RESEARCH

RESALE OF GREEN HOUSING COMPENSATES FOR ITS PREMIUM PRICING: AN EMPIRICAL STUDY OF CHINA

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ABSTRACT

Green housing reduces resource consumption and protects the ecological environment. Sustainable buildings and construction have gained increasing attention in the last decade. Many empirical studies have confirmed that green housing imposes a price premium at the presale stage. The high price could be a concern that prevents homebuyers from purchasing green buildings. However, there is a lack of empirical evidence on whether the premium pricing could be compensated for by the resale price. To address this gap, this study establishes a hedonic regression model to estimate the price premium of green housing at the resale stage. The results show that green housing certified with the Chinese Green Building Label (CGBL) offers a 6% price premium compared with non-green housing at the resale stage. The results also show that green housing with a higher level of green certification, e.g., the 3-star CGBL, provides a greater price premium at resale. The findings indicate that homebuyers can obtain financial compensation for the high cost when purchasing a green home. Our findings also indicate that the price premium for reselling a green home is not always enough to compensate for the purchase cost in different cities. Policy recommendations for government promotion of green housing are also discussed.

KEYWORDS

green housing, premium difference, resale stage, CGBL

1. INTRODUCTION

Traditional residential buildings consume a large amount of natural resources and cause environmental pollution. In contrast, green housing can effectively reduce resource consumption, protect the ecological environment, and provide a healthy living environment for occupants (Ahn et al., 2013; Holmgren et al., 2017; Pei et al., 2015; Wei et al., 2015; Zhao et al., 2017). However, the initial premium price has been increasingly recognized as a critical barrier to green housing development (Issa et al., 2010; Zhang et al., 2011). Issa et al. (2010) mentioned that high-cost premiums were the primary barrier to investing in green practices. Researchers have also proven that the price premium of green housing does exist at the presale stage (Deng and

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Wu, 2014; Heinzle et al., 2013; Hu et al., 2014; Hwang et al., 2017; Juan et al., 2017; Zhang et al., 2018).

Green buildings have been constructed rapidly and globally, such as in the United States, the UK, the European Union, Singapore, China, India, and Brazil (Li et al., 2014; Zhao et al., 2019). The BREEAM (Building Research Establishment Environmental Assessment Method) is the first widely used green building assessment method in the world. Then, the LEED (Leadership in Energy and Environmental Design) building rating system was launched in the US, which is the most complete and influential set of evaluation criteria worldwide. Most green buildings in developed countries have been LEED-certified. Afterwards, Japan introduced CASBEE, and Singapore introduced Green Mark.

In China, the development of green buildings started relatively late. The Evaluation Standards for Green Buildings (ESGB), a national standard, was established in 2006 and was first revised in 2014. The Chinese Green Building Label in 2014 was divided into a design certification and an operation certification, but few projects obtained the operation certification. To make the evaluation criteria more in line with the current situation in China's green building development, the new edition of the Assessment Standard for Green Building was issued in 2019 (hereinafter cited as 2019 Standard), in which five aspects are considered in the evaluation process: (1) safety and durability; (2) health and comfort; (3) life convenience; (4) resource conservation; and (5) livable environment. Green buildings are classified as either the basic level, one-star, two-star, or three-star CGBL. Meanwhile, green buildings have become the focus of governments and the public. For example, the document of "the 13th Five-Year Plan of Building Energy Conservation and Green Building Development" in 2017 set up a goal that the proportion of green buildings in new urban buildings shall exceed 50%, and the proportion of green residential buildings shall exceed 60% by 2020. By the end of 2018, green buildings had reached more than 40% of new building in urban areas (Ministry of Housing and Urban-Rural Development, 2019). Moreover, some provincial governments provide economic subsidies for green buildings with a high star green certification label. At present, nine provinces have offered financial subsidies for green buildings with two-star or three-star labels (Cheng and Huang, 2017). However, China's undertaking of the widespread use of green buildings in the construction industry still lags. The share of green housing with a CGBL accounts for only 0.8% of new residential buildings (Zhang et al., 2016), and uneven distribution indicates that the main agglomeration is in some major cities (Qiu et al., 2017).

In China, the focus of housing development has changed from solving housing shortages to improving the living environment and quality. This provides an opportunity for green housing development, which is an effective way to improve quality of life. However, due to the lack of education, knowledge, and experience concerning green housing (Darko and Chan, 2017), this option has not been appreciated by most homebuyers; only richer consumers and those with higher environmental awareness are willing to purchase green housing (Hu et al., 2014; Zhang et al., 2018). Housing prices are one of the most concerning elements for Chinese residents (Liu et al., 2018). Homebuyers need to increase their expenses to purchase green housing, so financial viability has always been a major problem for them in accepting green housing (Deng and Wu, 2014). Compared with traditional housing, the price premium at presale hinders households from purchasing green housing to a certain degree, although it can bring energy performance and good indoor air quality.

Du et al. (2017) demonstrated that housing prices have a positive effect on residential housing demand when basic consumption demand is satisfied (Du et al., 2017). Ofek et al.

(2018) pointed out that an increase in real estate values is a main factor influencing consumers' decisions regarding green housing (Ofek et al., 2018). If the resale of green housing can compensate homebuyers for the high purchase cost, it may increase their motivation to choose green housing. Unfortunately, existing studies have focused on the incremental costs and energy performance of green housing, and the premium compensation for green housing at the resale stage has rarely been addressed, especially in China, which is not conducive to a comprehensive understanding of the economic return for green housing. Even if there is a price premium at the presale stage, it will be financially viable to purchase green housing if the price premium at the resale stage is large enough to compensate for their increased expenses at the presale stage.

Therefore, this study focuses on multifamily, owner-occupied green housing to examine whether its resale value can compensate for the premium expense of purchasing such a home. The researchers analyzed residential project data from major Chinese cities, including green housing certified by CGBL and non-green housing, which were completed from 1986 to 2018. The study will also describe the premium compensation differences between projects with different star labels and with different certifications.

