Strategic Behavior in Certifying Green Buildings: An Inquiry of the Non-building Performance Value

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Abstract

This study determines the magnitude of the market signaling effect arising from LEED (Leadership in Energy and Environmental Design) certification for green buildings and explores the mechanisms behind the signaling effect. Previous studies have shown that signaling or marketability plays an important role in the pursuit for LEED and equivalent green-building certification. By analyzing all new construction projects receiving LEED certification from 2000 to 2012 in the US, this study estimates the relative importance of ‘green’ signaling. This broad perspective using project-level data enables an analysis of some drivers of signaling and the pursuit of marketing benefits. The roles of local competition and market conditions as well as municipal regulations are examined, especially as they differ between types of building owners (e.g., for-profit firms, governments, nonprofits). The results indicate that the non-building performance value – value captured by LEED signals above and beyond the specific building attributes that LEED certifies – dominates the attainment of LEED scores around certification tier thresholds. Further, strong evidence of spatial clustering of this non-building performance value for some owner types indicates that for-profit owners may be more responsive to local competition than non-profit owners. Local legislative mandates predict greater signaling intensity by government-owned buildings, as expected, but for-profit-owned projects tend to signal less, even after controls for local conditions. The results highlight the importance of local conditions, including peer effects and regulations, in driving non-building performance values across a wide range of green buildings. Richly characterizing local conditions and building heterogeneity remains a challenge to better understanding green building.

Keywords:

LEED, signaling, non-building performance value, spatial clustering, local regulation

Introduction

To an extent, all LEED (Leadership in Energy and Environmental Design) participants are signalers. Instead of “going green” quietly, LEED participants choose to pay to be certified, so that they can gain additional advantages other than energy savings. These additional advantages include enhancing marketing as a greener product or firm, a

premium on rents and property values, fulfilling legal obligations, and showing social responsibility.

Moreover, due to the design of the four-tier certification system, participants in the LEED certification program signal among themselves. A scorecard is used to determine the performance of LEED participants. Higher scores mean better or “greener” performance of buildings. Based on the score participants earned, LEED issues four different tiers of certificate: certified, Silver, Gold, and Platinum. Without any LEED-related signaling, each participant would attain a hypothetical ‘optimal’ score, when the marginal cost of reaching that score equals the marginal gains of performance enhancement. This is the counterfactual. However, the signaling effect induces some participants to pursue a higher score, especially when their optimal scores are just a few points shy of the next higher certificate tier. This allows participants to show that they surpass other participants, especially their competitors. This “signaling effect among signalers” is the main focus of this study. For simplicity purposes, the signaling effect in this study is defined as the effect that drives LEED participants to the next higher certificate tier than they would otherwise attain. We refer to this aspect of the signal, which is associated with the discontinuous jump to a higher LEED certification tier rather than the raw LEED score’s continuous measure of the building’s performance, as a “non-building performance signal” or a “signaling effect” for short. Of course getting LEED certified at a particular score sends a market signal about building performance quality as well, but the interest of this study is on the non-building performance aspects (discussed further below).

This study aims to identify the signaling effect of LEED certification and the mechanisms behind the effect. The first part of this study quantifies the size of the signaling effect of LEED certification. The methodology used to identify the size of the signaling effect is mainly from the method used in Matisoff et al. (2014). The result of this study confirms that the signaling effect exists in LEED certification, and the size of signaling effect differs by building owner type.

Further, this study examines mechanisms behind the signaling effect for each owner type from a broad perspective by analyzing the complete set of LEED-NC-certified projects (v2.0-v2.2) across the country from 2000-2012. A first step in analyzing the distribution of LEED projects as a whole is to assess peer effects (Qiu, Yin, & Wang, 2016). Whether geographically close projects influence each other's signaling effects can be evaluated with the global Moran's I , which is commonly used in identifying the spatial clustering. Based on the result of the global Moran's I , government-owned buildings and buildings owned by for-profit firms spatially cluster more than buildings owned by non-profit organizations. To further identify the sources of the signaling effect, a regression is conducted to verify the relationship between the signaling effect and municipal legislative mandates, where there is considerable local variation in policy. The results show that municipal regulations for constructing green buildings, which tend to apply to just new buildings, induce government agencies to signal more. This effect of regulation, however, is not evident for for-profit firms and nonprofit organizations. Also, the results indicates that local competition is unlikely to be the main mechanisms behind the signaling for for-profit firms.

This study has several potential applications. First, the signaling effect measured in this study can be viewed as a comprehensive consequence of non-building performance values in the pursuit of LEED certificate. While the appeal and function of LEED's performance values are relatively straightforward and easily understood, comprehending how non-building performance value affects the behavior of owners helps to better illustrate the whole picture of the pursuit of green signaling in buildings. Second, the empirical results of this study help clarify the sources of the signaling effect or non-building performance value for different types of building owners. Identifying the sources of the non-building performance value can help inform the design of policies to make buildings greener. For example, evidence of spatial clustering in this upgrading or signaling behavior supports raising LEED thresholds to use the contagious signaling to catalyze even higher performing buildings. If signaling spreads locally, then initially subsidizing new green buildings can spur a "race to the top." Further, results indicating the relative importance of the signaling effect can help policymakers target strategies to appeal to different adoption motivations across owner types.

