality or through indirectly affecting school quality. Given the current political situation in China, parents have little apparent political influence on designations because the city government makes its decisions unilaterally. China also lacks a free media, competitive elections, lobby groups, self-governing community organizations and other means that local parents might otherwise use to pressure governments and influence governmental decisions.

Furthermore, China has no property tax system[6] and public schools are funded via state-, city- and district-level governments, which are independent of residents' decisions within the school district. Parents with higher socioeconomic status are therefore much more likely to secure their choice of school directly by purchasing a house in a specific district or by bribing officials and teachers able to influence the admission decision, as opposed to seeking to exert political influence on the city government's education policies. Hence, the exogeneity of the EMSHS designation serves as the basis of the natural experiment to determine whether information about school quality influences housing prices.

4. Data and econometric specification

The empirical analysis in this study responds to two questions. The first is whether the quantity and quality of education influence housing prices in Shanghai. The second is whether the relationship between education and housing prices changes with education policy and developments in the housing market.

We restricted our samples to include only the prices of existing homes, because the market for newly constructed housing in China tends to be more speculative. Consequently, the price data for existing homes more accurately reflect residential demand for housing. Furthermore, as mentioned above, at the time of the analysis, residents could not obtain *hukou* by renting an apartment in Shanghai. Because only homeowners with local *hukou* may send their children to nearby quality public schools, apartment rentals may not fully capitalize education quality.[7] Therefore, we focused on prices, not rental rates, for housing.

In addition, we matched schools included in the first wave of EMSHS designations with schools of similar apparent quality but not designated as EMSHS, and then compared housing prices in their corresponding areas. We also estimated the effects of EMSHS designations for a subsample containing only residential areas with no core high schools (CHS's). If the result is that designation itself significantly affects housing prices, this will provide evidence that information regarding school quality is imperfect in the education market.

4.1. Data

We constructed the dependent variable using price data for existing housing. The key explanatory variable is the number of CHS's and EMSHS's in Shanghai. We matched other attributes, including the number of metro stations, top-level hospitals and the area devoted to public green space with the data for housing prices and education. Table 1 reports the statistical summary of variables. Specific details concerning the data construction are as follows.

4.1.1. Housing prices

Using publications from the Shanghai Secondhand Housing Price Index Office, we obtained monthly data on the average price per square meter for existing houses across 52 residential areas within Shanghai from April 2003 to April 2007.[8] The 52 residential areas are larger than the school districts, but smaller than the administrative districts, and are located across 11 administrative districts in downtown and suburban Shanghai. Each administrative district encompasses three to seven residential areas. In turn, each residential area comprises several school districts, such that the number of quality schools per square kilometer within a residential area is able to measure the average level of access to quality public education in the area. The boundary differences between a given residential area and the contour of all school districts contained in the residential area are relatively minor.

Another advantage of using the sales data for existing houses is that the average characteristics of existing sales

[6] More accurately, only a relatively small number of selected cities in China have recently begun to levy property tax.

[7] However, we cannot deny that the quality of schools may be indirectly capitalized into housing rents.

[8] After April 2007, the Secondhand Housing Price Index Office provided only a monthly city-level aggregate index.

Table 1
Statistical summary of variables.

Variable	Observations	Mean	Standard deviation	Min.	Max.
Explained variable (unit: RMB/m^2)					
Housingprice$_{it}$	2496	7993.11	1950.46	3514.00	13229.00
Explanatory variables					
(1) Accesses to quality public education (unit: number/km^2)					
Core	2496	0.09	0.16	0.00	0.77
EMSHS1	2496	0.08	0.15	0.00	0.77
EMSHS2	2496	0.06	0.17	0.00	0.77
(2) Other public goods (unit: number/km^2)					
Green (hectares)	2496	2.45	3.36	0.00	15.90
Metro (number)	2496	0.21	0.27	0.00	0.89
Hospital (number)	2496	0.15	0.35	0.00	2.31
(3) Distance (unit: km)					
Dcenter	52	6.80	3.57	0.00	14.50
Dsubcenter	52	4.99	2.29	0.00	12.00
(4) Population density (unit: 10,000 person/km^2)	2496	2.16	1.39	0.19	5.09
(5) Socio-economic characteristics (unit: 10,000 RMB per capita)					
Wage	2496	3.14	0.59	2.15	5.24
Government Expenditure	2496	0.50	0.20	0.16	1.07
Area (unit: km^2)	52	10.51	12.15	1.3	75

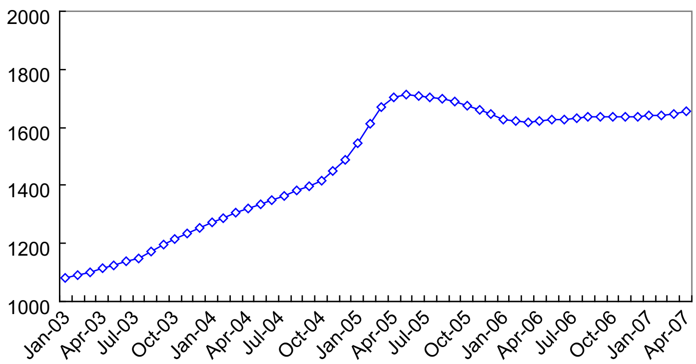

Fig. 1. Price index of existing home sales in Shanghai.

are far more stable than the average characteristics of new houses over time within a residential area.[9] This helps alleviate any potential bias arising from omitted variables in the data at the residential-area level, such as the number of bathrooms or bedrooms, or kitchen space. We controlled for the differences in average house characteristics across residential areas using a fixed-effects estimation. Furthermore, although we were unable to obtain data for housing trading volume in each residential area, we controlled for city-level variations by specifying time dummy variables.

