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Certifying green buildings in China: LEED vs. 3-star

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ABSTRACT

Over the past two decades, China has been devoted to promoting the construction of more green buildings, which are usually certified via specific rating systems, including LEED and 3-Star. LEED (Leadership in Energy and Environmental Design), an international certification originating from the United States, and 3-Star, a domestic certification created by China itself, are the two most common rating systems used in China. This research provides a comprehensive comparison of LEED and 3-Star in terms of their targets, certification criteria, and standards. In addition, by employing logistic models, this research provides the first empirical evidence regarding what factors might affect the green building certification options in the Chinese context. The empirical study reveals: (1) LEED is more likely to be chosen for business and industrial buildings, whereas 3-Star is more likely to be chosen for residential buildings; (2) buildings in China's eastern region are more likely be certified via 3-Star than those in the country's central and western regions; (3) buildings in cities with higher GDP per capita, more FDI, and more real estate investment are more likely to be certified via LEED; and (4) investors and architectural firms with international backgrounds tend to prefer LEED. Explanations behind the results and related theoretical and policy implications are also provided. This research aims to assistant policymakers in better understanding developers' and owners' motivations in choosing specific certifications, and in designing or improving rating systems to promote more green buildings.

1. Introduction

Throughout the last three decades, China has experienced unprecedented and hasty urbanization. This has resulted in the creation of a significant number of new buildings. The country developed approximately 2 billion square meters of new buildings each year during China's period of increased urbanization, but many of the buildings have been criticized for not being energy efficient due to little insulation and insufficient heating/cooling systems (Connelly, 2013). The building sector has a considerable impact on energy consumption; for instance, buildings consumed 25% of the nation's total energy in 2011 (Khanna et al., 2014). As the largest contributor of CO_2 emissions worldwide, China has attempted to reduce its energy consumption through a number of measures, one of which has been to initiate green building programs. According to its Twelfth Five-Year Plan (2011–2015), China expected that its green building efforts would help the country to meet its targets of a 16% reduction in energy consumption and a 17% reduction in CO_2 emissions (Institute of Building Efficiency, 2013; McGrawhill Construction, 2013).

Green buildings are expected to have a reduced impact on the natural environment and create a more resource-efficient model with regard to building-related practices (Prum, 2010; Cidell and Cope, 2013). Green buildings, however, do not only address issues related to ecological protection; they also address issues related to social justice, public health, and productivity (Cidell and Beata, 2009). Though there are several terms and meanings associated with what it is to be a green building, a green building is usually defined as that which has achieved one or more certifications via green building rating systems (Walsh, 2012). There are diverse green building rating systems worldwide, including LEED in the U.S., BREEAM in the U.K., CASBEE in Japan, EcoProfile in Norway, Green Star in Australia and New Zealand, and Green Mark in Singapore. While developers generally pursue third-party certifications voluntarily, governments may incentivize or compel developers to certify their green buildings (Prum and Kobayashi, 2014).

In China, the two most popular green building rating systems are LEED (Leadership in Energy and Environmental Design) and 3-Star (Geng et al., 2012). As an internationally accepted certification, LEED was first used in China in 2003 and has since been used by a

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number of developers. China has also developed its own green building standards, and in 2006, the country launched its first green building rating system, the National Building Evaluation Standard, which is known as the 3-Star system for its three levels of certification: three-stars is the highest level, and one star is the lowest (Accame et al., 2012). As developers and owners generally choose the most appropriate green building rating system to certify their buildings, it is important for them to understand the goals and criteria of different green building rating systems (Illankoon et al., 2017; BEE, 2013). This raises the first research question – what are the major differences between LEED and 3-Star? To address this question, I conduct a comprehensive comparison of the targets, criteria, and standards of these two distinct certification systems based on the analysis of the content of the related policies and documents issued by the Ministry of Housing and Uran-Rural Development (MOHURD) of China and the U.S. Green Building Council (USGBC) – two organizations that have developed 3-Star and LEED, respectively. After the comparison, it is rational to further examine the different factors that lead developers and owners to choose one rating system over another (Cidell and Cope, 2013). This raises the second research question – why have some green buildings been certified by LEED while others have been certified by 3-Star? To address this question, I employ logistic models and a unique dataset comprised of 2914 green buildings to provide the first empirical evidence regarding what factors, including building functions, geographic regions, city socio-economy, and building investors/design stakeholders, might affect the green building certification options in the Chinese context. Further, based on the empirical results, this research suggests theoretical and policy implications and offers relevant discussion. Combining policy content analysis and empirical quantitative analysis, this research aims to help readers to better understand the nascent green building market in China with regard to the differences among different certification schemes and developers' and owners' motivations for choosing specific certifications for their buildings. This research also aims to assist policymakers in improving the certification schemes in order to encourage developers and owners to develop more green buildings.

The remainder of this article is organized as follows. The second section provides a literature review, with a focus on examining the factors that motivate developers to build green. The third section compares the LEED and 3-Star certifications. The fourth section conducts an empirical study and explains the study's results. The fifth section offers discussion and implications. The sixth section concludes.