2. LITERATURE REVIEW

The benefits of green housing for energy savings, water efficiency and healthy indoor environments have been addressed in many studies (Geng et al., 2019; Lin et al., 2016; McCoy et al., 2018; Zhang et al., 2018). However, these benefits create incremental costs both in the design process and the construction process, which have been proven in previous studies. The design and construction of green buildings is a relatively new innovation in the real estate industry (Devine and McCollum, 2019; Mollaoglu et al., 2016), which has been shown to affect costs in different ways (Chegut et al., 2019). For instance, energy efficiency has been documented as requiring changes in the design methods (Mapp et al., 2011), construction materials (Tatari and Kucukvar, 2011) and green technologies (Teng et al., 2016). These changes inevitably require more costs in the early stages of development. Kat et al. pointed out that green buildings are between 0 and 7% more expensive than conventional non-green buildings, and the average green premium cost is 1.84% in the U.S. (Kats, 2003). Schnieders and Hermelink examined residential energy-efficient buildings in Europe and concluded that the specific extra investment was found to be 8% of the total building cost (Schnieders and Hermelink, 2006). Zhang et al. pointed out that the additional cost of green property projects with green elements is higher than that of conventional property projects (Zhang et al., 2011). Zalejska-Jonsson et al. pointed out that the average extra cost is estimated to be approximately 5% higher than the cost of conventional buildings (Zalejska-Jonsson et al., 2012).

Part of the incremental costs of green housing will ultimately be borne by homebuyers who need to increase their expenses to purchase green housing. Therefore, the cost premium has restricted the development of green housing to a certain extent due to the price sensitivity of homebuyers, although the premium could be made up through energy savings. The study by Kahn & Kok pointed out that green attributes of homes can be capitalized on in sales transactions (Kahn and Kok, 2014). Hopkins also found that some LEED certificated campus buildings demonstrated positive financial results (Hopkins, 2015). However, the house is a typical experiential product, and it is not easy to directly observe these benefits in advance. Moreover, home users are either unlikely to quantify these benefits in the short term or will have difficulty doing so. Fortunately, the establishment of a green building certification system not only provides a reference for evaluating the quality of green buildings but also provides a way to estimate the magnitude of the price premium. When the other attributes that affect housing prices are the same, the price difference caused by a green certification can basically represent the price premium of green buildings (Zhang et al., 2017).

Previous studies have identified price premiums for green housing compared with traditional housing. Fuerst & McAllister (2011) used hedonic regression analysis to study rent and price premiums of U.S. commercial real estate. The results showed that the certified buildings had both a rental and sale price premium compared with noncertified buildings (Fuerst and McAllister, 2011). Kahn & Kok (2014) also used a hedonic pricing analysis to study the capitalization of green labels, finding that there was a small premium for homes with green certification compared with nonlabelled homes in California (Kahn and Kok, 2014). Deng & Wu (2014) studied the economic returns of green housing investments in Singapore. Their results found a 4% green price premium at the presale stage and a 10% premium at the resale stage. Meanwhile, the study by Skewmake & Viscusi has pointed out that price premiums increase with green certification stringency (Shewmake and Viscusi, 2015). In China, there are also a few studies on green housing price premiums. Zhang et al. (2017) studied the price premium of green housing with the Chinese Green Building Label. The results showed that there is a 6.9% price premium of newly built green housing compared with nonlabelled counterparts (Zhang et al., 2017). Zhang et al. (2018) used the traditional hedonic pricing model to investigate the price premium of a green hotel. The results revealed a significant room rate premium of 6.5% (Zhang et al., 2018). However, due to the lack of green housing transaction data in the second-hand housing market, previous research on green housing premiums in China has focused on newly built green residential projects. There are scarce studies of green housing premiums at the resale stage. With the rapid development of green housing in China since 2011, we can seek sufficient transaction data for green housing in the second-hand housing market to support the study of price premiums at the resale stage. If the premium at the resale stage is higher than at the presale stage, the study will inform homebuyers that they can realize an economic return from a green housing premium when they sell their green home, although they will have had to pay more when they purchased the house from the home developer. However, if the premium at the resale stage is lower than at the presale stage, the study will suggest that the government provide some support policies, such as giving monetary subsidies, to compensate homebuyers for their increased expenses, to enlarge the demand and promote the development of green housing.

3. MATERIAL AND METHODS

3.1 Samples

According to the data from the Chinese Ministry of Housing and Urban-Rural Development (MOHURD), 2,078 housing projects received the CGBL certification between 2008 and September 2016. The projects with a one-star CGBL account for 43.8%, those with a two-star CGBL account for 43.0%, and those with a three-star CGBL account for 13.2%. Table 1 shows that the number of green housing projects has increased significantly since 2011 (Jiang and Payne, 2019), but the proportion of projects with high star CGBLs has decreased year by year since 2009.

Due to the differences in economic development and the real estate market among cities, the distribution of green housing is imbalanced in China (Huang et al., 2018; Qiu et al., 2017; Zou et al., 2017). Figure 1 shows the geographic distribution of green housing in China by