The sample period is set from April 2003 to April 2007, due to considerations with data availability. It is purely coincidental that 2003 marks both enhancements in the Attending Nearby Schools policy and the onset of a period of rapid growth in housing prices. Fig. 1 depicts the monthly price index for sales of existing houses in Shanghai during the sample period.

4.1.2. Education

As per our earlier discussion of the education system in Shanghai, we employed the number of CHS's per square kilometer (denoted "*Core*") to measure the quality and quantity of education within each residential area. Since the historically determined group of CHS's saw no changes in the 21st century, the reason why *Core* has variance across time is a result of school relocation. During the sample period, a core high school moved from one area to another, thus changing the number of *Core* in the two corresponding areas. This kind of school relocation changes the access to quality education in the residential areas, which is useful for identifying the effects of *Core* in the fixed effects model. To analyze whether the EMSHS designation also has an effect on housing prices, we included the numbers of first- and second-wave EMSHS's per square kilometer (denoted "*EMSHS1*" and "*EMSHS2*," respectively). The primary sources of school location data were

[9] This is because new home sales are typically concentrated in newly built neighborhoods, in which housing characteristics generally cluster, whereas sales of existing houses take place across a range of residential areas. We considered the changes in the average characteristics of sales of existing houses within a residential area over time as part of the random error term.

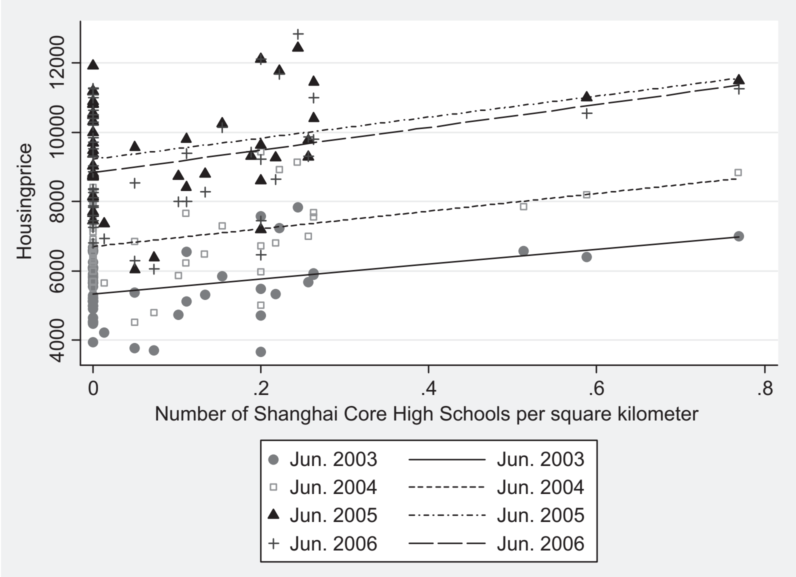

Fig. 2. Correlation between housing prices and number of Shanghai core high schools.

the official website of the Shanghai Municipal Commission on Education and other websites on education in Shanghai.[10] We spatially matched the data on housing prices and education. Fig. 2 illustrates the relationship between housing prices and the number of quality schools. As shown, the slopes of the fitted lines are always positive, which indicates a possible positive correlation between housing prices and the number of quality schools within a residential area.

4.1.3. Other public goods

The provision of other public goods may also influence housing prices. To estimate their possible influence, we included the hectares of public green space per square kilometer (denoted "*Green*"), the number of metro stations per square kilometer (denoted "*Metro*") and the number of top-level hospitals per square kilometer (denoted "*Hospital*") within each residential area. The data on public green space came from the Shanghai Green and Urban Amenities website (http://lhsr.sh.gov.cn) and government websites for related districts in Shanghai. The data on metro stations and hospitals came from the Shanghai Traffic Map (Shanghai Surveying and Mapping Institute and Chinese Map Publishing House, 2004, 2009) and related Shanghai Municipal Government websites. During our sample period, there were changes in the area of green space in some residential areas. The increase in green space came from newly built or enlarged parks, gardens or other public green spaces, while the decrease came from a closing or outright removal of these kinds of public green spaces. Also, there were changes in the number of metro stations in some residential areas, due to several newly built metro lines and additional stations on the existing lines during the sample period. The number of top-level hospitals in all areas remained unchanged during the sample period.

4.1.4. Distance

Location is an important exogenous factor determining housing prices. Our econometric analysis reflects this by including two location variables: namely, "*Dcenter*," the straight-line distance to the People's Square in the metropolitan center of Shanghai, and "*Dsubcenter*," the straight-line distance to the nearest subcenter. At the end of 2007, there were three subcenters in the Shanghai city plan: Xujiahui, Wujiaochang and Pudong Huamu.

4.1.5. Demographic and socio-economic characteristics

A potential endogeneity problem for identifying the effects of school quality arises because families with higher social economic status have a greater opportunity to send their children to quality schools as well as to reside in areas with better environment and amenities. As a result, housing prices may reflect not only the value of quality schools, but also the value of other amenities of interest to that families with high social economic status. In order to alleviate this kind of bias, we controlled social economic status at the administrative district level through the following three variables: population density (unit: 10,000 persons per square kilometer), average annual wage (unit: 10,000 RMB per capita), and the per capita annual local government expenditure (unit: 10,000 RMB per capita). The data of the above three variables were obtained from *Shanghai Statistical Yearbook*, *China Statistical Yearbook for Regional Economy*, and *Shanghai Yearbook*, respectively.