2. Literature review

Existing literature suggests that developers and owners have strong motivations to pursue green building certifications, through which they can gain a variety of economic, social, and ecological benefits (Cidell, 2009). In terms of economic benefits, securing superior rents and sales prices, sustaining higher occupancy, reducing energy consumption, and lowering operational expenses are drivers for developers to pursue green building certifications (Choi and Miller, 2011). A reduction in operating costs means enhancing operation efficiency and lowering carbon footprints (Simons et al., 2009). For instance, researchers have found that on average LEED-certified buildings are 25%–30% more energy efficient than conventional buildings (Kats, 2003; Geng et al., 2012; Cidell, 2009). In addition, a number of studies have indicated that price premium and market mechanism play pivotal roles in facilitating green building development (Eichholtz et al., 2010; Brounen and Kok, 2011; Fuerst and McAllister, 2011; Kok et al., 2011; Butler, 2008; Jang et al., 2018; Pivo, 2010). For example, research suggests that LEED-certified buildings in the United States garner rents that are between 5% and 17% higher than rents collected in non-certified buildings, and certified green buildings also tend to sell for 11%–25% more than non-certified buildings (Khanna et al., 2014; Choi and Miller, 2011). Literature also shows that green-labeled houses in China have a sales price premium of 6.9%, and green-labeled hotels enjoy a room rate premium of 6.5% (Zhang et al., 2017a; 2017b). In addition, evidences confirm that green building certification can enhance potential clients' willingness to purchase or rent (Jang et al., 2018; Sun et al., 2018). Competition among developers also serves as a motivation to build green. Many developers employ green building strategies in order to expand their market shares and to realize investment benefits and more successful self-promotion (Kahn and Kok, 2014; Zhang et al., 2017a).

Beyond pure economic benefits, social benefits, such as better ventilation, a healthy habitat environment, and higher working productivity, also result from the construction of green buildings. Green buildings can also enhance public awareness with regard to sustainability and can improve public health (Pivo and Fisher, 2009; Geng et al., 2012; Cidell and Beata, 2009). For instance, green buildings' better ventilation and cleaner indoor air quality will create heathier environment for the public (Cidell and Beata, 2009). Furthermore, as green buildings are more energy efficient than conventional buildings, they help to encourage the conservation of natural resources, decrease carbon emissions, and reduce waste discharge (Kats, 2003; Geng et al., 2012).

Though developers can secure many green benefits, such as those mentioned above, attaining certification will cost them. The literature indicates that, on average, developers must pay an extra 2%–9% to achieve green certification (Cidell, 2009). The additional cost accounts for green materials (i.e., materials that can reduce or eliminate hazardous substances), green facilities (i.e., insulation, cooling/heating system), green technologies (i.e., technologies that can reduce the environmental impacts), and increased design fees and labor costs. In addition, the pay-back period is relatively long. It is agreed that high up-front costs serve as one of the biggest barriers to building green (Cidell, 2009; Zhang et al., 2017a; Zhang et al., 2018). To help offset the additional costs associated with constructing green buildings, many governments apply either mandated or incentive-based policies to encourage developers to pursue green building certifications. For instance, in 2012, the Chinese government released an incentive-based policy, which regulated that the buildings that have achieved 3-Star certification would enjoy a financial subsidy of 80 Yuan per square meters (The Central Government of China, 2012).

The existing literature provides evidence that the promulgation of public policies can lead to more certified green buildings (Cidell and Cope, 2013). In China and the U.S., local governments have adopted diverse public policies, such as lower tax rates, lower interest rates, and financial subsidies, in order to encourage developers to seek green building certifications (Zou et al., 2017; Lee and Koski, 2012; Cidell and Cope, 2013; Prum and Kobayashi, 2014). Those incentive-based policies are compatible with local governments' efforts to strengthen local economies and make them more competitive (Dierwechter, 2010; Cidell and Cope, 2013). In addition, local governments generally expect that green building policies will garner citizen support because the policies can help to improve the sustainability of the collective living environment.

Though green buildings are associated with a number of benefits, such as energy efficiency, most users do not have the sort of professional knowledge that would enable them to comprehensively judge a building's performance; this results in serious information asymmetry and adverse selection problems in the green building market (Zhang et al., 2017a). Thus, a reliable market signal, such as a green building certification or rating system, can serve as an effective strategy aimed at overcoming those problems (Heinzle et al., 2013; Kahn and Kok, 2014; Zhang et al., 2017a; Zhang et al., 2018). As a result, a variety of green building certifications have been created (Illankoon et al., 2017; Ismaeel, 2018). Those certifications are run by the different creating institutions (i.e., government agencies or non-government organizations) and exhibit discrepancies in purposes, rating criteria, target clients, etc. Some rating systems are compatible with others, while some systems are competitive with the intent of expanding their market shares (Illankoon et al., 2017; Ismaeel, 2018). Furthermore, local governments' financial subsidies for building green are only eligible for specific certifications. For instance, only the green buildings certified by the 3-Star system are qualified to apply for the subsidies from the local governments of China (The Central Government of China, 2012). This is one reason why some developers and owners may choose a given certification. In the context of existing diverse green building certifications, developers and owners will assess their goals and benefits, as well as their buildings' characteristics and local contexts, before choosing one or more specific rating systems to certify their green buildings. Overall, the combination of building functions and geographic and socio-economic factors may drive developers to choose certifications that can maximize their benefits. However, what factors might cause developers and owners to choose which certification has not yet been empirically examined. This research attempts to fill this gap in the literature. To address this, I employ logistic regression to quantify the factors that may explain the two most common green building certification options in China (i.e. LEED and 3-Star).