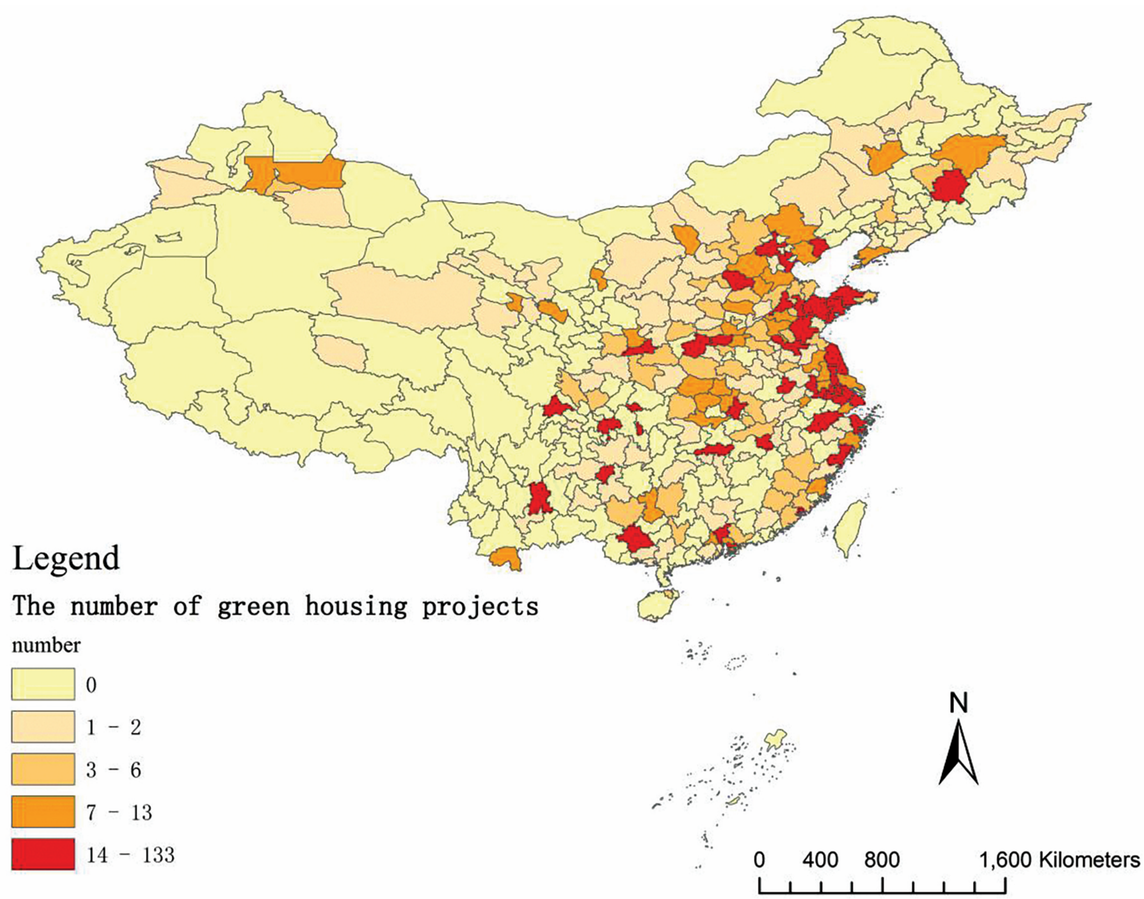
TABLE 1. Numbers of green housing in China.

	2008	2009	2010	2011	2012	2013	2014	2015	2016(Sep)
No. of One Star	3	1	10	48	74	145	236	323	70
No. of Two Star	0	2	25	49	93	207	215	256	47
No. of Three Star	1	1	10	43	31	35	74	56	23
Total	4	4	45	140	198	387	525	635	140

using quartile classification that divides the prefecture-level cities with different numbers of green housing into five categories. Figure 1 implies that most green housing is distributed in large and medium cities with relatively developed economies (Li et al., 2014; Qiu et al., 2017; Ye et al., 2013) and better real estate markets (Zhang et al., 2018).

First, we choose samples from 35 major cities, including Beijing, Changchun, Chengdu, Chongqing, Changsha, Dalian, Fuzhou, Guiyang, Guangzhou, Haikou, Hefei, Hohhot, Harbin, Hangzhou, Jinan, Kunming, Lanzhou, Ningbo, Nanchang, Nanjing, Nanning,

FIG. 1. Distribution of green housing projects in Chinese prefecture-level cities



Qingdao, Shanghai, Shijiazhuang, Shenyang, Shenzhen, Tianjin, Taiyuan, Wuhan, Urumqi, Xi'an, Xiamen, Xining, Yinchuan, and Zhengzhou, because these cities account for more than half of green housing and have a relatively active real estate market that ensures access to sufficient quantity and full information on green housing and their counterparts and are geographically diversified (Jiang et al.,2018). We seek out 1067 green housing projects from 35 major cities, accounting for 51.3% of all green housing projects. Among 35 cities, seven cities have more than 50 green housing projects, including Shenzhen (130), Xi'an (100), Shanghai (92), Tianjin (82), Wuhan (64), Beijing (51) and Nanjing (51), and nine cities have less than 10 green housing projects, including Xining (8), Yinchuan (8), Hohhot (7), Harbin (7), Shenyang (6), Taiyuan (6), Urumqi (6), Haikou (3) and Changchun (3).

We searched the transaction information in December 2018 in the Soufun database for the abovementioned projects. Soufun is a leading real estate data vendor, covering 336 cities and regions around the world, dedicated to serving the real estate industry. Because of our focus on resale transactions, some green housing projects were excluded for the following reasons: (1) the projects do not have transaction information in the second-hand housing market, such as green housing projects with only parcel information or new housing transaction information; (2) the projects cannot be matched with enough noncertified counterparts; (3) the projects searched in the second-hand housing market are fewer than 3 in a city, which is unfavorable research premium differences. The corresponding counterparts without CGBL were also searched from the Soufun database which are similar to the sample projects and within a radius of 1500 m of the sample projects. If a green housing project had many counterparts, we chose the projects with a close completion time.

Finally, we collected 720 housing projects, including 139 green housing projects and 581 non-green projects. There are 67 one-star CGBLs, 58 two-star CGBLs and 14 three-star CGBLs in 139 green housing projects, including 131 projects with a design certification and 8 projects with an operation certification. There are 581 counterparts with a non-green certification from 14 cities, 277 of which are considered one-star counterparts, 244 of which are considered two-star counterparts, and 63 of which are considered three-star counterparts. We divide 720 housing projects into 131 groups, and each group consists of at least one labeled project and two traditional counterparts.[1]

3.2 Variables

We collected the information on average transaction prices in December 2018 from the housing resale market of the Soufun database. The average price is 29148.38 yuan/m^2 for green certified projects and 26561.97 yuan/m^2 for non-green certified projects. Housing projects with CGBLs have higher resale prices than their counterparts from the comparison of average resale prices. We also collected the physical and location attributes of each project to serve as control variables according to the studies of Du & Huang (Du and Huang, 2018) and Zhang et al. (Zhang et al., 2017). The project's physical attributes include whether the project is green certified (Green) as well as the green space ratio (Green coverage), floor area ratio (FAR), building age (Age), number of apartments (Apartment), ratio of parking spaces to residents (Parking ratio), developer quality (Developers) and property management fees (Fees). The location attributes include distance to the city center (Distance), what kind of school district to which the community belongs (School), and the number of bus routes near the local community (Bus routes). However, the information on the parking ratio of several projects could not be found in the Soufun database. To avoid the influence of missing values, we use the stratified average value method to fill in the missing values. For instance, when the project without parking ratio information was built in 2005, we use the average parking ratio of the projects built between 2000 and 2009 in the same city to fill the vacancy. Table 2 shows the definition and description statistics of the variables.