Literature Review

LEED, or any other green-building certification system, can possibly benefit building owners through channels other than building performance-based benefits or lower lifecycle costs (Matisoff, Noonan, & Flowers, 2016; Matisoff et al., 2014). The building performance benefits can be viewed as energy savings and other internally beneficial environmental gains (e.g., cleaner indoor air, water efficiency) after adoption

(Kats, 2003; Singh, Syal, Grady, & Korkmaz, 2010; Turban & Greening., 1997). Many environmental benefits from green buildings, however, are public goods and thus not capitalizable or directly influencing return of investment. Thus, some buildings may not get a positive return of investment in pursuing green-building certificates (D'Antonio, 2007; Mapp, Nobe, & Dunbar, 2011; Mills et al., 2004; Newsham, Mancini, & Birt, 2009; Turner & Frankel, 2008). Benefits other than direct building performance benefits are considered as “non-building performance” benefits in this study. Since many of the benefits of adoption are external while all the costs are internal, it implies that there may be other reasons for the pursuit of LEED.

Non-building performance benefits from adopting LEED could come from several sources. The benefits are expected to vary by owner type. For government buildings, the most obvious reason is legislative obligations. At the state level, twenty U.S. states have adopted green-building related mandates (Green Building Pages, 2015), and most LEED or LEED-equivalent mandates only apply to government buildings (Matisoff et al., 2016). According to survey data collected by Feiock et al. (2014), 350 out of 2,003 cities (17 percent) in the dataset require a certain level of energy efficiency standards to be met for the new construction of municipal buildings (Feiock, Krause, Hawkins, & Curley, 2014). Currently, legislative mandates are usually limited to public-sector buildings (Lewyn, 2014). Using matching methods and instrumental variables, Simcoe and Toffel (2014) indicate that these municipal regulations on governmental buildings produce spillover effects that stimulate private-sector adoption of the LEED certification. Building on their work, this analysis informs whether and how these local regulations also stimulate pursuit of non-building performance benefits.

For private-sector buildings, previous literature lists many market benefits of green building and certification. For example, certified green buildings benefit from the increase in property value for commercial and residential properties (e.g., Deng & Wu, 2014; Fuerst & McAllister, 2011b; Shewmake & Viscusi, 2015), including a premium on sales prices or rental rates, and occupancy rates (Eichholtz, Kok, & Quigley, 2010; Fuerst & McAllister, 2011a). The sources of this premium could be reduced utility costs, improved productivity (e.g., lower staff turnover, absenteeism), and reputation benefits (Chegut, Eichholtz, & Kok, 2014; Fuerst & McAllister, 2011b; Pivo & Fisher, 2010). Many of these benefits are likely to geographically cluster, consistent with previous research showing the spatial clustering of LEED buildings (Kahn & Vaughn, 2009; Kok, McGraw, & Quigley, 2011).

The important market benefits for private-sector buildings arising through enhanced branding or reputation (Steel, Pierce, Warner, & Lovrich, 2014) often fall under the banner of Corporate Social Responsibility (CSR). CSR can allow firms to charge premium prices, or to attract better employees and investors (Eichholtz et al., 2010; Milgrom & Roberts, 1986; Turban & Greening., 1997). Many owners and managers invest in greener buildings for strategic, CRS-related reasons (Gliedt & Hoicka, 2015). Since CSR is difficult to identify, it is not surprising that there is not much positive empirical evidence on the relationship between CSR and profitability (Aupperle, Carroll, & Hatfield, 1985; Sen & Bhattacharya, 2001). In theory, however, CSR does provide many benefits to a firm (Amacher, Koskela, & Ollikainen, 2004; Lyon & Maxwell, 2008). These nonfinancial, strategic considerations can influence energy efficiency

investments (Cooermans, 2011), including marketing benefits and sending green signals to niche consumers (Fuerst, Oikarinen, & Harjunen, 2016)

Since the source of non-building performance benefits differs by owner type, the magnitude of non-building performance benefits is also expected to be different. For government agencies and non-profit organizations, non-building performance benefits may play a more important role than for profit-maximizing firms, because their missions may include “the right thing to do” (Wood, 1991), and because they are less constrained by profit-maximizing exigencies and competitive forces (Eichholtz, Kok, & Quigley, 2009). Based on the theory of the firm in microeconomics, Matisoff et al. (2014) theoretically show the output-maximizing organizations (like some government agencies and nonprofits) face similar incentives to invest in green signaling as profit-maximizing firms do, and they empirically find that non-profit organizations tend to signal non-building performance more. If improving a building’s environmental performance can be expressed as achieving higher scores in LEED certification, this argument leads to the hypothesis that the LEED achievement for government agencies and non-profit organizations is more affected by the non-building performance value than for-profit firms are.