3. Comparing LEED and the 3-star systems

LEED and 3-Star are the two most common green building certifications in China, as the majority of developers or owners of green-labeled buildings have chosen one of these two certifications. Before examining what factors might cause developers to choose a specific certification, I provide a comprehensive comparison of LEED and 3-Star. Having been developed and promulgated in 1998 by USGBC, a U.S.-based non-governmental organization, LEED is a globally recognized green building rating system (Cidell and Cope, 2013). With the support of a wide network of LEED-accredited professionals and complementary local policies, LEED has grown rapidly since its inception (Khanna et al., 2014). Created to provide a national standard to encourage a reduction in environment footprints and to lead to more sustainable building, LEED's influence has expanded to places all around the world, including China (Accame et al., 2012; Cidell, 2009). The 3-Star rating system was launched by China's Ministry of Housing and Urban-Rural Development (MOHURD), which is a government agency. Being a rating system designed only to apply to domestic green buildings across China, the 3-Star system has incorporated many valuable components associated with foreign systems, including LEED (Geng et al., 2012).

LEED and 3-Star share some similarities, the primary of which is that both are credit-based systems. With regard to LEED, credits are earned in six categories, including sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environment quality, and innovation and design (Cidell, 2009; Cidell and Beata, 2009). USGBC provides the LEED Credit Library to define the credit criteria and measure whether a building has met the requirements. For instance, the criteria of innovation and design examines whether a building has integrated up-to-date technologies and scientific research into its design strategies. There are also a few mandatory credits such as those earned by reducing energy usage by 10% over a conventional building (Cidell and Cope, 2013). Beyond the prerequisites, developers are free to select credits from the remaining options. In the end, all credits are totaled together for a final score regardless of the category. Based on the credits earned, LEED can grant four levels of certification (i.e., Certified, Silver, Gold, and Platinum) (Cidell and Cope, 2013). Further, LEED provides detailed certification tracks, which include New Construction (NC), Existing Building Operations (EB), Commercial Interiors Project (CI), Core and Shell Project (CS), Homes (H), and Neighborhood (ND), whereas 3-Star includes only two different evaluation standards for residential and public buildings (such as business and government-owned buildings) (Prum and Kobayashi, 2014). The 3-Star system also employs a credit-based system, which includes six primary categories (i.e., land savings and outdoor environment, energy savings, water savings, material savings, indoor environment quality, and operation management) and a seventh category referred to as "preference items" (NEEC, 2014).

The two credit-based systems, however, have a number of significant differences. For instance, LEED considers innovation, while 3-Star does not; further, LEED does not allocate credits on operations and maintenance, while 3-Star does (Accame et al., 2012; BEE, 2013). In addition, 3-Star considers land efficiency, but LEED has no such requirement; this is due, in large measure, to China's increasing land scarcity – a problem that does not affect the U.S. in the same way (Geng et al., 2012; BEE, 2013). Within each 3-Star category, indicators can be further grouped into prerequisites (control) items, general (credit) items, and premium (bonus) items. The 3-Star system requires buildings to achieve the control items and a minimum score for every category. The star level is decided by the minimum number of each category rather than by the total credits satisfied, which means that better performance in one category cannot offset poor performance in another (Geng et al., 2012; Khanna et al., 2014). In contrast, LEED allows buildings to receive high level certifications even if they excel in some areas but perform poorly in other areas, which can result in some developers choosing easier credits while ignoring the more important or difficult-to-earn credits (Khanna et al., 2014; China Builds Green, 2014). With regard to this problem, 3-Star is an improvement over LEED.

The process of achieving certification is also different for LEED and 3-Star. The LEED process is relatively straightforward: those applying register a project and submit a design/construction document to the Green Building Certification Institute (GBCI), which assesses the paperwork and awards a rating before the project is occupied. During the process, LEED credits are determined by design assumption rather than actual performance (China Builds Green, 2014). 3-Star, however, utilizes a two-stage approach. In the first stage, the building may earn a Green Building Design Label (GBDL), which is similar to the LEED Core and Shell precertification process (China Builds Green, 2014), intended to help the buildings to sell to potential tenants (Institute of Building Efficiency, 2013; Khanna et al., 2014). In the second stage, the building may earn an operational Green Building Label (GBL). Only buildings that earn the design label are eligible for the operational label (Khanna et al., 2014). The operational label is issued after one year of occupancy and operation and is based on on-site assessment, which is to ensure a more accurate assessment of the real performance of the green building (Accame et al., 2012). Table 1 lists the credit weighting by categories for the design label and operational label. Looking at the systems in terms of building operation suggests another way in which 3-Star is an improvement over LEED.

