Energy Policy 121 (2018) 225–235

Contents lists available at ScienceDirect

Energy Policy

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

Policies to enhance the drivers of green housing development in China[☆]

Li Zhang, Jing Wu[*], Hongyu Liu

Hang Lung Center for Real Estate, Department of Construction Management, Tsinghua University, China

ARTICLE INFO

Keywords:
Chinese Green Building Label
Residential building
Drivers
Economic returns
Policy instruments
Peer effects

ABSTRACT

China's housing sector has a major impact on global energy consumption due to the rapid urbanization. Although the Chinese government launched a wide variety of policies to encourage green building practices, only 1592 housing projects had been green-certified by the end of 2015, representing a small percentage in China's booming housing market and with very uneven distribution across cities. Based on a panel dataset of all the cities at the prefecture level or above in China for the period from 2008 to 2015, this paper employs Tobit model and Cox proportional hazard model to investigate the drivers of green housing development. Besides the factors associated with economic returns to green investment, the empirical results suggest that some policy instruments have effectively stimulated green practices in the private housing sector, such as land-related policies, priority in enterprise qualification inspection and upgrade, and demand-side subsidies. This paper also highlights the spillover effects of the government's green practices in public housing, implying that governments can also influence the building sector as leading actors. These findings could help governments create more effective and efficient policies to boost green housing development.

1. Introduction

The construction, operation and demolition of buildings make a major contribution to global energy consumption and environmental pollution, resulting in increasing attention to going "green" in the building sector (Zuo and Zhao, 2014). Various standards for green buildings have proliferated around the world, which share three common pillars: efficient use of energy and other resources, improvement of indoor environmental quality, and minimization of negative impacts on the environment (Sedlacek and Maier, 2012; Zhang et al., 2018). Governments around the world have also adopted a range of policies to encourage such green building practices (Shi et al., 2014; Simcoe and Toffel, 2014; Kuo et al., 2016).

Green building development in China has profound global implications, due to the massive construction boom in the rapid urbanization (Cai et al., 2009; Zhang et al., 2017a). Green practices in the residential sector are especially important, as residential buildings now account for around 70% of building starts in China.[1] However, promoting green practices in residential buildings faces greater challenges than for implementation in commercial buildings. For commercial buildings (e.g., office and retail buildings), developers typically hold and operate buildings by themselves, and thus evaluate costs and benefits from the building life-cycle perspective. In contrast, housing units in China are always sold to households immediately after completion, or may even be presold before completion, making homebuyers' payment the only opportunity for developers to reap rewards from green investments (Zhang et al., 2017a). As most residents lack the skills to gather information and conduct life-cycle calculations, future benefits of green housing may not be fully capitalized in transaction prices (Allcott and Taubinsky, 2015). Such risks of benefit-cost mismatch significantly hindered housing developers from building green (Deng and Wu, 2014). This potential market failure makes government policy especially important in Chinese green housing sector. It is in this context that we investigate what policies can enhance the drivers of green housing development in urban China.

Although dozens of studies analyzed the drivers of green building development based on questionnaire surveys, case studies and interviews (Darko et al., 2017), only a few econometric studies had been conducted until very recently, and most of them concentrated on commercial properties in developed countries (Kahn and Vaughn, 2009; Kok et al., 2011; Cidell and Cope, 2014; Dippold et al., 2014; Fuerst et al., 2014). Besides the factors that have been well documented by

☆ The authors greatly acknowledge the valuable comments from the editor and the anonymous referees, Cong Sun and the participants at the 2015 Asia-Pacific Real Estate Research Symposium and the 2016 Global Chinese Real Estate Congress. We appreciate the data support from the Ministry of Housing and Urban-Rural Development of China. We thank the National Natural Science Foundation of China (Project nos. 71673156, 71373006 and 91546113), Peking University-Lincoln Institute Center for Urban Development and Land Policy Dissertation Scholarship, Tsinghua University Initiative Scientific Research Program, Urban China Initiative, and China Scholarship Council for financial support.

* Correspondence to: Tsinghua University, Room 3-407 C, West Wing, Main Building, Beijing 100084, China.
E-mail address: ireswujing@tsinghua.edu.cn (J. Wu).

[1] Source: National Bureau of Statistics of China (http://data.stats.gov.cn/).

https://doi.org/10.1016/j.enpol.2018.06.029
Received 5 April 2016; Received in revised form 14 May 2018; Accepted 20 June 2018
Available online 30 June 2018

these studies (e.g., climate conditions, energy prices, economic status, environmental consciousness, real estate market conditions), this paper further examines the effectiveness of various policy instruments. This paper provides the first thorough empirical analysis on the drivers of green housing development by applying appropriate econometric techniques to analyze city-level panel data from China. We not only provide a comprehensive survey of various categories of policy instruments adopted by central and local governments in China, but also empirically investigate, compare, and discuss their effectiveness in stimulating the appearance and diffusion of green housing. This study also sheds light on the spillover effects of the government's own green practices in public housing.

The remainder of this paper is organized as follows. Section 2 reviews the related literature, and then an overview of green building development in China is provided in Section 3. Section 4 introduces the methodology and data, followed by a discussion of empirical results in Section 5. Section 6 concludes the paper.

2. Literature review

The past decade has witnessed quantities of studies examining the drivers of green building development (Darko et al., 2017). By surveying designers in Hong Kong and Singapore, Chan et al. (2009) found that economic force and government intervention were two strong forces to encourage green building development. Qi et al. (2010)'s survey on construction contractors identified managerial concern, government regulations and business size as the most important drivers for green practices. Berry et al. (2013)'s case study highlighted the exemplary leadership and spillover effects of niche events. While these survey and case studies provided valuable micro insights into corporates' green strategy, some recent studies began employing econometric methods to investigate the drivers of green building development at the national or regional level (Kahn and Vaughn, 2009; Kok et al., 2011; Cidell and Cope, 2014; Dippold et al., 2014; Fuerst et al., 2014; Zou et al., 2017). As summarized in Table 1, the major explanatory variables adopted by these studies include climate conditions, energy prices, economic status, environmental consciousness, real estate market conditions, policies, existing green buildings, market size, employment conditions, and LEED accredited professionals. These driving factors can be classified as *market drivers* and *policy drivers*, which are analyzed as follows by synthesizing the relevant literature of a wider range.

Market drivers are the focus of the existing studies, including economic returns and herding effects.

First, building owners and developers will be encouraged to build green if the economic returns are large enough to offset the incremental costs (Fuerst and McAllister, 2011; Eichholtz et al., 2013; Hyland et al., 2013; Zhang et al., 2017a). As green incremental costs are always unavailable and actually vary little among cities, the quantitative analyses have not taken them into analysis (Kok et al., 2011; Zhang et al., 2017a). Thus, economic returns are mainly determined by the base economic returns of developing general buildings and the green price premium (Jaffe and Stavins, 1994). The greater demand of the general real estate market will ease the absorption of green incremental costs and increase the potential gain of green housing investments (Oster and Quigley, 1977). The studies of office building market usually employ average rent and vacancy rate to indicate the market conditions, as presented in Table 1. The green premium relies on four main benefits of green buildings: (i) cost savings through reduced energy and other resource consumption; (ii) improved comfort, health and productivity; (iii) enhanced corporate reputation; (iv) environmental consciousness (Zhang et al., 2018). Cost saving potentials are usually measured by cooling and heating degree days and electricity prices (Kok et al., 2011; Dippold et al., 2014). Green buildings, which provide more comfortable built environment, are recognized as "luxury goods" that are more likely to be purchased by affluent consumers (Hu et al., 2014; Fuerst

Table 1
Variables included in the existing studies.