3.3 Methods

To examine whether green housing offers the benefit of premium compensation at the resale stage, a hedonic regression model is established as follows:

$$\ln P = \alpha + \beta \text{Green} + X\lambda + \sum \text{City} + \sum \text{Group} + \varepsilon \qquad (1)$$

where P represents the average resale price for each project in December 2018, *Green* is a dummy variable (yes = 1, no = 0); X represents a series of control variables, including the project physical

TABLE 2. Definition and description statistics of the variables.

Variables	Definition	Green housing		Non-green housing	
		Mean	Std.dev.	Mean	Std.dev.
P	Housing price (yuan/m^2) in December 2018.	29148.38	15821.50	26561.97	15532.07
Distance	Distance to city center (km), which is the area with high concentration of commerce, entertainment, and frequent population flow. For example, we define the city center in Jinan is Quancheng Square.	11.74	5.67	11.03	5.22
School	3 = in municipal key school district, 2 = in district key school district, 1 = in ordinary school district, 0 = otherwise	0.94	0.47	0.96	0.41
Bus routes	Total number of bus routes	15.52	5.38	17.64	6.19
Green coverage	Ratio of green space to total land area in community (%)	36.37	3.92	36.61	2.45
FRA	Floor area ratio	2.98	0.57	2.75	0.54
Age	Building age (which is equal to 2018 minus the year of completion)	3.90	1.05	8.27	2.95
Apartment	Total number of apartments in community	1935.07	794.65	1727.30	358.55
Parking ratio	Ratio of parking space to total number of apartments	1.13	0.29	0.87	0.22
Developers	1 = top 10 real estate developers, 0 = otherwise	0.20	0.18	0.07	0.05
Fees	Property management fees (yuan/m^2/month)	2.42	0.61	1.77	0.62

and locational attributes; α is the constant; and ε represents error terms. A biased estimation can be led by the traditional hedonic regression model due to some omitted variables (Du and Huang, 2018; Zhang et al., 2017). Considering the regional characteristics of the housing market (Pan, 2019; Shi, 2017), we introduce urban virtual variables and group virtual variables to the traditional hedonic regression model. $\Sigma City$ represents the urban fixed effect. $\Sigma Group$ represents group fixed effect. The above model is estimated by the mixed ordinary least square method (OLS) and controls for the urban fixed effect and the group fixed effect at the same time. The urban fixed effect is measured by adding 14 urban virtual variables, and the group fixed effect is measured by adding 131 group virtual variables. If β is larger than zero and significant, green housing offers the benefit of premium compensation at the resale stage to compensate homebuyers for the increased expenses at the presale stage.

To discriminate the premium compensation differences of green housing projects with different star CGBLs and with different certifications, we further regress the log of housing price on the dummy variable of one-star, two-star and three-star CGBLs and the log of housing price on the dummy variable of design and operation certification. In this part, the empirical tests are carried out from two levels: full sample and grouped sample. Meanwhile, we compare the premium difference of green housing with different star CGBLs and with different certifications between the presale stage and the resale stage by comparing our results with the research results of Zhang et al. (2017).

To test the robustness of the empirical results, spatial models are used to estimate the price premium of green housing projects. Kuminoff (2010) found that spatial regression techniques substantially reduce bias from traditional hedonic regression techniques (Kuminoff et al., 2010). The spatial lag model (SLM) and spatial error model (SEM) are used to test the robustness. SLM controls spatial dependence resulting from the spillover effect from neighboring housing prices. SLM is represented as follows:

$$\ln P = \rho W \ln P + \beta \text{Green} + X\lambda + \varepsilon \tag{2}$$

where W is the $n \times n$ spatial weight matrix. $W\ln(P)$ is the spatial lag-dependent variable of the spatial weight matrix. The weighting element is defined as follows:

$$W_{ij} = \begin{cases} 1/d_{ij}, & i \neq j \\ 0, & i = j \end{cases} \tag{3}$$

SEM controls spatial dependence resulting from the influence of other unobservable factors and neighboring housing prices. SEM is represented as follows:

$$\ln P = \beta \text{Green} + X\lambda + \mu \tag{4}$$

$$\mu = \gamma W \mu + \varepsilon \tag{5}$$

where γ is the spatial autoregressive parameter.

Anselin (1996) put forward a judgment standard for model selection that if the LM-lag (Lagrange Multiplier-lag) is more significant than the LM-error (Lagrange Multiplier-error) and the RLM-lag (Robust Lagrange Multiplier-lag) is significant but the RLM-error (Robust

Lagrange Multiplier-error) is not significant, the SLM is appropriate; otherwise, the SEM is appropriate (Anselin et al., 1996).

4. RESULTS AND DISCUSSION

4.1 Premium compensation ability of green housing at the resale stage

First, we regress the log of housing price on the dummy variable of Green by adding different control variables, without including any control variables, only controlling for the project physical attributes, only controlling for the project location attributes, and controlling for the project physical and location attributes at the same time, to identify the premium compensation ability of green housing at the resale stage. Columns (1)-(4) in Table 2 represent the estimation results by using the OLS method. The coefficients of the dummy variable of Green are all statistically significant at a 1% confidence level, which means there is a price premium for green housing compared with non-green projects. Column (4) in Table 2 shows that the coefficient of the dummy variable of Green is 0.0583 under controlling for the project's physical and locational attributes at the same time, which indicates that the price per square meter of the housing with CGBL is 6.00% higher than their counterparts.[2] This is very important information to homebuyers, suggesting that green housing may maintain or even increase its value in future resale transactions. Although homebuyers increase their expenses to purchase newly built green housing, the premium is always there, and homebuyers are compensated for their increased expenses in the resale transaction. Although the premium at the resale stage is lower than at the presale stage by comparing with the research result of Zhang et al. (2016), it tells us that the government should adopt appropriate support policies to homebuyers to promote the development of green housing. Unfortunately, most of the policies are aimed at home developers, such as giving a monetary subsidy for a high star CGBL, fee and tax reductions, and referential loan policies.