LEED and 3-Star are designed and run by organizations with different attributes. LEED is designed by USGBC, a committee of building industry stakeholders, including developers, architects,

Table 1
Credit weighting by categories for design label and operational label in the 3-Star Rating System.

	Land efficiency and Outdoor Environment	Energy Saving & Energy Utilization	Water Saving & Utilization of Water Resources	Material Saving & Utilization of Material Resources	Indoor Environment Quality	Construction Management	Operation Management
Design Label	0.15	0.35	0.10	0.20	0.20	0	0
Operation Label	0.10	0.25	0.15	0.15	0.15	0.10	0.10

(Source: Institute for Building Efficiency, 2013)

engineers, and material suppliers, with a straightforward and predictable approach (China Builds Green, 2014). For instance, after developers submit their applications to the GBCI, LEED assessment results can be predicted based on the checklist – if the building satisfied the criteria, it will obtain the credit. Because the criteria are uniform and will not vary across different buildings the total credits are the result of an objective system (China Builds Green, 2014). In contrast, 3-Star is initiated by the national government, and its application process is more complicated. For both GBDL and GBL, the government will organize a committee to review the paperwork submitted by the developers and to conduct on-site reviews (China Builds Green, 2014). The one- and two-star label applications will be processed by the local Green Building Label Office (GBLMO), while the three-star label application will be processed by the national GBLMO (Accame et al., 2012). Although it is a national rating system, 3-Star offers some flexibility; for instance, local governments might add or eliminate certain items based on how compatible they are or are not with local conditions, suggesting that the rigidity in measurement may differ across different provinces (Khanna et al., 2014). Compared to the transparency and objectivity associated with LEED, the credits achievement criteria associated with 3-Star is vague and subjective in some provinces (China Builds Green, 2014).

The differences between LEED and 3-Star reflect their different goals and philosophies. LEED's goals include generating a market of green buildings, promoting green products and services, and encouraging sustainable design (China Builds Green, 2014). As a market-oriented system, LEED successfully facilitates developers' abilities to market their buildings to potential tenants and to capture green benefits via premium pricing, which in turn drives more developers to build green (Geng et al., 2012). This indicates that LEED's philosophy follows a market-driven approach rather than an approach concerned with encouraging compliance through government edicts (Prum and Kobayashi, 2014). Unlike LEED, 3-Star is a government-led program, which was initiated under the context of China's efforts to build a resource-saving and environmentally friendly society (MOHURD, 2006). While 3-Star has a goal to transform the market, this is not its primary goal. For example, to earn an operational label, a building should be certified after a full year of occupation, but this post-facto certification process will slow market transformation. Instead, 3-Star has a more important goal of reducing energy consumption and CO_2 emissions. Many details suggest that 3-Star focuses more on energy consumption than LEED does. For example, 3-Star has rigid requirements for energy saving and energy structure optimization, whereas LEED focuses more on green technology, materials, and innovations (China Builds Green, 2014; Geng et al., 2012). In addition, LEED and 3-Star have different energy evaluation baselines. LEED refers to internationally accepted standards, such as the American Society of Heating, while 3-Star refers to domestic standards (China Building Green, 2014). LEED's baseline model allows for greater basic energy consumption than 3-Star's baseline model; if LEED- and 3-Star-certified buildings want to achieve a comparable energy rating, then the former must permit lower levels of energy consumption than the latter (China Building Green, 2014). Furthermore, while LEED credits are based on energy savings predicted via modeling rather than actual savings, 3-Star requires real measurable energy reduction, which suggests that 3-Star focuses more on the actual energy saving (NEEC, 2014). As the answer to the first research question, Table 2 briefly summarize the comparison between LEED and 3-Star.

4. Empirical studies

4.1. Data, variables, and models

Various factors might influence developers and prompt them to choose a specific certification when labeling their green buildings. For the current study, I tested four primary categories of explanatory variables hypothesized to contribute to green building certification options; these include building functions, geographic locations, host city's socio-economic characteristics, and building stakeholders. The dataset related to the variables was collected from a variety of sources.

The primary dataset includes all LEED and 3-Star certified green buildings across mainland China through December 31, 2014. The data was collected from a publicly available database via GBMAP (Green Building Map), a professional green building website in China,[1] which provides information regarding each green building's certification type (LEED or 3-Star), address, and function (i.e., business, industrial, public, residential). In addition, the dataset also lists the names of some green buildings' investors or owners and architectural firms. As of December 31, 2014, there were 2954 green buildings certified by LEED or 3-Star, including all the certification tracks and all the certification levels from these two rating systems. Among the whole sample, 881 were LEED-certified and 2073 were 3-Star-certified, and 40 were certified by both systems. As I employed a logistic model that requires the dependent variables to be binary in nature, those green buildings certified by both systems were excluded from the empirical studies; thus, the final dataset included observations regarding 2914 green buildings.

To examine whether geographic locations contribute to choices developers and owners make with regard to green building certifications, I grouped the cities with green buildings into three regions (i.e., eastern, central, and western [2]) according to their

[1] The address of GBMAP is http://www.gbmap.org.