Author (Year):	Kahn and Vaughn (2009)	Kok et al. (2011)	Cidell and Cope (2014)	Dippold et al. (2014)	Fuerst et al. (2014)	Zou et al. (2017)
Country:	US	US	US	US	US	China
Building Type:	All buildings	Office buildings	All buildings	Office buildings	Office buildings	All buildings
Dependent Variable:	Number of green buildings	Annual change in the proportion of green office space	Number of green buildings	Whether the building is green-certified	Proportion of green office space	Number of green buildings
Independent Variables:						
(1) *Climate conditions*		Cooling/heating degree days		Cooling/heating degree days	Climate zones	
(2) *Energy prices*		Electricity price		Electricity price	Electricity price	
(3) *Economic status*	Income	Income		Income	GDP per capita	GDP
(4) *Environmental consciousness*	Political preference; Voting on environmental initiatives		Political preference	Education level; Political preference	Education level; Political affiliation of mayor	
(5) *Real estate market conditions*		Vacancy rate; Average rent		Vacancy rate; Average rent	Vacancy rate	Real estate price
(6) *Policies*		Number of policies	Climate Protection Agreement; Number of nearby cities with green building policies	Number of incentive policies	City-level/ state-level mandatory/ incentive policies	Subsidy policy; Local green building standard; Green building committee
(7) *Existing green buildings*				Existing share of green office buildings	Existing share of green office buildings	
(8) *Market size*	Population count		Population density	Population density; Total number of office buildings	Population count; Total floor space of office buildings	
(9) *Others*	Population age and race	Employment conditions; Office space per worker; LEED accredited professionals	Employment conditions; Population age; LEED accredited professionals	Employment conditions; Lease type; CO_2 emissions; Number of patents	Employment conditions; CO_2 emissions; LEED accredited professionals	Location; Energy efficiency

et al., 2014), so the income level is also an important factor for green price premium. Environmental consciousness is always indicated by political preference and education level. It is believed that compared with Republicans, Democrats are on average more likely to accept change and show greater interest on environmental topics (Kahn and Vaughn, 2009; Dippold et al., 2014). The education level is hypothesized to positively affect environmental concern, because highly educated individuals are more aware of the risks and long-term implications of environmental pollution (Dippold et al., 2014; De Silva and Pownall, 2014).

Second, herding effects suggest that developers tend to imitate each other to build green out of a fear of being at a competitive disadvantage (DeCoster and Strange, 1993; Kaza et al., 2013; Fuerst et al., 2014). A greater number of existing green buildings would also lower the incremental costs due to learning-curve effects and economies of scale (Jaffe and Stavins, 1994).

Policy drivers include policy instruments (mandates and incentives) and spillover effects. Fuerst et al. (2014) suggested that compulsory requirements for LEED certification had positive effects in the US commercial building sector. Zou et al. (2017) found that fiscal subsidies could stimulate green building development in China. Furthermore, governments can also influence the building sector as investors or users of buildings (Circo, 2007; Matisoff et al., 2016). As a recent example, Simcoe and Toffel (2014) found that government procurement rules presented significant spillover effects and stimulated subsequent adoption of LEED standards in the private sector.

Several limitations still exist in the existing literature. First, none of these empirical studies investigated the drivers for green practices in the residential sector, which may differ from those in the commercial sector as discussed earlier. Some studies examined the price premium enjoyed by green housing (Deng and Wu, 2014; Kahn and Kok, 2014; Koirala et al., 2014; Zhang et al., 2017a), but did not directly test whether such price premium or associated factors could boost the diffusion of green housing. Second, most of the existing studies focused on developed countries, yet the pattern in developing countries may be different due to economic and political differences (Zhou, 2015; Zhang et al., 2017b). Zou et al. (2017) attempted to investigate the determinants of green building development in China, but the province-based cross-sectional analysis with 30 observations was insufficient to offer statistically robust conclusions. Third, there is a dearth of thorough analysis on the effectiveness of different policies in stimulating green practices. Shi et al. (2014) evaluated green building policies in China based on expert grading, but did not examine the effects on the actual development of green buildings.

3. Background

The Ministry of Housing and Urban-Rural Development (MOHURD) of China issued *Evaluation Standards for Green Buildings* in 2006. Based on the standards, a nationwide voluntary program, the “Chinese Green Building Label” (CGBL), was launched in 2008. The standards provide criteria for the CGBL ratings for residential buildings and commercial buildings.[2] These criteria cover six categories, namely, land saving and outdoor environment, energy saving, water saving, material saving, indoor environmental quality, and operational management. As exhibited in Table 2, to receive CGBL certification, a building must meet all of the compulsory items first, and then its rating level is determined by the numbers of optional and optimal items met. The CGBL is a two-stage certification system - a building's developer or owner can apply for design certification based on the inspection of construction drawings, and/or operation certification after being in operation for at least one year.[3] The green buildings discussed hereafter in this paper are defined as CGBL-certified buildings, because this domestic certification better fits the green building practices in China than foreign certifications, such as LEED (Zhou, 2015; Zhang et al., 2017a).[4]

Based on the information released by MOHURD,[5] we calculated the number of buildings receiving CGBL certification during 2008–2015. Table 3 shows that the growth of green buildings has accelerated significantly in recent years, but even in 2015 the market penetration level is still low: the 1091 green buildings only constituted 12% of the building starts in that year.[6] The *2014–2020 National Plan on New Urbanization* issued by the State Council has set a goal that by 2020, 50% of new buildings must be green, but the current level is still far below the target. Moreover, Table 3 reveals that promoting green practices in the residential sector faces greater challenges than are found in the commercial sector. Among those green housing, the proportions of top-rated and operation-certified housing were only 14.9% and 4.5%, respectively, which were much lower than the proportions in the commercial sector.

We further aggregated the number of green housing projects by cities at the prefecture level or above.[7] The geographic distribution of green housing is illustrated in Fig. 1, implying a substantial spatial imbalance of green housing development. We further plotted the Lorenz curves of green housing by city or population in Fig. 2 to reveal the inequality level in green housing development. In recent years, the inequality has been alleviated but is still noticeable. As of 2015, 20% of the cities possessed 80% of the green housing, and 30% of the population possessed 70% of the green housing.

The low penetration and uneven distribution of green housing demonstrate the importance of investigating what policies can drive the green housing market forward. This is the focus of the following empirical analysis.

4. Method and data

There are three steps in this empirical study - policy review, data collection, and regression analysis, as illustrated in Fig. 3, and we will explicate them in this section.

4.1. Policy review

In order to motivate developers to commit to green building standards, an incentive scheme for CGBL was introduced by the central government in 2012, stating that developers of two-star green buildings would receive a subsidy of 45 yuan/m^2 of floor area, and the corresponding subsidy for three-star green buildings would be 80 yuan/m^2. On January 1, 2013, the State Council issued the *Green Building Action Plan*, requiring three kinds of buildings to be green, namely, government-funded public buildings, affordable housing in provincial capitals, and commercial buildings of more than 20,000 m^2 in size. Thereafter, provincial governments launched local incentive policies based on their financial resources (Zhou, 2015).

We carried out a comprehensive review on the provincial policies by searching for the keyword “green building (*lv se jian zhu*)” on www.pkulaw.cn, a leading search engine for legislation and regulations in

[2] Residential buildings include private housing, as well as public housing financed by local governments (e.g., affordable housing) and some other types of institutional residential buildings (e.g., university dormitories). Commercial buildings include both private commercial buildings (e.g., offices, hotels, retail properties,) and government-funded public buildings (e.g., schools, hospitals, museums).

[3] See Ye et al. (2013) for more details about the application and evaluation procedures of CGBL.

[4] The overwhelming majority of LEED-certified buildings are high-end commercial buildings hosting foreign or upper-class clients (Zhou, 2015).

[5] Source: MOHURD (http://ginfo.mohurd.gov.cn).

[6] The floor area of CGBL-certified buildings is available at http://www.cngb.org.cn/, and the floor area of building starts is available at http://data.stats.gov.cn/.

[7] For the period 2008–2015, there are 287 cities at the prefecture level or above according to the *China City Statistical Yearbook*. In the following analysis, 45 institutional residential buildings (e.g. university dormitories) are excluded.

Table 2
Standards in evaluating CGBL.
Source: Green Building Evaluation Standards (GB/T 50378-2006).