4.2. Econometric specification

4.2.1. Baseline panel data econometric model

The econometric model we used to analyze the relationship between housing prices and access to quality education was derived from the hedonic housing price models in Black (1999) and Wang et al. (2007). Because the data we used are values per square kilometer for each residen-

[10] See www.shmec.gov.cn, www.edu.sh.cn and www.shmeea.com.cn.

tial area, the explanatory variables are also area level ones. We included monthly dummy variables to capture the nonlinear common trend in housing prices. We specified our baseline econometric model in Eq. (1) as follows:

$$\begin{aligned}\ln(Housingprice_{it}) = \beta_0 &+ \beta_1 \cdot Core_{it} + \beta_2 \cdot Core_{it} \times Dreform \\ &+ \beta_3 \cdot Green_{it} + \beta_4 \cdot Metro_{it} \\ &+ \beta_5 \cdot Hospital_{it} + \beta_6 \cdot Dcenter_i \\ &+ \beta_7 \cdot Dsubcenter_i \\ &+ \beta_8 \cdot Population\ Density_{it} \\ &+ \beta_9 \cdot Average\ Wage_{it} \\ &+ \beta_{10} \cdot Government\ Expenditure_{it} + \gamma_i \\ &+ \alpha_i + \epsilon_{it} \qquad (1)\end{aligned}$$

where subscript i denotes the residential area, and subscript t denotes the month during the period April 2003–April 2007. $Housingprice_{it}$ is the housing price per square meter of area i in month t. The natural logarithm of housing prices is specified as the dependent variable. $Core_{it}$ denotes the number of CHS's per square kilometer in area i, which is the key explanatory variable measuring the average access to quality public education in a given residential area. *Dreform* is a dummy variable that took the value of one after the beginning time of academic year 2004–05 (September 2004), and zero otherwise. We used the interaction term between $Core_{it}$ and this dummy variable to control for the effects of reforms in Shanghai senior high schools' enrollment means from the 2004–05 academic year, when students were able to apply for admission to a greater number of higher-quality schools.

A vector of variables controls for other public goods: the hectares of public green space per square kilometer ($Green_{it}$), the number of metro stations per square kilometer ($Metro_{it}$) and the number of top-level hospitals per square kilometer ($Hospital_{it}$). Another vector of variables controls for demographic and socio-economic characteristics at the administrative district level, namely population density ($Population\ Density_{it}$), average annual wage ($Average\ Wage_{it}$) and per capita annual local government expenditure ($Government\ Expenditure_{it}$). $Dcenter_i$ is the distance to the metropolitan center and $Dsubcenter_i$ is the distance to the nearest city subcenter. When measuring the distances at the residential area level, we use the straight-line distance between the center of a residential area and the metropolitan center (or the nearest city subcenter). The coefficients for γ_t are monthly dummy variables measuring the common trend in housing prices; α_i are also dummy variables reflecting unobservable residential area attributes, including geographic characteristics, city planning for streets and buildings, and similar attributes; ε_t is the random error term.

To control for the influence of unobservable factors, we employed two models, a fixed-effects (FE) model and a random effects (RE) model, both of which were based on different assumptions. For the FE model, we eliminated the fixed effects α_i when we demeaned the data within the group. We then estimated the model using ordinary least squares. For the random effects (RE) model, we assumed α_i was uncorrelated with the explanatory variables, and estimated the model using generalized least squares. As a result of school location, there is time variance in the key explanatory variable *Core;* given this, we employed both models to estimate Eq. (1). We used the Hausman test to select between the FE and RE specifications.

4.2.2. The designation of EMSHS's in Shanghai

Schools were designated as EMSHS based only on their quality; this designation can affect housing prices only by disseminating information on school quality or by indirectly affecting school quality according to our earlier discussion. Therefore, we can eliminate the possibility of a reverse causal effect from housing prices to school quality. To analyze whether the designation influences housing prices, we substituted *EMSHS1* and *EMSHS2* for *Core* in the econometric model to obtain Eq. (2). Because these high-quality schools existed before becoming EMSHS's, the regression parameters "*EMSHS1*" and "*EMSHS2*" indicate only the number of schools designated for first- and second-wave EMSHS's per square kilometer in each residential area, respectively.

We denoted the variable of the time of designation for first-wave EMSHS's as "*Designation1*," which is a dummy variable taking a value of one for months after designation occurs and zero otherwise. Similarly, we denoted the variable of the time of designation for second-wave EMSHS's as "*Designation2*." We then used respective interaction terms between the time of designation and *EMSHS1* (denoted as "*EMSHS1* × *Designation1*") and *EMSHS2* (denoted as "*EMSHS2* × *Designation2*") to estimate the difference in housing prices before and after the designations.[11] To model whether there is a fadeout effect in the EMSHS designation, we also included respective interaction terms between *EMSHS1* × *Designation1* (*EMSHS2* × *Designation2*) and *time200502* (*time200509*), where *time200502* and *time200509* are variables indicating the amount of time since designation. These variables equal zero before designation, increasing by one for each month after the initial month of designation. Hence, we obtained Eq. (2) as follows:

$$\begin{aligned}\ln(Housingprice_{it}) = \theta_0 &+ \theta_1 \cdot EMSHS1_{it} \\ &+ \theta_2 \cdot EMSHS1_{it} \times Dreform \\ &+ \theta_3 \cdot EMSHS1_{it} \times Designation1 \\ &+ \theta_4 \cdot EMSHS1_{it} \times Designation1 \\ &\times time200502 + \theta_5 \cdot EMSHS2_{it} \\ &+ \theta_6 \cdot EMSHS2_{it} \times Dreform \\ &+ \theta_7 \cdot EMSHS2_{it} \times Designation2 \\ &+ theta_8 \cdot EMSHS2 \times Designation2 \\ &\times time200509 + \theta_9 \cdot Green_{it} \\ &+ \theta_{10} \cdot Metro_{it} + \theta_{11} \cdot Hospital_{it} \\ &+ \theta_{12} \cdot Dcenter_i + \theta_{13} \cdot Dsubcenter_i \\ &+ \theta_{14} \cdot Population\ Density_{it} \\ &+ \theta_{15} \cdot Average\ Wage_{it} \\ &+ \theta_{16} \cdot Government\ Expenditure_{it} \\ &+ \gamma_t + \alpha_i + \epsilon_{it} \qquad (2)\end{aligned}$$

[11] We did not include the third wave of designations in the analysis because it took place outside our sample period.