[2] The approach of grouping China's provinces into three regions follows many existing literature pertaining to Chinese region studies, such as Fan and Sun (2008).The eastern region includes 11 provinces or municipalities (Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan), the central region includes 8 provinces (Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan), and the western region includes 12 provinces or provincial-level municipalities/autonomous regions (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, and Tibet).

Table 2
The differences between LEED and 3-star rating systems.

	LEED	3-Star
Running Organizations	USGBC (the United States Green Building Council) – Non-government Organization	MOHURD (Ministry of Housing and Urban-Rural Development, China) –Governmental Agency
Initiated Year	1998	2006
Application Countries	Worldwide	China
Certification Levels	Four (Certified, Silver, Gold, and Platinum)	Three (One star, two stars, and three stars)
Credit Categories	Sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environment quality, and innovation and design	Land savings and outdoor environment, energy savings, water savings, material savings, indoor environment quality, and operation management.
Numbers of Certification Criteria	The number of certification criteria is 110. The certification level is decided by the total credits satisfied of all categories.	The numbers of certification criteria of residential buildings and public buildings are 40 and 43, respectively. The certification level is decided by the minimum credits of each category.
Certification tracks	New Construction (NC), Existing Building Operations (EB), Commercial Interiors Project (CI), Core and Shell Project (CS), Homes (H), and Neighborhood (ND),	Residential buildings, public buildings
Scoring Methods	All credits are totaled together for final score regardless of the category.	Achieving the control items and a minimum score for every category.
Review and Certifying Process	The review process is straightforward based on paperwork. Certifications are awarded before the project is occupied, and credits are determined by design assumption rather than actually performance of a green building.	The review process is conducted by a committee with both paperwork and on-site reviews. Utilizing a two-stages approach – design label and operational label. The operational label tries to ensure a more accurate performance of a green building.

provinces/municipalities. I also examined the socio-economic characteristics of the different cities, and I chose three variables from the year 2013: (1) GDP per capita, which represents a city's level of wealth; (2) the amount of Foreign Direct Investment, which represents the international economic activities associated with a city; and (3) the amount of real estate investment, which represents the real estate market activity of a city. The data was collected from the China City Statistic Yearbook (NBSC, 2014).

For the current study, I employed logistic models to assess the factors that may affect green building certification options. A logistic regression is an estimation method used to examine the strengths and significance of a set of explanatory factors that were hypothesized to explain the dependent variables (Achmad et al., 2015). The relative weight of the factors in predicting the certification option is given by the respective coefficients. In the logistic models, the probability that a green builder will choose a given certification is a function of the building's characteristics, geographic location, city-based socio-economic variables, and building stakeholders (i.e., investors and architectural firms).

The equation of the logistic model can be specified as:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \ldots + \beta_k X_{ik} + \varepsilon$$

where P_i represents the probability that green building i chooses LEED certification; X_{i1} to X_{ik} represent a set of explanatory variables; β_1 to β_k represent the coefficient of each variable; k represents the number of explanatory variables; α represents the intercept; and ε represents the random error term.

The dependent variable is the green building certification option. As mentioned previously, I only considered those green buildings that were certified by either LEED or 3-Star in the empirical studies. The certification option is a binary variable; namely, if the building is certified by LEED, the value is 1, and if the building is certified by 3-Star, the value is 0. The four categories of explanatory variables include building function variables (BUSINESS, INDUSTRIAL, PUBLIC, and RESIDENTIAL), geographic region variables (EASTERN, CENTRAL, and WESTERN), city socio-economic variables (GDP_C, FDI, and REAL_ESTATE), and investor/architect variables (FR_INVESTOR, PR_INVESTOR, PB_INVESTOR, and FR_ARCHITECT). Table 3 lists the definitions and descriptive statistics of all of the variables for the logistic regressions.

I built four models to examine how the different explanatory variable combinations may affect the probability that a developer or owner would choose LEED certification. In the first model (Model 1), I attempted to confirm that developers or owners choose appropriate certification methods based on building functions. The explanatory variables are building functions, including BUSINESS, INDUSTRIAL, PUBLIC, and RESIDENTIAL, which indicate that the functions of a building are for business, industrial, public, or residential use, respectively. Regarding this model, I hypothesized that business, industrial, and public buildings are more likely LEED-certified, while residential buildings are more likely to be 3-Star-certified.

In the second model (Model 2), I added the geographic region variables, EASTERN, CENTRAL, and WESTERN, so that I could examine the probabilities of choosing a specific means of certification across different regions. I hypothesized that buildings in the eastern region are more likely than those in either the central or western region to be LEED-certified, because the eastern region is the most open region nationwide and has more chances to access to international ideas and practices in green building. In the third model (Model 3), I added the socio-economic variables of cities that are home to the green buildings. I hypothesized that cities with higher GDP per capita (GDP_C), higher amounts of Foreign Direct Investment (FDI), and greater real estate investment (REAL_ESTATE) may be more likely to house LEED certified buildings. The final model (Model 4) includes the additional variables of investors and architectural firms. I hypothesized that investors, owners, and designers with international backgrounds prefer LEED certifications.

Table 3
Descriptive statistics for the Variables of the Logistic Regression Model.