	Level	Part 1: Compulsory Items	Part 2: Optional Items						Part 3: Optimal Items
			Land Saving & Outdoor Environment	Energy Saving & Energy Utilization Efficiency	Water Saving & Water Utilization Efficiency	Material Saving & Material Utilization Efficiency	Indoor Environmental Quality	Operational Management	
Commercial Buildings	One-Star	26/26	3/6	4/10	3/6	5/8	3/6	4/7	0/14
	Two-Star	26/26	4/6	6/10	4/6	6/8	4/6	5/7	6/14
	Three-Star	26/26	5/6	8/10	5/6	7/8	5/6	6/7	10/14
Residential Buildings	One-Star	27/27	4/8	2/6	3/6	3/7	2/6	4/7	0/9
	Two-Star	27/27	5/8	3/6	4/6	4/7	3/6	5/7	3/9
	Three-Star	27/27	6/8	4/6	5/6	5/7	4/6	6/7	5/9

Note: “a/b” represents “the number of items required / the number of all items”.

Table 3
Number of green buildings in China.
Source: MOHURD (http://ginfo.mohurd.gov.cn)

	2008	2009	2010	2011	2012	2013	2014	2015	Total
1. Total	10	20	82	241	386	509	916	1091	3255
2. Usage									
-Commercial Buildings	6	16	37	100	188	222	468	626	1663
-Residential Buildings	4	4	45	141	198	287	448	465	1592
-Private Housing	4	4	41	119	155	231	370	379	1303
-Public Housing	0	0	3	20	37	49	67	68	244
-Other Residential Buildings	0	0	1	2	6	7	11	18	45
3. Rating Level									
-Commercial Buildings									
-One-Star	1	3	4	28	67	86	191	258	638
-Two-Star	2	4	19	37	60	71	156	220	569
-Three-Star	3	9	14	35	61	65	121	148	456
-Residential Buildings									
-One-Star	3	1	10	48	74	93	190	221	640
-Two-Star	0	2	25	50	93	161	185	199	715
-Three-Star	1	1	10	43	31	33	73	45	237
4. Rating Period									
-Commercial Buildings									
-Design	6	14	31	93	167	194	434	608	1547
-Operation	0	2	6	7	21	28	34	18	116
-Residential Buildings									
-Design	4	4	43	135	194	265	431	444	1520
-Operation	0	0	2	6	4	22	17	21	72

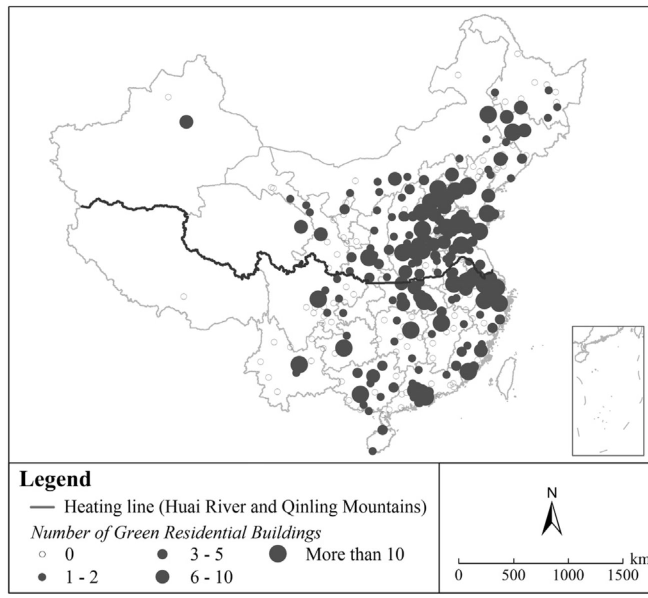

Fig. 1. Distribution of green residential buildings.
Source: MOHURD (http://ginfo.mohurd.gov.cn)

China. 626 local laws and regulations were initially found.[8] Then we manually scanned these documents and identified 84 provincial laws and regulations that introduced incentive policies for promoting green buildings. To avoid missing relevant policies, we compared our list with two existing policy reviews (Ma et al., 2014; Xu, 2014), and found another 18 laws and regulations. These processes yielded a total of 102 provincial laws and regulations.

Following Ma et al. (2014)’s framework of incentive policies for green buildings, we grouped the provincial policies as presented in Table 4. Supply-side policies aim to encourage developers to adopt green building standards, including four categories: land-related policies, direct or indirect subsidies, preferential policies for projects, and preferential policies for enterprises (Zhang et al., 2011; Shi et al., 2014; Zhou, 2015; Darko et al., 2017; Zou et al., 2017). Particularly, “land supply” indicates that the government prescribes the proportion of green buildings at the stage of land-use right sale,[9] or provides additional points in the bidding evaluation for developers promising to adopt green practices; “additional floor area” indicates additional awards (0.5–3%) of the permitted floor area for green building projects; “monetary subsidy” indicates subsidies for developers based on the area of green buildings; “urban infrastructure facility fee reduction” indicates reduction (20–100%) of urban infrastructure facility fees which developers should pay; “preferential loan policy” indicates lower interest rate or higher loan amount for developers of green buildings; “tax reduction” indicates tax rebates for developers of green buildings; “expedited approval process” indicates expedited approval process for green buildings in construction and presale permits; “priority in building awards” indicates priority for green buildings in applying for building quality awards; “priority in enterprise qualification inspection and upgrade” indicates that developers of green buildings can be exempt from or gain additional points in inspection and upgrade of enterprise qualification. Demand-side policies are relatively limited and focus on providing direct or indirect subsidies for buyers, including

[8] The search was conducted on March 9, 2017.

[9] All land in urban China is state-owned. The municipal governments, as representatives of the state, sell land-use rights to buyers for a fixed period through auction, tender, or negotiation (Ding, 2003).

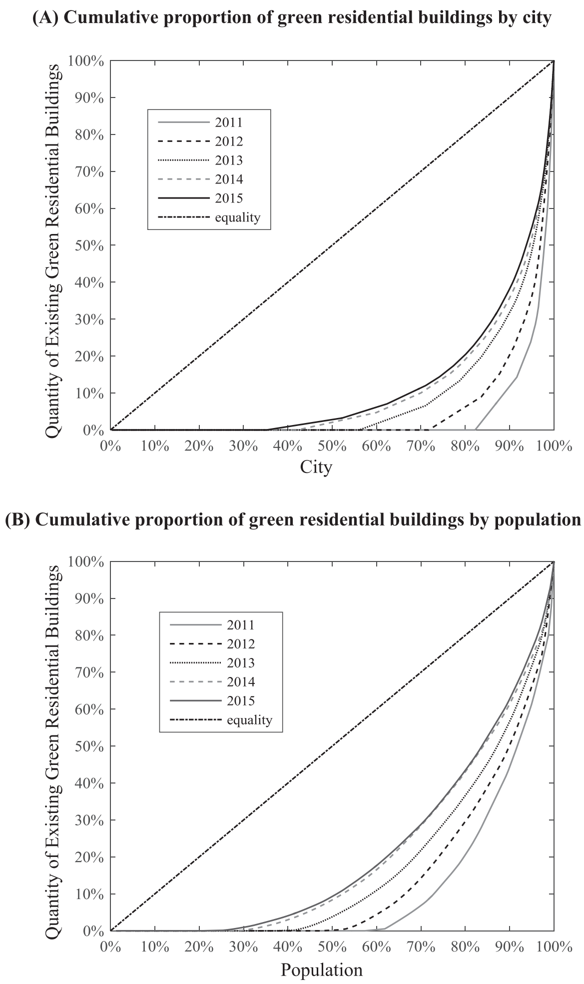

Fig. 2. Lorenz curve of green residential buildings.

monetary subsidy, lower interest rate or higher loan amount, and tax rebates (Shi et al., 2014).