Furthermore, we estimated the effects of EMSHS designation on two subsamples using a methodology similar to DID estimation. With the first subsample, we matched two schools designated as EMSHS's in the first wave (but of relatively lower quality than other first-wave EMSHS's) with two other schools of similar quality that were not designated in the first wave, and then compared housing prices in the corresponding areas. By using this method, we obtained Eq. (3) as follows:

$$\begin{aligned}\ln(Housingprice_{it}) = {} & \varphi_0 + \varphi_1 \cdot EMSHS1L_i + \varphi_2 \\ & \cdot EMSHS1L_i \times Designation1 + \varphi_3 \\ & \cdot Green_{it} + \varphi_4 \cdot Metro_{it} + \varphi_5 \\ & \cdot Hospital_{it} + \varphi_6 \cdot Dcenter_i + \varphi_7 \\ & \cdot Dsubcenter_i + \varphi_8 \\ & \cdot Population\ Density_{it} + \varphi_9 \\ & \cdot Average\ Wage_{it} + \varphi_{10} \\ & \cdot Government\ Expenditure + \gamma_t \\ & + \alpha_i + \epsilon_{it} \qquad (3)\end{aligned}$$

The estimation of Eq. (3) employs a subsample that includes four residential areas, two of which have former CHS's that were not included in the first wave of EMSHS designations in February 2005. The other two residential areas have schools of similar quality that were designated in the first wave (which means they are of relatively lower quality than other first-wave EMSHS's). As discussed earlier, there has been no official disclosure of school quality rankings in Shanghai, but informal quality rankings for guiding students' school choices are available on the Internet. These rankings provide clues for us to determine which schools are of "similar quality" to the two former CHS's not included in the first-wave EMSHS designations.

We have been unable to confirm which informal ranking is correct because the alternative rankings are generally inconsistent, but we found that two of the first-wave EMSHS's always received the lowest ranking. We then matched these two schools with former CHS's that were not included in the first wave of EMSHS designations. The variable "*EMSHS1L*" denotes the number of schools designated as first-wave EMSHS's (but of relatively lower quality than other first-wave EMSHS's) per square kilometer in each residential area. "*EMSHS1L* × *Designation1*" is an interaction term between the time of designation (*Designation1*) and *EMSHS1L*. The coefficient of *EMSHS1L* × *Designation1* estimates the difference in housing prices before and after the designation of lower-quality marginal schools than other first-wave EMSHS's.

In the second subsample, we focused on the 29 residential areas without any former CHS's. In this subsample, four areas have schools designated as EMSHS's in the second wave. By replacing *EMSHS1L* and *EMSHS1L* × *Designation1* in Eq. (3) with *EMSHS2,* and its interaction term with the time of designation (this interaction term is thus the variable *EMSHS2* × *Designation2*), we estimated the effects of second-wave EMSHS's designations on housing prices for this subsample. Given that the "common trend" assumption in the DID estimation is crucial for our methodology, we performed a test to determine whether the time trend in housing prices diverged before treatment, between the treatment and control groups in both subsample estimations.

One complication in our analysis was that if we were to observe the positive effects of key explanatory variables on housing prices, there could be some ambiguity about whether these effects were school district effects (access to a quality public school) or distance effects (lower transportation costs when nearer a quality school). We were unable to distinguish perfectly between these two forms of housing capitalization when estimating a single school quantity variable coefficient; however, if we were able to observe a significant difference between the first- and second-wave EMSHS effects, we could then plausibly attribute the difference to school district effects. In addition, as the distance to quality schools does not change over time, we were able to control for these using FE estimation. In particular, the changes in housing prices during the very short period when they were used as treatment effects before and after EMSHS designation are unlikely to be distance effects.

5. Empirical results

Table 2 reports the results of Eq. (1) for the panel of 52 residential areas. Column (1) details the results of the FE estimation, and Column (2) provides the results for the RE estimation. The table does not report the results for the monthly dummy variables included in the two estimations. The value of the Hausman test statistic is 43.40 with a p-value of 0.849. Because the null hypothesis is that there is no systematic difference between the FE and RE estimations, this implies that we should choose the RE estimation for our results. The key explanatory variable, *Core*, which measures the average access to quality public education in a residential area, is significantly positive. The interaction term between *Core* and *Dreform* is negative but not significant, which implies that reforms in the enrollment practices of senior high schools starting in September 2004 did not have significant effects, although the reforms weakened the link between access to quality public education and housing locations. Even if we considered the effects of the negative interaction term, the aggregate effects of *Core* on housing prices are still positive. The estimated coefficients indicate that when an area has an additional quality school per square kilometer, the housing prices are approximately 15.3%[12] higher. By comparing the coefficients for the explanatory variables, we can see that this is equivalent to the effect of housing prices after increasing green space by 15.3 hectares per square kilometer, or increasing per capita government expenditure by 17 thousand RMB, or moving the area 3.6 km closer to the metropolitan center.

In terms of the other explanatory variables, the estimated coefficient for *Green* is significantly positive, indi-

[12] The coefficient of *Core* is 0.142, so the effect is calculated by exp(0.142) – 1 = 0.153 because of the log-linear specification.

Table 2
Regression of housing prices on number of core high schools.