Variable	Description	Observations	Mean	Std. Dev.	Min	MAX
LEED	Dummy: 1 = Green buildings certified by LEED; 0 = Green buildings certified by 3-Star	2914	0.289	0.453	0	1
BUSINESS	Dummy: 1 = Buildings for commercial use; 0 = Otherwise	2914	0.464	0.499	0	1
INDUSTRIAL	Dummy: 1 = Buildings for industrial use; 0 = Otherwise	2914	0.034	0.180	0	1
PUBLIC	Dummy: 1 = Buildings for public use; 0 = Otherwise	2914	0.086	0.281	0	1
RESIDENTIAL	Dummy: 1 = Buildings for residential use; 0 = Otherwise	2914	0.416	0.493	0	1
EASTERN	Dummy:1 = Buildings located in the eastern region; 0 = Otherwise	2914	0.750	0.433	0	1
CENTRAL	Dummy: 1 = Buildings located in the central region; 0 = Otherwise	2914	0.134	0.341	0	1
WESTERN	Dummy: 1 = Buildings located in the western region; 0 = Otherwise	2914	0.116	0.320	0	1
GDP_C	GDP per capita of cities that buildings locate (Thousand Yuan)	2852	85.727	29.165	15.916	293.346
FDI	Foreign direct investment of cities that buildings locate (Billion $)	2776	5.346	5.216	0.031	15.185
REAL_ESTATE	Real estate invests amount of cities that buildings locate (Billion Yuan)	2904	107.443	91.457	0.001	309.105
FR_INVESTOR	Dummy: 1 = Buildings invested by foreign investors; 0 = Otherwise	2796	0.140	0.347	0	1
PR_INVESTOR	Dummy: 1 = Buildings invested by private investors; 0 = Otherwise	2796	0.711	0.453	0	1
PB_INVESTOR	Dummy: 1 = Buildings invested by public investors; 0 = Otherwise	2796	0.148	0.356	0	1
FR_ARCHITECT	Dummy: 1 = Green buildings designed by foreign architectural firms; 0 = Green buildings designed by domestic architectural firms	1112	0.122	0.328	0	1

4.2. Empirical results

Table 4 summarizes the empirical results of the logistic regressions. In the table, I report both logistic coefficients and odds ratios for each model. In Model (1), I include three dummy variables representing building functions (BUSINESS, INDUSTRIAL, and PUBLIC), with residential function as the omitted category. The result of Model (1) shows that the coefficients of BUSINESS, INDUSTRIAL, and PUBLIC are all significant with positive signs, meaning that business, industrial and public buildings are more likely than residential buildings to be LEED certified. In addition, industrial buildings, followed by business buildings, have the highest probability of being LEED certified. The result also implies that residential buildings are more likely to be 3-Star certified.

In Model (2), I control for the eastern and central region variables (EASTERN and CENTRAL), with the western region as the omitted category. The results show that, compared with buildings located in the western region, buildings located in the eastern region are more likely to be LEED certified, whereas buildings in the western region are more likely to be certified by 3-Star. This spatial variation, however, disappears after I control for additional city socio-economic variables in Model (3), in which three city socio-economic variables (GDP_C, FDI, and REAL_ESTATE) are all positively significant. The disappearance of significance of regional

Table 4
Logistic regression estimates for LEED certification choice.

Independent Variable	Model (1)		Model (2)		Model (3)		Model (4)	
	Coefficient	Odds Ratio	Coefficient	Odds Ratio	Coefficient	Odds Ratio	Coefficient	Odds Ratio
BUSINESS	3.286*** (20.36)	26.735	3.275*** (20.19)	26.436	3.072*** (17.34)	21.589	2.245*** (5.00)	9.444
INDUSTRIAL	5.134*** (15.36)	169.709	5.268*** (15.44)	194.113	5.766*** (14.97)	319.171	3.184** (3.25)	24.153
PUBLIC	1.055*** (4.06)	2.871	1.049*** (4.02)	2.856	1.138*** (4.10)	3.122	1.139 (1.76)	3.125
EASTERN			0.693*** (4.28)	2.000	0.0500 (0.25)	1.051	−1.247* (-2.19)	0.287
CENTRAL			−0.506* (-2.19)	0.603	−0.148 (-0.58)	0.862	−0.853 (-1.26)	0.426
GDP_C					0.00634** (2.75)	1.006	0.0200** (3.11)	1.020
FDI					0.0581*** (3.66)	1.060	0.0695 (1.66)	1.072
REAL_ESTAT					0.00803*** (9.04)	1.008	0.00517* (2.15)	1.005
FR_INVESTOR							4.028*** (6.76)	56.173
PB_INVESTOR							−0.277 (-0.66)	0.758
FR_ARCHITECT							3.949*** (11.23)	51.865
_cons	−3.256*** (-21.44)	−0.039	−3.750*** (-17.57)	−0.005	−5.136*** (-17.43)	−0.0017	−6.507*** (-8.26)	−0.0015
Log likelihood	−1249.11		−1218.50		−979.36		−165.06	
chi 2	1003.82		1065.05		1332.54		546.77	
Number of Observations	2914		2914		2724		993	
pseudo R^2	0.287		0.304		0.405		0.624	

t statistics in parentheses.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

variables also confirms that the spatial variation of certification options is affected by city-based socio-economic factors rather than by geographic location factors.