We distinguish between policies with and without clear implementation rules using the solid round (●) and the hollow circle (○), respectively. Taking the policies associated with land supply as an example, Anhui takes the proportion of green buildings in land use planning as a prerequisite for bidders of land-use rights (marked as ●), while Beijing only provides some additional points (not clearly defined) in the bidding evaluation for developers promising to commit to two/three-star requirements (marked as ○). Similarly, in terms of supply-side monetary subsidy, Shandong subsidizes developers of one-, two-, and three-star rated buildings with 15, 30, and 50 RMB/m^2 respectively (marked as ●), while Fujian only generally states that local governments will provide green building developers with some subsidies according to local conditions (marked as ○). It is evident from Table 4 that the most common policies for developers include monetary subsidy, land supply, additional floor area and tax reduction, and the most common policy for buyers is preferential loan policy. The effectiveness of these policies will be compared later in the empirical analysis.

4.2. *Variables and data*

As public housing in provincial capitals are mandated to be green, we focus on the drivers of green private housing development. Building on the literature reviewed in Section 2, we examine how the market and policy drivers have influenced the development of green private housing in the 285 Chinese cities during 2008–2015.[10] More specifically, we focus on three perspectives: economic returns, policy instruments, and peer effects from both private and public housing, as exhibited in Fig. 3.

4.2.1. *Economic returns*

As mentioned in the literature review, for green housing, the price premium can be attributed to the cost saving potential at the operation stage (mainly energy costs), improvement in living comfort, and environmental consciousness. In terms of energy saving potential, based

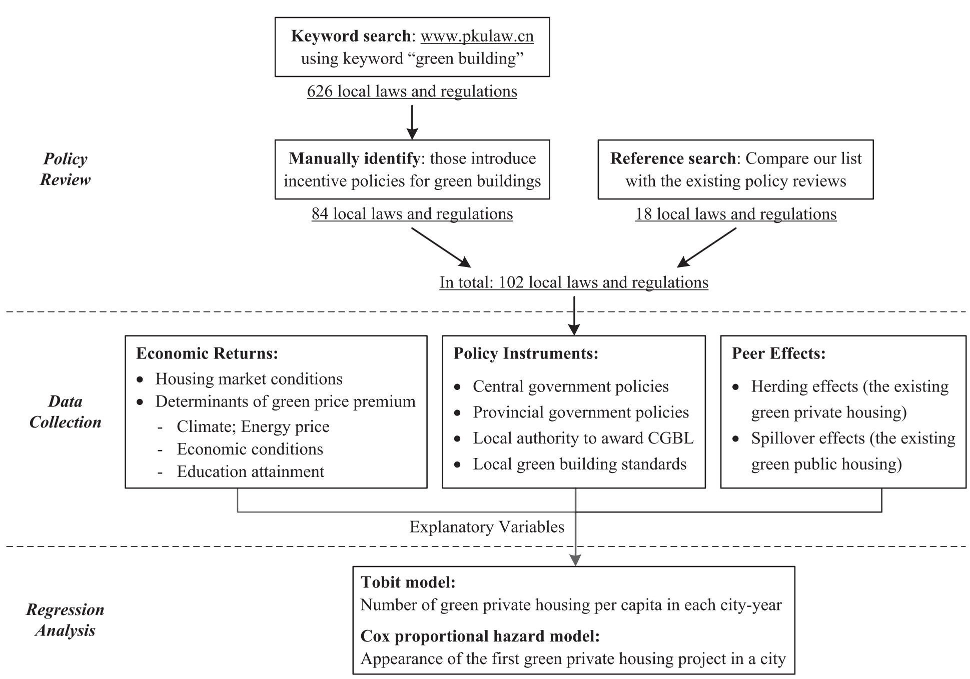

Fig. 3. Methods of data collection and regression analysis.

[10] Lhasa and Chaohu are excluded due to missing values.

Table 4
Provincial policies for promoting green buildings in China.
Source: www.pkulaw.cn

Provinces	Supply-side policies									Demand-side policies		
	Land-related policies		Direct or indirect subsidies				Preferential policies for projects		Preferential policies for enterprises	Direct or indirect subsidies		
	Land supply	Additional floor area	Monetary subsidy	Urban infrastructure facility fee reduction	Preferential loan policy	Tax reduction	Expedited approval process	Priority in building awards	Priority in enterprise qualification inspection and upgrade	Monetary subsidy	Preferential loan policy	Tax reduction
Beijing	○		●			○			○		○	○
Tianjin			●			○					○	
Hebei			○		○	○						
Shanxi	●	○	○			○		○				○
Inner Mongolia				●			○	○	○			
Liaoning		○				○		●			○	
Jilin	●	○	○		○	○			○		○	○
Heilongjiang	●	○	○		○	○		○	○		○	○
Shanghai	●		●		○	●					○	●
Jiangsu	○	○	●	○		○		○		●	●	
Zhejiang	●	●	○		○	○	●				●	
Anhui	●	○	○	○	●			○			●	
Fujian		●	○		○	●	○	○			○	●
Jiangxi		○	○			○		○			●	
Shandong		○	●	○		○		○			○	
Henan	●	○	○			○		○			○	
Hubei		○	○		○	○	○	●	●		○	○
Hunan		○	○		○		○	●	○	○		
Guangdong	●	○	●									
Guangxi	●	○	○	○		○		○			○	○
Hainan			○	●								
Chongqing	●	○	●			○					○	○
Sichuan	●		○		○	○						
Guizhou	●	●	○		○	○		○			○	○
Yunnan	○		○		○							
Tibet												
Shaanxi	●	○	●	○			○	○		●		
Gansu												
Qinghai	●	○	○	●	○			●	○		○	
Ningxia		○	○		○	○		○				
Xinjiang	○		○			○					○	○

Notes: (1) Taiwan, Hong Kong and Macao are not included in the analysis due to lack of information. (2) The solid round (●) indicates that there are clear implementation rules for the policy, while the hollow circle (○) indicates that there is no clear implementation rule for the policy. No circle indicates that the policy has not been adopted by the provincial government.

on historical climate data of Chinese cities,[11] the numbers of days requiring cooling and heating in a year (*COOLING_DAYS*, *HEATING_DAYS*) are calculated to indicate local climatic conditions; electricity prices for residential usage (*EPRICE*) are employed to represent energy price.[12] A dummy variable, *HEATING*, is constructed to indicate whether there is central heating in winter in the city,[13] as energy saving is expected to be more important in cities requiring winter heating. The annual per capita GDP (*GDPPC*) from the *China City Statistical Yearbook* is employed to measure residents' income level, which determines demand for living comfort. Referring to the existing literature and considering that the data of political preference in China is difficult to obtain, residents' environmental consciousness is indicated by the average schooling year (*EDU*) from the National Population Census in 2010. In addition, we adopt the per capita floor area of housing transactions (*AREAPC*) from the *China Statistical Yearbook for Regional Economy* to approximate general housing market conditions.

4.2.2. Policy instruments

While some commercial buildings and public housing are mandated to be green, the certification is voluntary in the private housing sector. We construct a panel dataset of national and provincial incentive policies that apply to the private housing sector. The most influential policy at the central government level is the national monetary subsidy scheme introduced in 2012. A dummy variable of *NATION_SUBSIDY* is used to indicate the period after the launch of this scheme. The variables of provincial policies are based on the review in Table 4. Four variables (*PROV_LAND*, *PROV_SUBSIDY*, *PROV_PROJECT*, and *PROV_QUALIFY*) are introduced to indicate the four categories of supply-side policies, and *PROV_DEMAND* is used to indicate direct or indirect subsidies for the demand side. For these five variables, the value is 1 if there are clear implementation rules for the policy; the value is 0.5 if the policy is mentioned in the legislation and regulation but there is no clear implementation rule; the value is 0 if the policy has not been adopted by the provincial government. If a province adopts more than one policy in a category, the variable takes the highest value according to those policies. In addition, the certification process is time-consuming if all applications have to be submitted to the institutes supervised by the central government. To reduce such "transaction costs" (Qian et al., 2016), local construction authorities were gradually authorized to evaluate and award CGBL certifications, though the top rating level can still only be awarded by the two national-level offices. The dummy variable of *AUTHORITY* is used to indicate such local authority in green certification. Moreover, a dummy variable, *STANDARD*, is employed to represent whether the province has adapted *Evaluation Standards for Green Buildings* to local climatic conditions and released local green building standards.