Dependent variable:	(1) FE ln(*housingprice$_{it}$*)	(2) RE ln(*housingprice$_{it}$*)
Core	0.181***	0.172***
	(0.0117)	(0.0144)
Core × *Drefrom*	−0.0382	−0.0302
	(0.0269)	(0.0286)
Green	0.0161	0.00929*
	(0.00904)	(0.00482)
Metro	0.00586	0.00684
	(0.0276)	(0.0296)
Hospital		0.0202
		(0.0307)
Population Density	−0.106	−0.0291
	(0.0700)	(0.0208)
Average Wage	−0.0241	−0.0209
	(0.0182)	(0.0179)
Government Expenditure	0.0640	0.0838**
	(0.0401)	(0.0335)
Dcenter		−0.0396***
		(0.00990)
Dsubcenter		−0.0158
		(0.00977)
Constant	8.791***	8.969***
	(0.133)	(0.0743)
Monthly Time Dummy Variables	YES	YES
Observations	2496	2496
Panel groups	52	52
R^2 (within groups)	0.977	0.977
Hausman test		43.40
(*p*-Value)		0.849

Notes: (1) Standard error in parentheses, clustered in districts. (2) ***Denotes significance at the 1% level, **at the 5% level, and *at the 10% level.

cating that housing prices are approximately 1.0% higher in areas that have an additional hectare of green space per square kilometer. However, the coefficients for *Metro* and *Hospital* are not significant, possibly because the positive effects of more convenient transportation (or access to medical care) are generally offset by the negative effects of congestion (or an uncomfortable environment). The coefficient for *Dcenter* is significantly negative, thereby indicating that moving an area one kilometer closer to the metropolitan center will increase housing prices by 4.0%, while the coefficient for *Dsubcenter* is negative but not significant. After considering Shanghai's spatial economic structure wherein economic activities are concentrated in the city's center and the subcenters, the result that job location and transportation costs determine housing prices is consistent with the theoretical models in Alonso (1964) and Zenou (2008). It is also consistent with Hao and Chen's (2007) empirical findings concerning the influence of location on housing prices for 106 residential blocks in Shanghai. The coefficients for *Population Density* and *Average Wage* are not significant, while the coefficient for *Government Expenditure* is significantly positive. If the per capita annual government expenditure is 10 thousand RMB higher, then housing prices increase by 8.7%.

Table 3 details the influence of EMSHS designation on housing prices. Because *EMSHS2*, one of the most important explanatory variables, has no variance across time, we used the RE model to estimate the coefficients in Eq. (2). Column (1) shows the results without interaction terms between designation and time trends starting from the designation period. In Column (1), the coefficient for *EMSHS1* is significantly positive. However, its interaction term with *Dreform* is not significant. These results suggest that when a residential area has an additional EMSHS per square kilometer, housing prices are approximately 17.1% higher. This increase is equivalent to the effects of increasing green space in an area by 16.4 hectares or increasing per capita annual government expenditure by 19 thousand RMB or moving the area 4.1 km closer to the metropolitan center. These results imply that as higher-quality schools, first-wave EMSHS's have a positive effect on housing prices, but that this effect existed prior to their official designation. *EMSHS1* × *Designation1*, which is actually the interaction term between *EMSHS1* and a dummy variable indicating the periods before and after designation, is not significant. This is likely because designation did not release much new information concerning these better schools.

The estimated coefficient for *EMSHS2* is not significant, but its interaction term with *Dreform* is significantly negative. These results suggest that the second-wave of EMSHS's (as schools of inferior average quality when compared with first-wave EMSHS's) did not have significantly positive effects on housing prices prior to their designation. Furthermore, the negative effects of enrollment reforms on the link between housing prices and access to quality schools arise mainly in relation to these relatively inferior schools (although they are still of high quality when compared with non-designated schools). However, the estimated coefficient for *EMSHS2* × *Designation2* is significantly positive. The aggregate effect of second-wave EMSHS's on housing prices is significantly positive (0.0852),[13] which implies that when a residential area has an additional second-wave of EMSHS's per square kilometer, housing prices are approximately 8.9% higher. The new information generated by the second-wave EMSHS designations thus discriminates between these schools and other public schools in terms of housing price capitalization, even though the aggregate effects of second-wave EMSHS's (8.9%) are about half the effects of first-wave EMSHS's (17.1%). The above results suggest that parents might have had a great deal of unofficial information available to them regarding school quality prior to the EMSHS designations. This type of information comes through channels such as Internet websites and social connections, which lead to the fact that EMSHS's designations are less likely to have significant effects on well-known high quality schools while only the second-wave designations, on average, have additional positive effects. In order to further explore whether the designation is capturing something new, we also performed a check to include some of the school quality information previously

[13] As shown in Column (2), the coefficient of *EMSHS2* is 0.0848, the coefficient of *EMSHS2* × *Dreform* is – 0.0299, and that of *EMSHS2* × *Designation2* is 0.0303. Therefore, the aggregate effect of the second-wave EMSHS's on housing prices is 0.0848 – 0.0299 + 0.0303 = 0.0852.

Table 3
Influence of "Shanghai Experimental Model Senior High Schools" Designation on Housing Prices.

Dependent variable:	(1) RE $\ln(housingprice_{it})$	(2) RE $\ln(housingprice_{it})$
EMSHS1	0.158***	0.158***
	(0.0177)	(0.0225)
EMSHS1 × Dreform	−0.00999	−0.00989
	(0.0256)	(0.0260)
EMSHS1 × Designation1	−0.0164	−0.0135
	(0.0222)	(0.0198)
EMSHS1 × Designation1 × time200502		−0.000228
		(0.00190)
EMSHS2	0.0853	0.0848
	(0.0612)	(0.0608)
EMSHS2 × Dreform	−0.0296*	−0.0299*
	(0.0178)	(0.0162)
EMSHS2 × Designation2	0.0406*	0.0303***
	(0.0234)	(0.00771)
EMSHS2 × Designation2 × time200509		0.00108
		(0.00195)
Green	0.00963**	0.00964**
	(0.00487)	(0.00487)
Metro	0.00472	0.00440
	(0.0279)	(0.0285)
Hospital	0.00437	0.00463
	(0.0245)	(0.0238)
Population Density	−0.0275	−0.0272
	(0.0175)	(0.0173)
Average Wage	−0.0211	−0.0212
	(0.0176)	(0.0175)
Government Expenditure	0.0845**	0.0841**
	(0.0329)	(0.0337)
Dcenter	−0.0387***	−0.0386***
	(0.00897)	(0.00900)
Dsubcenter	−0.0162	−0.0162
	(0.0101)	(0.0101)
Constant	8.962***	8.962***
	(0.0649)	(0.0665)
Monthly Time Dummy Variables	YES	YES
Observations	2496	2496
Panel groups	52	52
R^2 (within groups)	0.977	0.977