4.2 THE PREMIUM COMPENSATION DIFFERENCES OF GREEN HOUSING

Then, we further compare the premium differences between green housing projects with different star CGBLs and between design certification and operation certification projects. Columns (1)–(7) in Table 3 represent the estimation results for the premium of green housing with one-star CGBL, two-star CGBL, three-star CGBL, design certification and operation certification, respectively, by using the OLS method. Among them, columns (1) and (5) show full sample estimation results, and columns (2)–(4) and (6)–(7) show grouped sample estimation results. The coefficients of the dummy variables in columns (1)–(7) are all statistically significant at a confidence level of at least 10%, which means that there is also a price premium for the resale of green housing. The results of columns (1)–(4) show that the premium of green housing with different star CGBLs is different whether it is estimated by using the full sample or grouped sample. The results show that there is a much higher premium for green housing with a high star CGBL, which is consistent with the study of Shewmake & Viscusi (Shewmake and Viscusi, 2015). According to the estimation results of the full sample, green housing with a three-star CGBL has a maximum premium of 7.87%, followed by a two-star CGBL with a premium of 6.25% and a one-star CGBL with a premium of 5.37%. The estimation results of the grouped sample also confirm this rule, that is, green housing with a three-star CGBL has a maximum premium of 8.83%, a two-star CGBL with a premium of 6.01%, and a one-star CGBL with

TABLE 2. Estimation results for OLS and spatial models.

Variables	(1)lnP	(2)lnP	(3)lnP	(4)lnP
Green	0.1172*** (0.0148)	0.0595*** (0.0145)	0.1149*** (0.0147)	0.0583*** (0.0144)
ln(Distance)			–0.1769*** (0.0645)	–0.2057*** (0.0585)
School			0.0081 (0.0107)	0.0152 (0.0097)
Bus routes			–0.0027*** (0.0010)	–0.0013 (0.0009)
Age		–00077*** (0.0016)		–0.0080*** (0.0016)
ln(Apartment)		0.0040 (0.0083)		0.0037 (0.0083)
Parking ratio		–0.0061 (0.0089)		–0.0041 (0.0088)
Green coverage		0.0033*** (0.0009)		0.0033*** (0.0009)
FAR		–0.0287*** (0.0066)		–0.0301*** (0.0066)
Developer		0.0562*** (0.0209)		0.0570*** (0.0206)
Fees		0.0414*** (0.0093)		0.0411*** (0.0092)
Urban fixed effect	Yes	Yes	Yes	Yes
Group fixed effect	Yes	Yes	Yes	Yes
Constant	9.2062*** (0.0895)	9.7776*** (0.2201)	9.1216*** (0.1058)	9.7731*** (0.2105)
R^2	0.9217	0.9229	0.9362	0.9376
N	720	720	720	720

Note: Robust standard errors in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01.

a premium of 4.56%. The results of columns (5)–(7) show that the premium between green housing with a design certification and an operation certification is also different; that is, green housing with an operation certification has a higher premium than those with a design certification. According to the estimation results of the full sample, green housing with an operation certification has a premium of 13.72% and a design certification has a premium of 5.50%. The estimation results of the grouped sample show that green housing with an operation certification

TABLE 3. Estimation results for OLS and spatial models.

Variables	(1)lnP	(2)lnP	(3)lnP	(4)lnP	(5)lnP	(6)lnP	(7)lnP
One Star	0.0523** (0.0201)	0.0446* (0.0229)					
Two Star	0.0606*** (0.0216)		0.0584*** (0.0209)				
Three Star	0.0758* (0.0416)			0.0855* (0.0474)			
Design					0.0535*** (0.0148)	0.0515*** (0.0151)	
Operation					0.1286** (0.0549)		0.1241** (0.0567)
ln(Distance)	−0.2055*** (0.0586)	−0.3029*** (0.1049)	−0.1721** (0.0731)	−0.0140 (0.2138)	−0.2107*** (0.0585)	−0.2244*** (0.0678)	−0.1551 (0.1125)
School	0.0152 (0.0097)	0.0175 (0.0137)	0.0073 (0.0159)	0.0181 (0.0398)	0.0147 (0.0097)	0.0150 (0.0101)	−0.0044 (0.0379)
Bus routes	−0.0013 (0.0009)	−0.0027* (0.0015)	−0.0002 (0.0014)	0.0013 (0.0035)	−0.0014 (0.0009)	−0.0015 (0.0010)	0.0021 (0.0034)
Age	−0.0080*** (0.0016)	−0.0080*** (0.0027)	−0.0077*** (0.0022)	−0.0093 (0.0065)	−0.0079*** (0.0016)	−0.0069*** (0.0017)	−0.0048 (0.0083)
ln(Apartment)	0.0038 (0.0083)	0.0032 (0.0130)	−0.0062 (0.0117)	0.0247 (0.0302)	0.0033 (0.0083)	0.0007 (0.0085)	0.0307 (0.0420)
Parking ratio	−0.0043 (0.0089)	−0.0120 (0.0131)	0.0009 (0.0119)	−0.0121 (0.0377)	−0.0045 (0.0088)	−0.0058 (0.0090)	0.0139 (0.0592)
Green coverage	0.0032*** (0.0009)	0.0035*** (0.0013)	0.0041*** (0.0015)	0.0012 (0.0027)	0.0033*** (0.0009)	0.0034*** (0.0009)	0.0018 (0.0047)
FAR	−0.0299*** (0.0066)	−0.0243** (0.0094)	−0.0427*** (0.0109)	−0.0220 (0.0257)	−0.0299*** (0.0066)	−0.0329*** (0.0068)	0.0248 (0.0326)
Developer	0.0578*** (0.0208)	0.0578** (0.0292)	0.0676* (0.0361)	0.0920 (0.0788)	0.0575*** (0.0206)	0.0586*** (0.0107)	0.0644 (0.0705)
Fees	0.0410*** (0.0092)	0.0479*** (0.0175)	0.0436*** (0.0142)	0.0311 (0.0199)	0.0424*** (0.0092)	0.0521*** (0.0107)	0.0253 (0.0192)
Urban fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Group fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	9.7734*** (0.2108)	10.4499*** (0.2591)	9.7105*** (0.2568)	9.6843*** (0.6479)	9.7909*** (0.2107)	9.8385*** (0.2371)	9.9771*** (0.4549)
R^2	0.9374	0.9337	0.9388	0.9378	0.9377	0.9353	0.9658
N	720	344	302	77	720	677	43