4.2.3. Peer effects

So-called peer effects include both herding effects from green private housing and spillover effects from green public housing. It is noteworthy that such effects not only influence green housing development in the same city, but may also influence nearby cities (Simcoe and Toffel, 2014). Thus, we construct city distance-weighted numbers of existing green private and public housing projects to examine peer effects, as specified in Eqs. (1) and (2):

[11] Historical climate data during 1951–2008 are available at http://weather.sina.com.cn. According to the winter heating standard and operation rules of central air-conditioners in China, days with an average temperature higher than 26 °C or lower than 5 °C are defined as cooling days and heating days, respectively.

[12] Source: National Development and Reform Commission, http://jgs.ndrc.gov.cn/.

[13] A key line tracing the Huai River and Qinling Mountains near the latitude 33 degrees north bisects China into two parts, with the northern part providing central heating in winter.

$$EXIST\_G\_PRIVATE_{it} = \sum_{j=1}^{285}\left[\left(\sum_{y=2008}^{t-1} G\_PRIVATE_{jy}\right)\exp\left(-d_{ij}\right)\right], (t = 2008, 2009, \ldots, 2015) \quad (1)$$

$$EXIST\_G\_PUBILC_{it} = \sum_{j=1}^{285}\left[\left(\sum_{y=2008}^{t-1} G\_PUBLIC_{jy}\right)\exp\left(-d_{ij}\right)\right], (t = 2008, 2009, \ldots, 2015) \quad (2)$$

where $G\_PRIVATE_{jy}$ is the number of green private housing projects in city *j*, year y, and G_PUBLIC_{jy} is the corresponding variable for public housing projects; d_{ij} is the distance between city *i* and city *j* (in thousand kilometers) and exp($-d_{ij}$) means the weight exponentially declines as the distance between city *i* and city *j* increases.

The development of green housing is measured by the per capita number of green private housing projects (*G_PRIVATE_PC*), the per capita numbers of one-star and two/three-star green private housing projects (*GL_PRIVATE_PC*, *GH_PRIVATE_PC*), and the dummy for the appearance of the first green private housing project (*APPEAR*). While the first two variables are normalized by the total population in the city-year (*POP*), we also do the normalization with total investment in housing development for the city-year (*INV*) as a robustness check. The data of *POP* and *INV* are collected from the *China City Statistical Yearbook*. Table 5 lists the definitions and descriptive statistics of the variables.

Besides the variables of climate, energy price, economic status, education, real estate market conditions, policies, peer effects and population, the previous studies on green office buildings in developed countries (Table 1) also included the variables associated with employment conditions and LEED accredited professionals. However, the occupants of green housing are residents instead of corporations, so the employment conditions may not be a significant factor in green housing development. Currently, there is no accredited professional for CGBL (Zhou, 2015). Therefore, these two variables were not considered in this paper.

4.3. Regression models

We adopt regression models to investigate the effects of the aforementioned economic returns (***ER***), policy instruments (***PI***), and peer effects (***PE***) on the number of green private housing projects. It is noteworthy that green housing development in China is still nascent and 81% of the 2280 observations of *G_PRIVATE_PC* are zero, employing the OLS model is problematic as the estimator is inconsistent. *G_PRIVATE_PC* can be treated as censored data: it is set to zero when it should be negative according to the local market and policy conditions. To address this problem, we adopt the Tobit model proposed by Tobin (1958). Consider the linear regression model with city-level random effects[14]:

$$\begin{aligned} GPRIVATEPC_{it}^{*} &= \alpha + \boldsymbol{\beta_1 ER_{it}} + \boldsymbol{\beta_2 PI_{it}} + \boldsymbol{\beta_3 PE_{it}} + u_i + \varepsilon_{it} \\ GPRIVATEPC_{it} &= GPRIVATEPC_{it}^{*}, \quad \text{if } GPRIVATEPC_{it}^{*} > 0 \\ GPRIVATEPC_{it} &= 0, \quad \text{if } GPRIVATEPC_{it}^{*} \le 0 \end{aligned} \quad (3)$$

where: $G\_PRIVATE\_PC_{it}^{*}$ is the latent variable which is an unobserved continuous outcome, while $G\_PRIVATE\_PC_{it}$ is the observed censored outcome; α is a constant; $\boldsymbol{\beta_1}$, $\boldsymbol{\beta_2}$ and $\boldsymbol{\beta_3}$ are vectors of coefficients; the city-level random effect, u_i, is independent and identically distributed (i.i.d.), $N(0, \sigma_u^2)$, and the error term, ε_{it}, is i.i.d., $N(0, \sigma_\varepsilon^2)$ independently of u_i. The coefficients ($\boldsymbol{\beta_1}, \boldsymbol{\beta_2}, \boldsymbol{\beta_3}$) are estimated by maximizing the log-likelihood function ($G\_PRIVATE\_PC_{it}$ is indicated by Y_{it} for concision):

[14] There is no command for a fixed-effect model, because there is no sufficient statistic allowing the fixed effects to be conditioned out of the likelihood.

Table 5
Definition and summary statistics of variables.

Variables	Definition	Obs.	Mean	SD	Min	Max
G_PRIVATE	Number of green private housing projects	2280	0.56	1.97	0.00	30.00
G_PRIVATE_PC	Number of green private housing projects per 10^7 people	2280	3.06	9.92	0.00	156.30
G_PRIVATE_INV	Number of green private housing projects per 10^{10} RMB investment in housing development	2280	0.46	2.16	0.00	47.41
GL_PRIVATE_PC	Number of one-star green private housing projects per 10^7 people	2280	1.13	5.15	0.00	111.60
GH_PRIVATE_PC	Number of two/three-star green private housing projects per 10^7 people	2280	1.93	7.24	0.00	122.00
APPEAR	Whether the first green private housing project appears in the city-year; 0 = there has been no green private housing project in the city by the end of the year; 1 = the first green private housing project appears in the city in that year; no values for years after the appearance of the first project	1841	0.10	0.29	0.00	1.00
Economic Returns (ER)						
COOLING_DAYS	Days with average temperature higher than 26 °C in a year	285	58.67	50.07	0.00	189.00
HEATING_DAYS	Days with average temperature lower than 5 °C in a year	285	72.05	64.12	0.00	247.00
HEATING	Whether there is central heating in winter in the city; 1 = yes, 0 = no	285	0.46	0.50	0.00	1.00
EPRICE	Residential electricity price; in RMB/kWh	2280	0.53	0.05	0.42	0.62
GDPPC	Per capita GDP; in 10^4 RMB	2280	6.07	4.90	0.59	49.31
EDU	Average schooling year of urban population according to the 2010 Population Census	285	8.97	0.81	6.55	11.71
AREAPC	Per capita floor area of housing transactions; in sq.m	2280	2.69	2.05	0.01	22.60
Policy Instruments (PI)						
NATION_SUBSIDY	Whether the central government adopts subsidy policies for green buildings; 1 = yes, 0 = no	2280	0.50	0.50	0.00	1.00
PROV_LAND	Whether the provincial government has launched land-related policies for green building development; 1 = there are clear implementation rules for the policy, 0.5 = the policy is mentioned but there is no clear implementation rule, 0 = the policy is not mentioned	2280	0.26	0.40	0.00	1.00
PROV_SUBSIDY	Whether the provincial government has launched direct or indirect subsidy policies for green buildings; 1 = there are clear implementation rules for the policy, 0.5 = the policy is mentioned but there is no clear implementation rule, 0 = the policy is not mentioned	2280	0.26	0.37	0.00	1.00
PROV_PROJECT	Whether the provincial government provides preferential policies for green buildings; 1 = there are clear implementation rules for the policy, 0.5 = the policy is mentioned but there is no clear implementation rule, 0 = the policy is not mentioned	2280	0.16	0.28	0.00	1.00
PROV_QUALIFY	Whether the provincial government provides preferential policies for developers of green buildings; 1 = there are clear implementation rules for the policy, 0.5 = the policy is mentioned but there is no clear implementation rule, 0 = the policy is not mentioned	2280	0.05	0.17	0.00	1.00
PROV_DEMAND	Whether the provincial government has launched direct or indirect subsidy policies for buyers of green buildings; 1 = there are clear implementation rules for the policy, 0.5 = the policy is mentioned but there is no clear implementation rule, 0 = the policy is not mentioned	2280	0.16	0.31	0.00	1.00
AUTHORITY	Whether the provincial government is authorized to evaluate and award the CGBL certification; 1 = yes, 0 = no	2280	0.68	0.47	0.00	1.00
STANDARD	Whether the provincial government has released local green building standards; 1 = yes, 0 = no	2280	0.52	0.50	0.00	1.00
Peer Effects (PE)						
EXIST_G_PRIVATE	Distance-weighted number of existing green private housing projects; in $(10^3\ \text{km})^{-1}$	2280	98.78	130.40	0.00	508.80
EXIST_G_PUBLIC	Distance-weighted number of existing green public housing projects; in $(10^3\ \text{km})^{-1}$	2280	17.82	24.71	0.00	89.95
Control Variables (C)						
POP	Total population at end of the year; in 10^4	2280	141.40	178.90	15.10	2129.00
INV	Total investment in housing development; in 10^{10} RMB	2280	1.14	2.29	0.001	21.56