Notes: (1) Standard error in parentheses, clustered in districts. (2) ***Denotes significance at the 1% level, **at the 5% level, and *at the 10% level.

known by the public in the regression, discovering that the main results remained unchanged.[14]

It is useful to compare our findings for China with previous studies in developed countries using either the RDD or the DID method. To start with, Bogart and Cromwell (2000) concluded that the redistricting of quality neighborhood schools led to a reduction in housing prices of about 10% in areas losing a quality school, which our analysis shows to be smaller than the effect of adding an additional quality school per square kilometer. The effect of raising the number of better (first-wave) EMSHS's per square kilometer in a residential area by one standard deviation (0.15) is about 2.4%. Compared with many other studies showing the effects of a one standard deviation increase in school performance on housing prices, our finding is nearer to the 2.5% increase found in Massachusetts by Black (1999) and the 2% increase found in Paris by Fack and Grenet (2010). In contrast, our findings are significantly larger than the 1.3%–1.4% increase found in Connecticut by Clapp et al. (2008) and the 1.6% increase found in New Jersey by Caetano (2009). They are, however, significantly smaller than the 3.8–7.7% increase found in Minnesota by Reback (2005) and the 3.5% increase found in Australia by Davidoff and Leigh (2008). Since residing in a residential area containing an EMSHS does not guarantee admission, it is reasonable that the value is lower when relative to a system where students attend their neighborhood school. Although the differences in measurement across these studies do not permit direct comparison, the abovemen-

[14] According to the discussion in Section 3.3, we excluded two schools being ranked lowest (among first-wave EMSHS's) in all school rankings on the Internet from the list of first-wave EMSHS's, and used the remaining part of the list to create a variable *Highquality*, which is high schools per square kilometer recognized as high quality on the Internet before the designations. We then substituted the variable *EMSHS1* in Column (2) with *Highquality*, and obtained nearly the same results as Column (2): *Highquality* is significantly positive (0.155), while *EMSHS1 × Designation1* is not significant and *EMSHS2 × Designation2* is significantly positive (0.031).

Table 4
Effects of "Shanghai experimental model senior high schools" designation: sub-sample estimations.

Dependent variable:	(1) RE ln(*housingprice*)	(2) RE ln(*housingprice*)	(3) RE ln(*housingprice*)	(4) RE ln(*housingprice*)
EMSHS1L	0.642	0.135		
	(1.100)	(1.413)		
EMSHS1L × *Designation1*	0.283***	0.379*		
	(0.0955)	(0.202)		
EMSHS1L × *1mbefore*		0.265		
		(0.223)		
EMSHS1L × *2mbefore*		0.228		
		(0.216)		
EMSHS1L × *3mbefore*		0.168		
		(0.216)		
EMSHS1L × *4mbefore*		0.0614		
		(0.202)		
EMSHS1L × *5mbefore*		0.0699		
		(0.172)		
EMSHS1L × *6mbefore*		0.0281		
		(0.173)		
EMSHS2			0.105*	0.113*
			(0.0603)	(0.0615)
EMSHS2 × *Designation2*			0.0670***	0.0613**
			(0.0229)	(0.0274)
EMSHS2 × *1mbefore*				−0.00177
				(0.0204)
EMSHS2 × *2mbefore*				−0.0161
				(0.0259)
EMSHS2 × *3mbefore*				−0.0345
				(0.0282)
EMSHS2 × *4mbefore*				−0.0454
				(0.0352)
EMSHS2 × *5mbefore*				−0.0331
				(0.0265)
EMSHS2 × *6mbefore*				−0.0226
				(0.0182)
Green	−0.0610***	−0.0552**	0.00834	0.00843
	(0.0159)	(0.0228)	(0.00599)	(0.00593)
Metro	−0.120**	−0.161**	0.0367	0.0367
	(0.0590)	(0.0733)	(0.0253)	(0.0255)
Hospital	−1.550	−2.476	0.117*	0.117*
	(1.640)	(2.172)	(0.0661)	(0.0671)
Population Density	−0.0198	0.0830	−0.00821	−0.00970
	(0.255)	(0.311)	(0.0195)	(0.0195)
Average Wage	0.0477**	0.0504***	−0.0265	−0.0259
	(0.0218)	(0.0154)	(0.0186)	(0.0185)
Government Expenditure	−0.480***	−0.544***	0.113***	0.114***
	(0.165)	(0.0731)	(0.0425)	(0.0425)
Dcenter	−0.200***	−0.215***	−0.0286***	−0.0291***
	(0.0219)	(0.0228)	(0.0103)	(0.0102)
Dsubcenter			−0.00773	−0.00756
			(0.0119)	(0.0119)
Constant	10.56***	10.72***	8.807***	8.811***
	(0.113)	(0.135)	(0.0676)	(0.0665)
Monthly Time Dummy Variables	YES	YES	YES	YES
Observations	192	192	1392	1392
Treated groups	2	2	4	4
Control groups	2	2	25	25
R^2	0.982	0.982	0.979	0.979

Notes: (1) Standard error in parentheses, clustered in districts. (2) ***Denotes significance at the 1% level, **at the 5% level, and *at the 10% level.

tioned results imply that we have established similar effects of quality education on housing prices in China's emerging housing markets, which is a transitional and developing economy, to those in more developed countries.