Note: Robust standard errors in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01.

has a premium of 13.21% and a design certification has a premium of 5.28%. Although there is a high premium for green housing projects with a three-star CGBL and an operation certification, these projects account for a very small proportion of the total projects at present, which is the main problem of green housing development in China. To achieve the high-quality development of green buildings, the 2019 Standard adds safety, health and suitability for aging residents to improve the performance of green buildings, for example, fall prevention measures, technical measures suitable for the old and the young, barrier-free facilities, indoor air quality improvement and comfortable indoor environments. To solve the problem of attaching important design elements and disregarding operations, the design certification has been cancelled in the 2019 Standard, which noted that the evaluation of green buildings should be carried out after the completion and acceptance of the construction project.

The results of Zhang et al. (2017) show that newly built green housing projects with one-star and two-star CGBLs have higher premiums than those with three-star CGBLs at the presale stage. Home developers can obtain higher economic returns when they develop green housing projects with one-star and two-star CGBLs, so most newly built green housing projects are one-star and two-star CGBLs. When compared with the research results of Zhang et al. (2017), we find that the premium of green housing with three-star CGBL is significantly higher at the resale stage (7.87%) than at the presale stage (4.34%, which is not significant in the study of Zhang et al., 2017), which means that it is enough to compensate for the increased expenses of homebuyers at the presale stage by improving the resale value of green homes. The premium of green housing with a two-star CGBL is significantly lower at the resale stage (6.25%) than at the presale stage (8.70%), which means that there is not enough of a resale premium to compensate for the increased expenses of homebuyers at the presale stage. The premium of green housing with one-star CGBL at the resale stage (5.37%) is slightly lower than that at the presale stage (5.78%). Therefore, green housing with one-star and two-star CGBLs increases the burden to homebuyers, which is not conducive to the development of green housing. How to reasonably share the benefits of green housing between presale and resale stages, that is, allocating the benefit associated with green housing between home developers and homebuyers, may be a problem that must be solved to promote further development of green housing.

4.3 Robustness check

To test the robustness of the empirical results, we choose other distance thresholds, such as 1200 m and 800 m, to check the robustness of the OLS. The results of the robustness check are displayed in Table 4. Column 1 and Column 2 are the results of distance thresholds of 1200 m and 800 m, respectively. The coefficients of the dummy variable of Green are all positive and statistically significant at a 1% confidence level. Meanwhile, we also adopt the spatial model to estimate the robustness of the empirical results. Moran's I is used to test whether the explained variable has spatial autocorrelation. We use a spatial weight matrix based on the threshold inverse distance to calculate the Moran's I of global spatial autocorrelation of the average resale transaction price. The result is 0.710 and significant at a 1% confidence level, which indicates that there is a positive spatial correlation among the average resale transaction prices. The results of diagnostic tests for spatial dependence show that the LM error is significant but the LM lag is not significant, so we choose SEM to test the robustness of the empirical results. The SEM results are shown in column (3) in Table 4, and the coefficient of green certification is also positive and highly significant. The results of columns (1)-(3) in Table 4 confirm the robustness of the green housing premium.

TABLE 4. Robustness check.

Variables	(1)ln(P)	(2)ln(P)	(3)ln(P)
Green	0.0643*** (0.0158)	0.0664*** (0.0185)	0.0675*** (0.0232)
ln(distance)	–0.2085** (0.0837)	–0.3769** (0.1588)	0.0162 (0.0320)
School	0.0137 (0.0121)	0.0065 (0.0164)	0.0050 (0.0147)
Bus routes	–0.0008 (0.0013)	–0.0023 (0.0022)	0.0064*** (0.0012)
Age	–0.0084*** (0.0020)	–0.0078*** (0.0027)	0.0106*** (0.0023)
ln(apartment)	0.0058 (0.0100)	0.0280 (0.0130)	0.0123 (0.0133)
Parking ratio	0.0000 (0.0107)	0.0186 (0.0157)	–00113 (0.0142)
Green coverage	0.0022** (0.0010)	0.0017 (0.0014)	0.0037*** (0.0014)
FAR	–0.0384** (0.0084)	–0.0561*** (0.0115)	–0.0277*** (0.0108)
Developer	0.0740*** (0.0237)	0.0757** (0.0294)	0.0449 (0.0335)
Fees	0.0337*** (0.0108)	0.0453*** (0.0152)	0.1587*** (0.0125)
Constant	9.8238*** (0.2833)	10.2864*** (0.5054)	9.2812*** (0.1514)
γ			2.0833*** (0.0185)
N	555	365	720

Note: Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5. CONCLUSION

China has now gone into a new stage to improve the living environment and quality of life. Green housing can effectively improve occupants' living environment and meet their needs for a better life. However, due to the price premium of green housing at the presale stage (6.89%, according to the study of Zhang et al., 2017), homebuyers need to increase their expenses when they purchase newly built green housing, which causes weak demand for green housing. If a price premium exists at the resale stage and is enough to compensate for the increasing expenses at the presale stage, this information will certainly boost green housing demand and enhance developers' confidence in developing green housing. Even if it is not enough to offset the price premium of green housing at the presale stage, it can provide some reference for the government to design policies to support the development of green housing. Therefore, a hedonic regression model is established to study the premium compensation of green housing at the resale stage.