$$\ln L = \ln P(Y_{1t}, Y_{2t}, ..., Y_{nt}) = \sum_{Y_{it}>0} \ln P(Y_{it}^{*}) + \sum_{Y_{it}=0} \ln P(Y_{it}^{*} \leq 0) \quad (4)$$

$P(Y_{it}^{*})$ is the probability density function of Y_{it}^{*}. As ε_{it} has a normal distribution of $N(0, \sigma_{\varepsilon}^{2})$, the distribution of Y_{it}^{*} is $N(\alpha + \boldsymbol{\beta_1 ER_{it}} + \boldsymbol{\beta_2 PI_{it}} + \boldsymbol{\beta_3 PE_{it}} + u_i, \sigma_{\varepsilon}^{2})$. Therefore, the coefficients can be estimated with Maximum Likelihood Estimation (MLE) based on Eq. (4).

The second empirical question is why green private housing appears earlier in some cities while later or even had not yet appeared in others. To assess this, we employ the Cox proportional hazard model (Cox, 1972). The failure time variable is *t*, indicating the years elapsed since the launch of CGBL certification until the first green housing project appeared; *t* equals 1 for the year of 2008, and so forth. The censoring indicator variable is *APPEAR*, identifying the appearance of the first green private housing project in a city. The hazard is assumed as Eq. (5) referring to Cox (1972).

$$h(t, i) = h_0(t)\exp(\boldsymbol{\gamma_1 ER_{it}} + \boldsymbol{\gamma_2 PI_{it}} + \boldsymbol{\gamma_3 PE_{it}} + \mu_{it}) \quad (5)$$

$$\ln[h(t, i)/h_0(t)] = \boldsymbol{\gamma_1 ER_{it}} + \boldsymbol{\gamma_2 PI_{it}} + \boldsymbol{\gamma_3 PE_{it}} + \mu_{it} \quad (t = year - 2007) \quad (6)$$

where $h(t,i)$ represents the probability that the first green private housing project in city i appears in year t; $h_0(t)$ is the baseline hazard; the explanatory variables are generally consistent with Eq. (3). γ_1, γ_2 and γ_3 are estimated using MLE (Cox, 1972).

5. Results and discussion

The regression results of Eq. (3) are reported in column (1) of Table 6, revealing the drivers of green private housing development in China during 2008–2015. In terms of economic returns, the variables contributing to the green premium (e.g. days requiring cooling or heating, central heating in winter, residents' income and education level) are significant as expected, but electricity price (*EPRICE*) turns out to be not significant. While the energy price is deemed to be an important determinant of household energy efficiency in the U.S. (Costa and Kahn, 2011), this motivation is lessened in China as residential electricity prices remain rather low and the variance among cities is very small due to central government regulations (Zheng et al., 2012). The result also confirms that cities with more housing transactions (*AREAPC*) have witnessed faster diffusion of CGBL certification.

Among policy instruments, we find that the influences of subsidies from the central government (*NATION_SUBSIDY*) or provincial governments (*PROV_SUBSIDY*) are not significant. Zhou (2015)'s interviews with developers arrived at similar conclusions, determining that developers were actually not enthusiastic about subsidies, offering the reasoning that they would not end up with much money because most of it would vanish in different layers of government. The coefficient of *PROV_LAND* is significant at the 5% level, implying that land-related policies matter considerably more than subsidies from the perspective of developers. This finding is in line with expectations, because taking the proportion of green buildings as a prerequisite is actually a

Table 6
Drivers of green housing development in China.

Variable	(1) Number of green housing/ population G_PRIVATE_PC	(2) Number of green housing/ housing investment G_PRIVATE_INV	(3) Number of one-star rated housing/population GL_PRIVATE_PC	(4) Number of two/three-star rated/population GH_PRIVATE_PC	(5) Appearance of the first green housing $\ln(h/h_0)$
Economic Returns (ER)					
ln(*COOLING_DAYS*)	0.385***	0.077***	0.098	0.483***	0.015
	(2.86)	(2.65)	(0.77)	(3.26)	(1.50)
ln(*HEATING_DAYS*)	0.402***	0.057*	0.068	0.570***	0.007
	(2.85)	(1.87)	(0.52)	(3.58)	(0.71)
HEATING	6.107*	1.599**	3.264	6.135*	− 1.434***
	(1.84)	(2.24)	(1.03)	(1.74)	(−2.69)
EPRICE	− 41.823	− 5.599	− 12.218	− 42.674	− 3.916**
	(−1.36)	(−0.85)	(−0.43)	(−1.25)	(−2.36)
ln(*GDPPC*)	11.202***	1.645***	8.972***	9.609***	1.498***
	(4.51)	(3.08)	(3.73)	(3.52)	(3.72)
ln(*EDU*)	67.718***	13.282***	49.831***	73.790***	19.970***
	(3.83)	(3.51)	(3.00)	(3.82)	(5.93)
ln(*AREAPC*)	5.244***	0.465	2.924*	4.388**	0.234**
	(3.22)	(1.34)	(1.87)	(2.50)	(2.41)
Policy Instruments (PI)					
NATION_SUBSIDY	3.755	0.625	2.240	1.696	
	(1.12)	(0.81)	(0.65)	(0.49)	
PROV_LAND	6.570**	1.367**	6.947**	3.049	0.333
	(2.12)	(1.96)	(2.26)	(0.92)	(1.26)
PROV_SUBSIDY	4.503	0.608	− 0.602	6.769*	0.557*
	(1.24)	(0.74)	(−0.17)	(1.78)	(1.81)
PROV_PROJECT	− 4.866	− 1.712*	− 4.087	− 2.873	− 0.525
	(−1.07)	(−1.67)	(−0.96)	(−0.60)	(−1.61)
PROV_QUALIFY	11.377**	4.178***	8.663*	5.475	0.812**
	(2.22)	(3.66)	(1.78)	(1.02)	(2.19)
PROV_DEMAND	9.428**	3.153***	8.921**	5.979	0.738**
	(2.17)	(3.22)	(2.14)	(1.30)	(2.25)
AUTHORITY	6.027	1.499	0.349	10.599**	0.109
	(1.35)	(1.49)	(0.07)	(2.19)	(0.30)
STANDARD	4.967*	0.928	3.782	3.218	0.263
	(1.86)	(1.56)	(1.42)	(1.14)	(1.30)
Peer Effects (PE)					
ln(*EXIST_G_PRIVATE*)	0.390	0.080	0.104	0.687	0.298
	(1.24)	(1.18)	(0.34)	(1.44)	(0.69)
ln(*EXIST_G_PUBLIC*)	0.542***	0.107**	0.601***	0.401**	0.784*
	(2.73)	(2.37)	(2.64)	(1.98)	(1.94)
HEATING **t*					0.315***
					(3.40)
ln(*GDPPC*) **t*					− 0.203***
					(−2.78)
ln(*EDU*) **t*					− 2.438***
					(−4.05)
Constant	− 192.064***	− 39.156***	− 158.807***	− 208.112***	
	(−4.88)	(−4.63)	(−4.27)	(−4.75)	
Observations	2280	2280	2280	2280	1841
Cities	285	285	285	285	
Log-likelihood	− 2430	− 1770	− 1352	− 1788	− 841.1