Column (2) reports the estimation results for Eq. (2), including interaction terms between designation and time trends beginning with the period of designation. Overall, the results show that the interaction terms are not significant, while the estimated coefficients for other variables display almost no difference from those shown in Column (1). Hence, the effects of designation do not fade over time, unlike the findings for Florida in the study by Figlio and Lucas (2004). However, as our sample period ended only

19 months after designation, we cannot confirm that there isn't a longer-term fadeout effect. The signs and significance of the remaining variables in Table 3 are consistent with those in Table 2.

Finally, Table 4 provides the results of the subsample estimation using a method very similar to DID estimation. Column (1) reports the results for the first subsample where we matched schools designated as EMSHS's in the first wave with undesignated schools of similar quality. The estimated coefficient for *EMSHS1L* is not significant, while the coefficient for *EMSHS1L* $\times$ *Designation1* is significantly positive, implying that the information on first-wave EMSHS designation has been capitalized into housing prices. It does this by distinguishing between marginal schools of relatively lower quality than other first-wave EMSHS's and schools of similar quality not designated in the first wave.

Comparing the results with those in Table 3, we can see that first-wave EMSHS designation is meaningful for discriminating between marginal schools because of the release of new information to parents through the designation. However, there is no significant effect for leading schools. Similarly, we estimated the difference in housing prices before and after the second-wave of EMSHS designations in the subsample containing only the 29 residential areas without any former CHS's. As shown in Column (3), the estimated coefficient for the interaction term is significantly positive (0.0670), which confirms that new information regarding high quality schools generated by the second-wave EMSHS designation helps distinguish these schools from other public schools in terms of housing price capitalization. If there is one additional, previously non-designated (neither core nor EMSHS) high school being designated as EMSHS per square kilometer in a residential area, the housing prices will be 6.9% higher.

Because our methodology is similar to a DID estimation, a major concern is whether the "common trend" assumption holds in our samples. For example, if the trend in housing prices for the treatment group diverged from that in the control group before the treatment, there may be some bias in our estimation. Therefore, we performed a test to see whether the time trend diverged before treatment in the above subsamples by including a series of dummy variables indicating the time periods prior to the designation (months before the designation). The results are in Columns (2) and (4), respectively. In both cases,

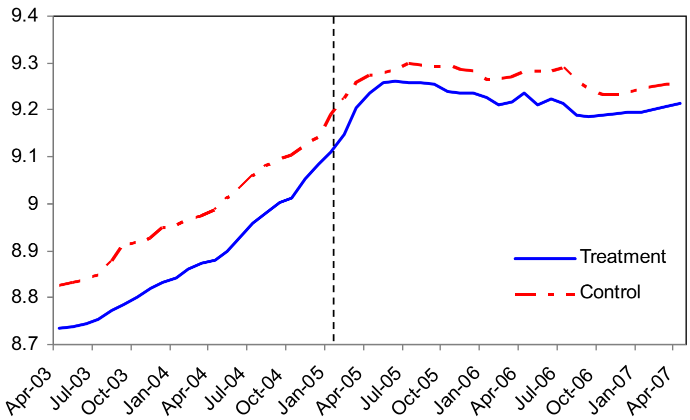

Fig. 3. Average housing prices (logged) in the first subsample.

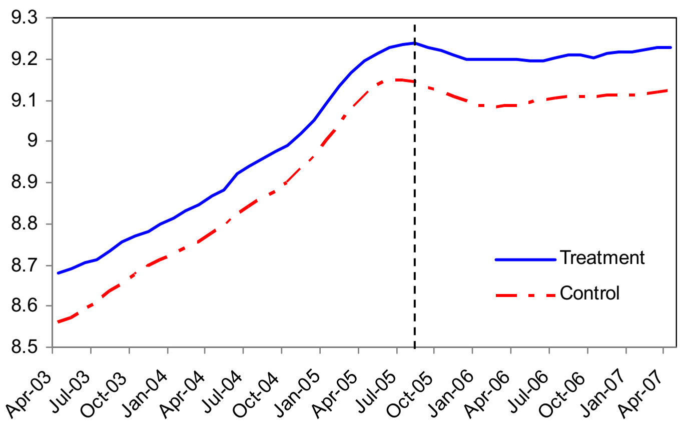

Fig. 4. Average housing prices (logged) in the second subsample.

Table 5
Robustness checks.

Dependent variable:	(1) RE ln(*housingprice*)	(2) RE ln(*housingprice*)	(3) RE ln(*housingprice*)	(4) RE ln(*housingprice*)
Core	0.168***		0.177***	
	(0.0212)		(0.0126)	
Core × *Dreform*	−0.0464*		−0.0385	
	(0.0250)		(0.0317)	
EMSHS1		0.154***		0.164***
		(0.0277)		(0.0207)
EMSHS1 × *Dreform*		−0.0151		−0.00603
		(0.0256)		(0.0266)
EMSHS1 × *Designation1*		−0.0182		−0.0281
		(0.0199)		(0.0180)
EMSHS1 × *Designation1* × *time200502*		−0.000493		0.000243
		(0.00184)		(0.00214)
EMSHS2		0.0549		0.0520
		(0.0532)		(0.0543)
EMSHS2 × *Dreform*		−0.0351**		−0.0270
		(0.0176)		(0.0164)
EMSHS2 × *Designation2*		0.0256***		0.0216**
		(0.00625)		(0.00898)
EMSHS2 × *Designation2* × *time200509*		0.00148		0.000957
		(0.00184)		(0.00218)
Green	0.00708**	0.00743**	0.00541	0.00608
	(0.00334)	(0.00362)	(0.00666)	(0.00675)
Metro	−0.00301	−0.00573	0.0168	0.0149
	(0.0331)	(0.0318)	(0.0289)	(0.0284)
Hospital	0.00678	−0.000763	−0.00555	−0.0135
	(0.0202)	(0.0187)	(0.0217)	(0.0223)
Population Density	−0.0176	−0.0183	−0.0159	−0.0159
	(0.0158)	(0.0150)	(0.0141)	(0.0132)
Average Wage	−0.0121	−0.0126	−0.0169	−0.0177
	(0.0150)	(0.0142)	(0.0372)	(0.0367)
Government Expenditure	0.0717*	0.0709*	0.103***	0.103***
	(0.0388)	(0.0402)	(0.0334)	(0.0334)
Dcenter	−0.0318***	−0.0317***	−0.0430***	−0.0423***
	(0.00697)	(0.00683)	(0.0108)	(0.0104)
Dsubcenter	−0.0250***	−0.0256***	−0.0271***	−0.0276**
	(0.00728)	(0.00781)	(0.00990)	(0.0114)
Constant	8.939***	8.946***	8.996***	8.997***
	(0.0587)	(0.0547)	(0.104)	(0.107)
Monthly Time Dummy Variables	YES	YES	YES	YES
Observations	2160	2160	1632	1632
Panel groups	45	45	34	34
R^2	0.980	0.980	0.977	0.977