The study investigates 139 projects with a CGBL and 581 of their non-green counterparts in some major cities, which are the leading cities in the development of green buildings. The results show that green housing generates a positive economic return for homebuyers at the resale stage, but the premium of green housing with different star CGBLs at the resale stage is not always enough to compensate homebuyers for their increased expenses at the presale stage. The results show that the transaction prices of green housing with CGBL are 6% higher than their counterparts at the resale stage. Moreover, green housing projects with three-star CGBL have a higher premium at the resale stage than at the presale stage, which means that the premium of green housing projects with three-star CGBL can compensate homebuyers for their increased expenses at the presale stage. However, the green housing projects with one-star CGBL and two-star CGBL cannot compensate homebuyers for their increased expenses at the presale stage. Overall, the premium of both design and operation certifications at the resale stage is less than at the presale stage. These all indicate that home developers obtain a higher premium while increasing the burden to homebuyers, which will lead to weak demand for green housing and is not conducive to its development. The government should issue some support policies to homebuyers (Portnov et al., 2018), such as giving a monetary subsidy, providing preferential loans, and reducing taxes and fees when they purchase newly built green housing, to balance the benefits of green housing between home developers and homebuyers.

The results show that the proportion of green projects with three-star CGBL accounts for a lower percentage of the total project, which illustrates why green housing is at a low level of development in China. Moreover, most homebuyers know very little or nothing about green buildings (Zhang et al., 2018), let alone that they may obtain premium compensation at the resale stage. Therefore, the higher housing prices they face at the presale stage lead to insufficient demand for green housing. The promulgation of the 2019 Standard indicates that green housing will enter a stage of high-quality development in China, and what we need to do next should be actively propagating the knowledge of green building, allowing the public to understand green buildings deeply to form a market environment with homebuyers as the main body. For example, the government could establish an official information exchange system about green buildings that provides homebuyers with access to accurate information (Zhang et al., 2016). Due to the magnitude of the data, two aspects need to be put on the agenda for future research: first, whether the extent of the premium changes over time. The other aspect is whether the degree of premium is related to the green building development level of the area (city).

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REFERENCES

Ahn, Y.H., Pearce, A.R., Wang, Y.W.G., 2013, Drivers and barriers of sustainable design and construction: The perception of green building experience. *International Journal of Sustainable Building Technology and Urban Development* 4, 35–45.

Anselin, L., Bera A, K., Florax, R., Simple diagnostic tests for spatial dependence. *Regional Science & Urban Economics* 26, 77–104.

Chegut, A., Eichholtz, P., Kok, N., 2019, The price of innovation: An analysis of the marginal cost of green buildings. *J ENVIRON ECON MANAG* 98, 102248.

Cheng, Y., Huang, J., 2017, Development and Comparison of Green Building Policy. *Construction Technology* 12, 110–112.

Darko, A., Chan, A.P.C., 2017, Review of Barriers to Green Building Adoption. *SUSTAIN DEV* 25, 167–179.

Deng, Y., Wu, J., 2014, Economic returns to residential green building investment: The developers' perspective. *REG SCI URBAN ECON* 47, 35–44.

Devine, A., McCollum, M., 2019, Understanding social system drivers of green building innovation adoption in emerging market countries: The role of foreign direct investment. *CITIES* 92, 303–317.

Du, J., Yang, Y., Li, D., Zuo, J., 2017, Do investment and improvement demand outweigh basic consumption demand in housing market? Evidence from small cities in Jiangsu, China. *HABITAT INT* 66, 24–31.

Du, X., Huang, Z., 2018, Spatial and temporal effects of urban wetlands on housing prices: Evidence from Hangzhou, China. *LAND USE POLICY* 73, 290–298.

Fuerst, F., McAllister, P., 2011, Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values. *REAL ESTATE ECON* 39, 45–69.

Geng, Y., Ji, W., Wang, Z., Lin, B., Zhu, Y., 2019, A review of operating performance in green buildings: Energy use, indoor environmental quality and occupant satisfaction. *ENERG BUILDINGS* 183, 500–514.

Heinzle, S.L., Augustin, B.Y.Y., Melissa, L.Y.X., 2013, The Influence of Green Building Certification Schemes on Real Estate Investor Behaviour: Evidence from Singapore. *URBAN STUD* 50, 1970–1987.

Holmgren, M., Kabanshi, A., Sörqvist, P., 2017, Occupant perception of "green" buildings: Distinguishing physical and psychological factors. *BUILD ENVIRON* 114, 140–147.

Hopkins, E.A., 2015, LEED Certification of Campus Buildings: A Cost-Benefit Approach. *Journal of Sustainable Real Estate* 7, 99–111.

Hu, H., Geertman, S., Hooimeijer, P., 2014, The willingness to pay for green apartments: The case of Nanjing, China. *URBAN STUD* 51, 3459–3478.

Huang, N., Bai, L., Wang, H., Du, Q., Shao, L., Li, J., 2018, Social Network Analysis of Factors Influencing Green Building Development in China. *INT J ENV RES PUB HE* 15, 2684.

Hwang, B.G., Zhu, L., Wang, Y., Cheong, X., 2017, Green Building Construction Projects in Singapore: Cost Premiums and Cost Performance. *PROJ MANAG J* 48, 67–79.

Issa, M.H., Rankin, J.H., Christian, A.J., 2010, Canadian practitioners' perception of research work investigating the cost premiums, long-term costs and health and productivity benefits of green buildings. *BUILD ENVIRON* 45, 1698–1711.

Jiang, H., Payne, S., 2019, Green housing transition in the Chinese housing market: A behavioural analysis of real estate enterprises. *J CLEAN PROD* 241, 118381.

Jiang, Y., Zhao, D., Sanderford, A., Du, J., 2018, Effects of Bank Lending on Urban Housing Prices for Sustainable Development: A Panel Analysis of Chinese Cities. *SUSTAINABILITY-BASEL* 10, 642.

Juan, Y., Hsu, Y., Xie, X., 2017, Identifying customer behavioral factors and price premiums of green building purchasing. *IND MARKET MANAG* 64, 36–43.

Kahn, M.E., Kok, N., 2014, The capitalization of green labels in the California housing market. *REG SCI URBAN ECON* 47, 25–34.