Model (4) is the full model containing all explanatory variables. With regard to the function variables, the coefficients of INDUSTRIAL and BUSINESS are still positively significant, and that of PUBLIC shows marginal significance at the 90% confidence level ($t = 1.76$), suggesting that industrial, business, and public buildings are more likely than residential buildings to be LEED-certified. With regard to the regional variables, the signs of EASTERN change to negative and indicate significance at the 95% confidence level, suggesting that green builders in the eastern region prefer 3-Star certification, after controlling for other explanatory variables. One possible explanation is that more local governments in eastern regions have initiated incentive policies to encourage developers to secure 3-Star certifications. The coefficients of the three socio-economic variables at the city level are still positively significant, though the FDI significance confidence level decreases to 90% ($t = 1.66$). The result suggests that green buildings located in cities with greater economic efficiency, more foreign direct investment, and an active real estate market are more likely be certified by LEED. One explanation is that those cities engage more frequently in economic and cultural exchanges with other countries and are inclined to accept such international standards as those associated with LEED. The additional explanatory variables included in Model (4) are FR_INVESTOR and PUB-INVESTOR (with private investors as the omitted category) as well as FR_ARCHITECT (with the domestic architectural firm as the omitted category). Compared with private and public investors, foreign investors have a significantly higher probability of choosing LEED certification. The positive significant coefficient of FR_ARCHITECT suggests that green buildings designed by foreign architectural firms have a greater probability of being certified by LEED. This result confirms that LEED is more appropriate for building stakeholders with international backgrounds. As the answer to the second research question, Table 5 briefly summarizes the factors that might affect the green building certification options.

4.3. Explanations of the empirical results

The empirical studies demonstrate that LEED and 3-Star have been appropriately tailored to different market segments with the purpose of attracting different target developers (China Builds Green, 2014). From a developer's perspective, there are various motivations to build green; these includes public perception, energy savings, rent or sale price premiums, and government-based financial subsidies (Simons et al., 2009). As such, developers will choose appropriate certifications based on their project features.

Developers and owners are inclined to choose LEED to certify their business and industrial buildings because it is a strategy aimed at improving their brands' images. In the U.S., LEED has maintained a dominant share of the commercial and institutional building market, and the system's reputation has made its way to China (Kok and Jennen, 2012). LEED certification is most often utilized as a means of enhancing developers' brand recognition, as it has become crucial for multinational companies or organizations to occupy green business and industrial buildings around the world (Li and Currie, 2011; China Builds Green, 2014). With regard to business buildings, LEED targets developers, owners, buyers, and tenants who take into consideration public perception and who appreciate their own social responsibilities (Choi and Miller, 2011). With regard to industrial buildings, because they are usually self-owned, a LEED-certified building can assist owners in establishing a brand image, and it can even serve as an advertisement to help facilitate expanded market share for the owner (Cidell, 2009).

Different levels of concern regarding up-front costs might also explain why some business and industrial builders are more likely to choose LEED, while residential builders are more likely to choose 3-Star certification. Though higher up-front costs often represent one of the biggest barriers to investment in green buildings, different developers have different levels of concern regarding these additional costs. Developers and owners of high-end projects are willing to pay extra for green technologies as their social image often takes priority over the up-front costs (China Builds Green, 2014). With regard to residential buildings, however, up-front costs are a developer's primary concern. Literature shows that, on average, developers in China expect that it will take three and a half years to recoup extra up-front costs (Li and Currie, 2011). As such, developers have to rely on financial subsidies from governments to offset the extra costs. In China, financial subsidies are offered on a square-meter basis to encourage developers to build green. For instance, some governments provide a subsidy of 75 Yuan per square meter for buildings that have achieved 3-Star certification; 75 Yuan represents approximately 30% of the extra cost to obtain the certification (China Builds Green, 2014). As the subsidy will not apply to foreign-based certification, developers must choose 3-Star certification (Walsh, 2012).

Public policies also play a critical role in encouraging developers to secure a specific green building certification. Local government attitudes regarding green policies are different in different locations. Local governments in the eastern region, for example, are more aggressive than governments in either the central and western region in their efforts to initiate incentive-based policies. As the incentive-based policies do not apply to LEED, it is reasonable that green building developers and owners in the eastern region are more likely to choose 3-Star certification, which is in accordance with the empirical results of the logistic regressions.

In addition, different stakeholders, such as investors and architectural firms, prefer certifications that are most suited to them. For instance, the criteria for a 3-Star certification is relatively

Table 5
The factors that might affect the green building certification options.