Notes: (1) Standard error in parentheses, clustered in districts. (2) ***Denotes significance at the 1% level, **at the 5% level, and *at the 10% level. (3) Columns (1) and (2) are based on sub-samples excluding Pudong. Columns (3) and (4) are based on sub-samples of 34 residential areas within 8 kilometers from the metropolitan center.

the dummy variables indicating the time periods prior to the designation are not significant, which implies that the time trend in housing prices did not diverge before designation. Also, we drew two figures (Fig. 3 and Fig. 4) showing a common trend of housing prices in the treatment group and control group for the subsamples in Column (2) and Column (4), respectively. For this reason, we did not violate the "common trend" assumption in our estimations. The subsamples thereby provided additional evidence of the capitalization of quality public education access into Shanghai housing prices.

6. Robustness check

Table 5 provides the results for several robustness checks. The Huangpu River separates the Pudong District from the metropolitan center. Therefore, the straight-line measurement of the distance to the center, as in the main analysis, underestimates the actual travel distance. Furthermore, Pudong developed quickly in the early 1990s; as such, its education development may not be comparable to the experience of other districts. Therefore, we performed a robustness check in Columns (1) and (2) using subsamples without Pudong, and observed that the signs and significance of the variable coefficients are almost the same as in Tables 2 and 3. We also performed a robustness check by considering only the subsample of residential areas closest to the metropolitan center. As shown in our estimations for the subsample of 34 residential areas within 8 kilometers of the metropolitan center in Columns (3) and (4), there is no change in the signs or significance of our main explanatory variables.

7. Conclusion

The endogeneity of education quality and quantity accounts for difficulties in appropriately identifying the causal relationship between education and housing prices. To determine how education quality is capitalized into housing prices, we employed a natural experiment occasioned by China's education reforms to deal with this endogeneity bias. Our natural experiment proved useful in analyzing how new information unveiled by designating grades on school quality affected housing prices in China's developing housing market. Based on the exogenous natural experiment in the EMSHS designations, we found evidence that housing prices included allowances for new information revealed by assigning quality-based grades to Shanghai schools. In general, the presence of an additional EMSHS (of the best quality) per square kilometer increases housing prices by 17.1%. If one additional, previously non-designated (neither core nor EMSHS) high school is designated as EMSHS per square kilometer in a residential area, the housing prices will be 6.9% higher.

On average, the first-wave designations had no further effects on housing prices, whereas the second-wave designations had significantly positive effects on housing prices. However, the aggregate effects for the second-wave EMSHS's (8.9%) were about half of the effects for the first-wave EMSHS's (17.1%). We also found that both the first- and second-wave EMSHS's designations had significantly positive effects on marginal quality schools using the subsample estimation and a method similar to the DID estimation. The effects on housing prices as a result of increasing the number of high-quality EMSHS's per square kilometer in a residential area is equivalent to that of increasing green space in an area by 16.4 ha, or increasing per capita annual government expenditure by 19 thousand RMB, or moving the area 4.1 km closer to the metropolitan center.

We compared our findings in China with previous studies in developed countries using the RDD or DID method, and found that our estimates generally fell in the range of results detailed in these comparable studies. Because the exogenous natural experiment efficiently eliminated the influence of endogeneity, our findings that housing prices capitalized school quality information represented convincing empirical evidence. In addition, the finding that the EMSHS designation itself has significant effects on housing prices in relation to marginal schools provides evidence that information on school quality remains imperfect in Shanghai's developing education and housing markets.

Our empirical findings also presented important evidence for Tiebout mobility in China's metropolitan housing market, which is a key mechanism in undertaking education policy. When education resources are effectively allocated through the housing market, regulations for seemingly equalized access to education, such as those governing the school choice and school fees may actually enhance the education-housing price relationship. This makes people compete for education resources through housing choices, thereby increasing the inequality of education access. Because we found that access to quality education is already capitalized into housing prices in China's emerging housing market when a neighborhood-based school admissions system is in place, our findings imply that developing countries should be prepared for similar consequences related to residential sorting in housing markets. Such sorting has the potential to affect social mobility and economic inequality in developing countries when their housing markets are in early stages of development, such as in China.

Acknowledgments

The authors gratefully acknowledge funding by the National Social Science Funds (12AZD045, 13&ZD015), the National Natural Science Funds (71133004), and support from the Fudan Lab for China Development Studies. The authors would like to thank anonymous referees, as well as conference and seminar participants at Fudan University, Shanghai University of Finance and Economics, Southwestern University of Finance and Economics, Peking University, and China's Young Economist Society for their helpful comments and suggestions. The authors also thank the Research Project of Policies for East Asia and the G-COE Hi-Stat, Hitotsubashi University, for providing financial support for English language proofreading. All content in the article is the sole responsibility of the authors.

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