Kats, G., 2003. The Costs and Financial Benefits of Green Buildings. A Report to Californias Sustainable Building Task Force.

Kuminoff, N.V., Parmeter, C.F., Pope, J.C., 2010, Which hedonic models can we trust to recover the marginal willingness to pay for environmental amenities? *J ENVIRON ECON MANAG* 60, 145–160.

Li, Y., Yang, L., He, B., Zhao, D., 2014, Green building in China: Needs great promotion. *SUSTAIN CITIES SOC* 11, 1–6.

Lin, B., Liu, Y., Wang, Z., Pei, Z., Davies, M., 2016, Measured energy use and indoor environment quality in green office buildings in China. *ENERG BUILDINGS* 129, 9–18.
Liu, Y., Hong, Z., Zhu, J., Yan, J., Qi, J., Liu, P., 2018, Promoting green residential buildings: Residents' environmental attitude, subjective knowledge, and social trust matter. *ENERG POLICY* 112, 152–161.
Mapp, C., Nobe, M.C., Dunbar, B., 2011, The Cost of LEED—An Analysis of the Construction Costs of LEED and Non-LEED Banks. *The Journal of Sustainable Real Estate* 3, 254–273.
McCoy, A.P., Zhao, D., Ladipo, T., Agee, P., Mo, Y., 2018, Comparison of green home energy performance between simulation and observation. *JOURNAL OF GREEN BUILDING* 13, 70–88.
Mohurd, 2019, Green Architecture: Beautiful China. http://www.mohurd.gov.cn/zxydt/201908/t20190826_241561.html
Mollaoglu, S., Chergia, C., Ergen, E., Syal, M., 2016, Diffusion of green building guidelines as innovation in developing countries. *Construction Innovation* 16, 11–29.
Ofek, S., Akron, S., Portnov, B.A., 2018, Stimulating green construction by influencing the decision-making of main players. *SUSTAIN CITIES SOC* 40, 165–173.
Pan, W., 2019, Detecting bubbles in China ' s regional housing markets. *EMPIR ECON* 56, 1413–1432.
Pei, Z., Lin, B., Liu, Y., Zhu, Y., 2015, Comparative study on the indoor environment quality of green office buildings in China with a long-term field measurement and investigation. *BUILD ENVIRON* 84, 80–88.
Portnov, B.A., Trop, T., Svechkina, A., Ofek, S., Akron, S., Ghermandi, A., 2018, Factors affecting homebuyers' willingness to pay green building price premium: Evidence from a nationwide survey in Israel. *BUILD ENVIRON* 137, 280–291.
Qiu, B., Li, D., Wu, Z., 2017, Study on the Character of Chinese Green Building Spatial Evolution. *Research on Urban Development* 24, 1–10.
Schnieders, J., Hermelink, A., 2006, CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building. *ENERG POLICY* 34, 151–171.
Shewmake, S., Viscusi, W.K., 2015, Producer and Consumer Responses to Green Housing Labels. *ECON INQ* 53, 681–699.
Shi, S., 2017, Speculative bubbles or market fundamentals? An investigation of US regional housing markets. *ECON MODEL* 66, 101–111.
Tatari, O., Kucukvar, M., 2011, Cost premium prediction of certified green buildings: A neural network approach. *BUILD ENVIRON* 46, 1081–1086.
Teng, J., Zhang, W., Wu, X., Zhang, L., 2016, Overcoming the barriers for the development of green building certification in China. *J HOUS BUILT ENVIRON* 31, 69–92.
Wei, W., Olivier, R., Corinne, M., 2015, Indoor air quality requirements in green building certifications. *BUILD ENVIRON* 92, 10–19.
Ye, L., Cheng, Z., Wang, Q., Lin, W., Ren, F., 2013, Overview on green building label in China. *RENEW ENERG* 53, 220–229.
Zalejska-Jonsson, A., Lind, H., Hintze, S., 2012, Low-energy versus conventional residential buildings: cost and profit. *Journal of European Real Estate Research* 5, 211–228.
Zhang, L., Liu, H., Wu, J., 2017, The price premium for green-labelled housing: Evidence from China. *URBAN STUD* 54, 3524–3541.
Zhang, L., Sun, C., Liu, H., Zheng, S., 2016, The role of public information in increasing homebuyers' willingness-to-pay for green housing: Evidence from Beijing. *ECOL ECON* 129, 40–49.
Zhang, L., Wu, J., Liu, H., 2018, Turning green into gold: A review on the economics of green buildings. *J CLEAN PROD* 172, 2234–2245.
Zhang, L., Wu, J., Liu, H., Zhang, X., 2018, The Value of Going Green in the Hotel Industry: Evidence from Beijing. *REAL ESTATE ECON* 48, 174–199.
Zhang, X., A., P., L., S., 2011, Green property development practice in China: Costs and barriers. *BUILD ENVIRON* 46, 53–60.
Zhang, X., Shen, L., Wu, Y., 2011, Green strategy for gaining competitive advantage in housing development: a China study. *J CLEAN PROD* 19, 157–167.
Zhang, Y., Kang, J., Jin, H., 2018, A Review of Green Building Development in China from the Perspective of Energy Saving. *ENERGIES* 11, 334.

Zhao, D., McCoy, A.P., Du, J., Agee, P., Lu, Y., 2017, Interaction effects of building technology and resident behavior on energy consumption in residential buildings. *ENERG BUILDINGS* 134, 223–233.
Zhao, D., Miotto, A.B., Syal, M., Chen, J., 2019, Framework for Benchmarking green building movement: A case of Brazil. *SUSTAIN CITIES SOC* 48, 101545.
Zou, Y., Zhao, W., Zhong, R., 2017, The spatial distribution of green buildings in China: Regional imbalance, economic fundamentals, and policy incentives. *APPL GEOGR* 88, 38–47.

NOTES

1. The number of groups is smaller than the number of green-labeled neighborhoods because the distance between some labeled communities is less than 1500 m. Thus, they are divided into the same group.
2. The price premium ratio is equal to [$\exp^{(0.0583)} - 1 \approx 0.0600$]