Variable Category	Factors	Prefer to be certified by LEED	Prefer to be certified by 3-Star
Building function variables	Commercial use	✓	
	Industrial use	✓	
	Residential use		✓
Geographic region variables	Eastern region		✓
	Central region	✓	
	Western region	✓	
City socio-economic variables	Cities with higher GDP per capita	✓	
	Cities with higher FDI	✓	
	Cities with higher real estate investment	✓	
Investor/architect variables	Investors with international background	✓	
	Architectural firms with international background	✓	

vague and subjective, and is associated with reduced transparency, which may result in uncertainty in the review process. Foreign investors may be less inclined to choose 3-Star because they are not familiar with China's institutional context and do not want to face uncertainty as it relates to their applications. Rather, they may be more inclined to choose LEED certification, as it is more straightforward; they also have the advantage of being able to more readily access LEED information, technologies, and engineers. Public investors, however, are less likely to choose LEED because some governments require government-funded buildings to secure 3-Star certifications through executive order. Because financial subsidy is critical to offset the up-front costs for private investors, it is reasonable that they would choose 3-Star certification in order to maximize their economic benefits. In addition, foreign architectural firms have more experience and are more capable of designing LEED-certified projects, while domestic designers are more familiar with Chinese building regulations and codes; this can explain why buildings designed by foreign firms are more likely to be LEED-certified, while those designed by domestic firms are more likely to be 3-Star-certified (Chan et al., 2009).

5. Discussion and implications

China has attempted to achieve sustainable development via decreases in energy consumption and carbon emissions. To this end, the state has implemented a measure aimed at promoting greater green building development. Green building certification plays a critical role in the development of green buildings, as it serves as a reliable market signal in that it discloses information of regarding a buildings' energy efficiency (Zhang et al., 2017a; Heinzle et al., 2013; Kahn and Kok, 2014). As there are a variety of green building certifications, it is worthwhile to compare the differences and similarities among them. Via a comprehensive comparison of LEED and 3-Star, this research can help developers and owners to better clarify and assess the targets, criteria, and standards between these two systems. Further, via an empirical analysis based on a comprehensive green building dataset, this research serves to enable developers and owners to better understand what factors might influence their certification choices for a given building.

This research can yield the following theoretical implications. First, this research provides theoretical guidance for developing more mature green building certifications. The development of a mature green building certification should be guided by a framework. To construct a sound framework, it's useful to refer to the results of the empirical study, such as considering the variables that show significance, weighing the variables appropriately, and understanding the motivations of developers and owners. Second, reliable certifications can more effectively deliver messages regarding the advantages associated with green buildings (e.g., enhanced energy efficiency and living comfort) to the public and can thus enhance the willingness of green building consumption. This perspective implies that this research can arouse public's interest in green buildings and therefore facilitate the country's achievement of its goals of reducing energy consumption and carbon emissions.

This research also has several policy implications. First, as many factors may impact green building certification options, top-down and bottom-up approaches should be integrated to improve the certification systems. In China, 3-Star certification was designed and implemented through a top-down approach, but bottom-up approaches could serve as a good supplement. For instance, the government can work closely with green building stakeholders (i.e., developers, designers, the public, material suppliers) in the formation and improvement of green building rating systems. Second, the government needs to overcome many challenges in improving its certification of green buildings, including the lack of a green building professional accreditation process, such as the USGBC's LEED Accredited Professionals; the lack of professionals qualified to conduct integrated green building design, operation, and maintenance; as well as the lack of a robust green materials supply chain, technical capacity, and innovation (Khanna et al., 2014; Walsh, 2012). These challenges suggest that there is still a great deal to consider with regard to the development or enhancement of a certification system that is adapted to the Chinese context. This research can assist policymakers in better understanding developers' and owners' motivations for choosing specific certifications, and it can also help them to design or improve the rating systems to promote the construction of more green buildings in China.

6. Conclusions

In China, most green-labeled buildings are certified by the LEED and 3-Star systems, with LEED serving as an international certification, and 3-Star serving China's domestic context (NEEC, 2014). LEED and 3-Star are similar in some ways and can complement one another in some ways, but there are also a number of differences between the two in terms of their targets, certification criteria, standards, and target tenants. Based on the two systems' characteristics, developers and owners will choose the option most suitable to their respective green building projects. This research provides a comprehensive comparison of LEED and 3-Star, and it empirically examines the effects of different factors (i.e., building types, geographic locations, host city's socio-economic characteristics, and the features of building stakeholders) on the decisions made regarding specific rating scheme. The empirical study reveals: (1) LEED is more likely to be chosen for business and industrial buildings, whereas 3-Star is more likely to be chosen for residential buildings; (2) buildings in the eastern region are more likely than buildings in the central and western region to be certified via 3-Star; (3) buildings in cities with higher GDP per capita, more FDI, and more real estate investment are more likely to be certified via LEED; and (4) investors and architectural firms with international backgrounds tend to prefer LEED. Through examining the factors that motive the developers and owners to choose LEED or 3-Star, this research can help readers to better understand the nascent green building market in China.

Some limitations of this research merit discussion and suggest directions for future research. First, while this research provides the first empirical evidence regarding the factors that impact developers and owners as they pursue given green building certifications in the Chinese context, it has not disclosed how those factors work. Future studies will conduct qualitative research (e.g., interviews with developers, owners, architects, and other stakeholders) to explore how the different factors influence developers and owners as they choose specific certifications (Gan et al., 2015). Second, this research needs to form a more comprehensive and generalized theoretical implications based on empirical results. Future studies will focus on constructing a theoretical framework that can assist relevant organizations in improving extant certification systems aimed at promoting more green buildings.

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