Notes: z-statistics are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

mandatory requirement, and additional permitted floor area for green building project means more housing units to sell. While the expedited approval process and priority in building awards (*PROV_PROJECT*) appears ineffective, priority in enterprise qualification inspection and upgrade (*PROV_QUALIFY*) and subsidies for homebuyers (*PROV_DEMAND*) present significant impacts on the development of green private housing. These results suggest that preferential policies for enterprises are more attractive than those policies for specific projects. The estimation of marginal effects based on the regression shows that, all else held constant, land-related policies, preferential policies for enterprises, and demand-side policies can increase per capita green private housing projects (*G_PRIVATE_PC*) by 0.12, 0.20, 0.17 standard deviations, respectively.[15] In addition, local governments' authority to evaluate and award the CGBL (*AUTHORITY*) and the issuance of local green building standards (*STANDARD*) have positive effects on green housing development, but such effects are only marginally significant.

From the perspective of peer effects, the most important finding is that existing green *public* housing projects present a much larger impact than the existing green *private* housing projects do on the subsequent development of green private housing. The marginal effect estimation suggests that one standard deviation increase of ln(*EXIST_G_PUBLIC*) would increase the dependent variable *G_PRIVATE_PC* by 0.11 standard deviation; in contrast, the influence of the existing green *private* projects is not significant. These results suggest that local governments' green public housing development have disseminated green practices to the private housing sector, producing considerable spillover effects, while there is no significant evidence about herding effects in the private housing sector.

The above results remain consistent in the robustness check when we replace population with housing investment to normalize the

[15] It is noteworthy that the estimated coefficients of Tobit analysis are the marginal effects of the independent variables on *G_PRIVATE_PC**, instead of *G_PRIVATE_PC* (McDonald and Moffitt, 1980).

number of green private housing projects, as shown in column (2). The significance of the coefficient of ln(*AREAPC*) decreases, because the influence of general housing market conditions has been controlled by employing *INV* as the denominator of the dependent variable.

In addition to the quantity, the quality (rating level) of green housing is also an important evaluation dimension of green housing development. In columns (3) and (4), we examine and compare the drivers of one-star and two/three-star certifications. It is clear from the results that policy instruments are generally more effective in encouraging the development of one-star rated green housing. Moreover, the spillover effects of the government's green practices on one-star rated private housing development are more significant than that on higher-rated housing. In contrast, cities with greater energy-saving potential witness a more rapid increase of higher-rated green housing projects that are expected to be more energy-efficient. The coefficient of *PROV_SUBSIDY* is significant at the 10% level in column (4), implying that subsidies for developers of green buildings can stimulate the development of higher-rated green housing to some extent. We also find that local governments' authority to evaluate and award the CGBL (*AUTHORITY*) can significantly increase the number of green housing with higher ratings. This result is reasonable, as the provinces that are authorized to evaluate the CGBL will establish green building committees and train professionals, both of which are crucial in the coordination of green building knowledge and information. The presence of green building committees and professionals is particularly important for the development of green housing with high-level certifications.

We finally turn to the question about what factors stimulated the appearance of green private housing in the 285 cities during 2008–2015. The variable of *NATION_SUBSIDY* is omitted, because this national incentive is consistent across all cities and its impact is included in the baseline hazard $h_0(t)$. In estimating Eq. (5), *HEATING*, ln(*GDPPC*) and ln(*EDU*) do not satisfy the proportional hazards assumption, that is, their coefficients are time-variant. Following Cameron and Trivedi (2005), we include time interactions on these three variables in the model. The estimation result is reported in column (5) of Table 6. It is encouraging to find that the demand-side subsidies (*PROV_DEMAND*) and the priority in inspection and upgrade of enterprise qualification (*PROV_QUALIFY*) can significantly induce the first green practice in the private housing sector. In particular, the adoption of a demand-side subsidy policy with clear implementation rules (*PROV_DEMAND*) increases the probability of the first green private housing appearance by 109% ($\exp(0.738) - 1 = 1.09$). This result is understandable, referring to the coordination problem suggested by Simcoe and Toffel (2014). As developers are awaiting evidence of ample demand for green housing, the government's subsidy policies for homebuyers provide a guaranteed driver for green housing demand, and thus may jump-start the development of green housing. In provinces where subsidies for developers (*PROV_SUBSIDY*) are introduced, the appearance probability of the first green private housing increases by 75%. Priority for developers of green buildings in enterprise qualification inspection and upgrade is also effective in triggering the first green private housing practice, increasing the probability of appearance by 125%. The effects of other policies (e.g. land-related policies, local green building standards) are relatively weak. Furthermore, the government's green practices in public housing also play a pivotal role in inducing the appearance of green private housing.

Besides policy drivers, the effects of income, education and general housing market conditions are consistent with expectations. However, one noteworthy difference between the results here and that in column (1) (i.e., the quantity of green private housing) is the influence of energy saving potential. While most of the variables associated with energy consumption present significantly positive effects on the quantity of green private housing, they turn out to be not significant or even negative in explaining the first green private housing practice. One possible reason may be information asymmetry, as households are unlikely to acquire sufficient information about the benefits of green housing in a market without green housing. Only after the first few green housing projects are put into use can residents learn about their cost-saving benefits and thus increase demand for green housing.

6. Conclusions and policy implications

Based on a unique dataset of all the cities at the prefecture level or above in China from 2008 to 2015, we investigated the drivers of green housing development by analyzing spatial and temporal variations in the adoption of CGBL in the private housing sector. In line with expectations, the development of green housing is faster in cities with greater potential in energy saving, wealthier and higher-educated residents, and a more prosperous housing market, because these factors may lead to higher economic returns to green housing investment. Some policy instruments (i.e. land-related policies, priority in enterprise qualification inspection and upgrade, and demand-side subsidies) have significantly stimulated the appearance and development of green housing. The empirical analysis also reveals the importance of the government's pioneering green practice in the public housing sector.

This paper contributes to a growing literature investigating the drivers of green building development. Rather than commercial buildings, we provide the first analysis on the promotion of green practices in the residential sector, which is more profound given that a larger percentage of China's buildings serve as residential housing. This paper provides a comprehensive review and reliable empirical analysis regarding policies adopted to promote green buildings in China, yielding several policy implications for further leveraging developers to engage in green building practices.

First, although most of the factors associated with potential economic returns to green investments significantly contributed to green housing development, the motivation from energy prices was lessened in China due to the government's control of electricity prices. Effective pricing mechanisms for energy are required to accelerate the development of green housing, especially for higher-rated green housing, in areas where energy efficiency is more urgently needed.

Second, current subsidies for developers only present a marginal effect on the appearance of the first green practice and the development of high-rated green housing. In order to use fiscal subsidies more effectively, instead of subsidies based on green-certified building area, funds can be allocated to support developers' initial Research & Development on green buildings at the enterprise level. Besides monetary subsidies, in the context of tight regulation and control on the housing market in China, developers' enthusiasm can also be stimulated by differentiated price and trade restriction policies for green housing.

Third, the demand-side policies proved to be crucial in facilitating the appearance and subsequent development of green housing, but only a few provinces have adopted incentives for homebuyers so far. Considering the financial constraints, besides subsidies, the government can explore other ways to improve residents' awareness and engagement, and thus increase demand for green housing. For instance, publicity campaigns regarding the CGBL and related knowledge may be a relatively low-cost strategy to nudge residents toward pursuing green housing (Zhang et al., 2017a).

Fourth, successful green housing practices require a greater number of professionals, which is proven by the significant influence of *AUTHORITY* on high-rated green housing. However, besides the green building committees, qualified CGBL professionals are still scarce, compared with LEED-accredited professionals (Zhou, 2015; Zou et al., 2017). The government needs to improve professional education and capacity building to hasten green housing development.

Fifth, the empirical analysis provides inspiring evidence about the substantial spillover effects of the government's green practices. The current mandatory requirement to obtain CGBL for public housing in provincial capitals can be applied to all cities gradually. Making the best of these driving factors, a booming green housing market can be anticipated in China.

References

Allcott, H., Taubinsky, D., 2015. The lightbulb paradox: evidence from two randomized experiments. NBER Work. Pap. Ser. 19713.

Berry, S., Davidson, K., Saman, W., 2013. The impact of niche green developments in transforming the building sector: the case study of Lochiel Park. Energy Policy 62, 646–655.

Cai, W.G., Wu, Y., Zhong, Y., Ren, H., 2009. China building energy consumption: situation, challenges and corresponding measures. Energy Policy 37 (6), 2054–2059.

Cameron, A.C., Trivedi, P.K., 2005. Microeconometrics: Methods and Applications. Cambridge University Press, New York.

Chan, E.H., Qian, Q.K., Lam, P.T., 2009. The market for green building in developed Asian cities—the perspectives of building designers. Energy Policy 37 (8), 3061–3070.

Cidell, J., Cope, M.A., 2014. Factors explaining the adoption and impact of LEED-based green building policies at the municipal level. J. Environ. Plan. Manag. 57 (12), 1763–1781.

Circo, C.J., 2007. Using mandates and incentives to promote sustainable construction and green building projects in the private sector: a call for more state land use policy initiatives. Penn State Law Rev. 112, 731.

Costa, D.L., Kahn, M.E., 2011. Electricity consumption and durable housing: understanding cohort effects. Am. Econ. Rev. 101 (3), 88.

Cox, D.R., 1972. Regression models and life-tables. J. R. Stat. SocSer. B (Methodol.) 187–220.

Darko, A., Zhang, C., Chan, A.P., 2017. Drivers for green building: a review of empirical studies. Habitat Int. 60, 34–49.

De Silva, D.G., Pownall, R.A.J., 2014. Going green: does it depend on education, gender or income? Appl. Econ. 46 (5), 573–586.

DeCoster, G.P., Strange, W.C., 1993. Spurious agglomeration. J. Urban Econ. 33 (3), 273–304.

Deng, Y., Wu, J., 2014. Economic returns to residential green building investment: the developers' perspective. Reg. Sci. Urban Econ. 47, 35–44.

Ding, C., 2003. Land policy reform in China: assessment and prospects. Land Use Policy 20 (2), 109–120.

Dippold, T., Mutl, J., Zietz, J., 2014. Opting for a green certificate: the impact of local attitudes and economic conditions. J. Real Estate Res. 36 (4), 435–473.

Eichholtz, P., Kok, N., Quigley, J.M., 2013. The economics of green building. Rev. Econ. Stat. 95 (1), 50–63.

Fuerst, F., Kontokosta, C., McAllister, P., 2014. Determinants of green building adoption. Environ. Plan. B: Plan. Des. 41 (3), 551–570.

Fuerst, F., McAllister, P., 2011. The impact of energy performance certificates on the rental and capital values of commercial property assets. Energy Policy 39 (10), 6608–6614.

Hu, H., Geertman, S., Hooimeijer, P., 2014. The willingness to pay for green apartments: the case of Nanjing, China. Urban Stud. 51 (16), 3459–3478.

Hyland, M., Lyons, R.C., Lyons, S., 2013. The value of domestic building energy efficiency - evidence from Ireland. Energy Econ. 40, 943–952.

Jaffe, A.B., Stavins, R.N., 1994. The energy paradox and the diffusion of conservation technology. Resour. Energy Econ. 16 (2), 91–122.

Kahn, M.E., Kok, N., 2014. The capitalization of green labels in the California housing market. Reg. Sci. Urban Econ. 47, 25–34.

Kahn, M.E., Vaughn, R.K., 2009. Green market geography: the spatial clustering of hybrid vehicles and LEED registered buildings. B E J. Econ. Anal. Policy 9 (2), 1–24.

Kaza, N., Lester, T.W., Rodriguez, D.A., 2013. The spatio-temporal clustering of green buildings in the United States. Urban Stud. 50 (16), 3262–3282.

Koirala, B.S., Bohara, A.K., Berrens, R.P., 2014. Estimating the net implicit price of energy efficient building codes on U.S. households. Energy Policy 73, 667–675.

Kok, N., McGraw, M., Quigley, J.M., 2011. The diffusion of energy efficiency in building. Am. Econ. Rev. 101 (3), 77–82.

Kuo, C.J., Lin, C., Hsu, M., 2016. Analysis of intelligent green building policy and developing status in Taiwan. Energy Policy 95, 291–303.

Ma, X., Gong, W., Song, L., 2014. Collection of green building policies in China during 2013. Constr. Sci. Technol. 6, 36–44.

Matisoff, D.C., Noonan, D.S., Flowers, M.E., 2016. Green buildings: economics and policies. Rev. Environ. Econ. Policy 10 (2), 329–346.

Oster, S.M., Quigley, J.M., 1977. Regulatory barriers to the diffusion of innovation: some evidence from building codes. Bell J. Econ. 361–377.

Qi, G.Y., Shen, L.Y., Zeng, S.X., Jorge, O.J., 2010. The drivers for contractors' green innovation: an industry perspective. J. Clean. Prod. 18 (14), 1358–1365.

Qian, Q.K., Fan, K., Chan, E.H., 2016. Regulatory incentives for green buildings: gross floor area concessions. Build. Res. Inf. 44 (5–6), 675–693.

Sedlacek, S., Maier, G., 2012. Can green building councils serve as third party governance institutions? An economic and institutional analysis. Energy Policy 49, 479–487.

Shi, Q., Lai, X., Xie, X., Zuo, J., 2014. Assessment of green building policies–a fuzzy impact matrix approach. Renew. Sustain. Energy Rev. 36, 203–211.

Simcoe, T., Toffel, M.W., 2014. Government green procurement spillovers: evidence from municipal building policies in California. J. Environ. Econ. Manag. 68 (3), 411–434.

Tobin, J., 1958. Estimation of relationships for limited dependent variables. Econometrica 26 (1), 24–36.

Xu, Z., 2014. Research and suggestions on green building incentive policies of provincial governments in China. Constr. Sci. Technol. 2, 56–64.

Ye, L., Cheng, Z., Wang, Q., Lin, W., Ren, F., 2013. Overview on green building label in China. Renew. Energy 53, 220–229.

Zhang, L., Liu, H., Wu, J., 2017a. The price premium for green-labelled housing: evidence from China. Urban Stud. 54 (15), 3524–3541.

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., 2017b. The value of going green in the hotel industry: evidence from Beijing. Real Estate Econ. http://dx.doi.org/10.1111/1540-6229.12225.

Zhang, X., Shen, L., Wu, Y., 2011. Green strategy for gaining competitive advantage in housing development: a China study. J. Clean. Prod. 19 (2), 157–167.

Zheng, S., Wu, J., Kahn, M.E., Deng, Y., 2012. The nascent market for "green" real estate in Beijing. Eur. Econ. Rev. 56 (5), 974–984.

Zhou, Y., 2015. State power and environmental initiatives in china: analyzing china's green building program through an ecological modernization perspective. Geoforum 61, 1–12.

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.

Zuo, J., Zhao, Z., 2014. Green building research–current status and future agenda: a review. Renew. Sustain. Energy Rev. 30, 271–281.