Data

Since spatial distribution is critical to this study, the study area is limited to the contiguous United States. The data used in this study comes from two sources. The data on LEED certification is publicly available on the USGBC website. The dataset includes

scores achieved and certificate tier, as well as characteristics for each building, such as project name, address, version of LEED, date of certification, owner type, project type, and building size. The USGBC data divide owner type into several categories: federal government, state government, local government, for-profit organization, non-profit organization (e.g., Environmental Defense Fund, Alliance to Save Energy), individual, and others. For simplicity, this study divides the data into three types of owners: government agencies (including federal/state/local government), non-profit organizations, and for-profit firms. Individual owners and other owner types, which contribute less than 10 percent of the data as a whole, are not included in this study for simplicity purposes.

In order to keep the scoring system consistent and comparable, this study only includes 4,472 buildings that are in the U.S. and are with LEED New Construction (LEED NC) version 2.0 to 2.2. In this scoring system, a score of 26 to 32 earns a certificate, a score of 33 to 38 earns a Silver certificate, a score of 39 to 51 earns a Gold certificate, and a score over 52 earns a Platinum certificate. Figure 1 shows the frequencies for each score at the national level. Figure 2 shows the spatial distribution of the 4,472 LEED buildings included in this study.

[Insert Figure 1 here]

[Insert Figure 2 here]

As shown in Figure 1, the skewed, “upside-down sawtooth” distribution clearly indicates some interesting patterns in the data at the macro level, implying the existence of signaling effect. Of course, project-specific factors facing building owners affect where that observation falls in the observed distribution. Yet, broadly speaking, some discontinuous benefits with each tier attracts bunching just above thresholds (Shewmake & Viscusi, 2015). Owners tend to recognize the potential benefits of upgrading to the next highest certificate level, and thus choose to pay additional costs to move up a tier rather than stay just below the threshold. The high density at scores just above thresholds implies that building owners tend to either earn a couple more credits to upgrade to the next certificate tier, or stop making improvements since a couple more credits will not bring them to the next highest tier. Note that the potential benefits for achieving the next highest certificate tier are not for certain. Building owners have to evaluate their own risks and make the choice. The fact that not every just-below-threshold building chooses to go for the next level and take the additional benefits implies the existence of upgrading costs and risks. Of course, the LEED context is very complicated at the micro level, where cost-benefit analysis and simple return on investment is highly contextual. This study analyzes the green building data at a more systemic, macro perspective. Future work, including case studies, could investigate these micro-level factors in more detail.

The high frequency of scores above threshold scores indicates that building owners sometimes overshoot when they aim for threshold scores. For a building that is only one credit shy of the next higher certificate tier, the best improvement available might worth at most, say, three points. The building thus might end up with two points higher than the threshold, and the driving force of moving to its current score is mainly signaling from

the next tier. Thus, scores that are one or two points just above thresholds should also be included in the identification of the amount of signaling associated with upgrading to the next LEED tier.

To further clarify the effect of municipal regulations on the signaling of LEED certification, the regulation data from the Integrated City Sustainability Database (ICSD) is used in this study (<https://localgov.fsu.edu/ICSD/>). ICSD is a comprehensive dataset of U.S. municipal government sustainability programs and policies (Feiock et al., 2014). The variable used here is a dummy variable from the survey question “Does your city require all new government construction projects to be LEED or Energy Star certified?” Surveys related to this variable are conducted between 2010 and 2011. The response rate is over 70%, which is relatively high. Altogether, 350 out of 2,003 respondent cities reported these requirements at the time of survey. The variable reflects whether the policies are in the place at that time.

Methodology

This study quantifies the signaling effect in the pursuit of LEED certification by utilizing a kernel density function, which generates smooth conditional expectations based on input-distributions (Silverman, 1981). The identification of the signaling effect can be summarized into four steps. First, a histogram of scores achieved at the national level is generated for each owner type. Second, all the densities that are around thresholds, both below and above, where the signaling effect mainly occurs, are dropped from the histogram. Third, the kernel density estimation is performed to generate a new

distribution based on the histogram for remaining observations. And finally, the original, observed densities are compared to the new distribution, where densities that are dropped in the second step are replaced by kernel estimates from the third step. The theoretical background and more details about this process can be found in Matisoff et al. (2014) and in a very similar model by Shewmake & Viscusi (2015). The advantage of this process is that, by removing densities that are affected by the signaling effect, the observations left reflect the distribution as if there were no signaling effect. After recovering the missing densities with the kernel density function, the new distribution can be viewed as the counterfactual distribution based on pure building performance value (not influenced by the disturbances around the thresholds). Thus, by comparing the original and the counterfactual densities, the *Signaling factor* for each threshold score i can thus be defined as:

$$(\textit{Signaling factor})_i = \frac{(\textit{Original density})_i - (\textit{Counterfactual density})_i}{(\textit{Original density})_i}$$

The signaling factor represents the estimated proportion of observations that exceeds what we would otherwise expect in the absence of threshold effects for each score because of the discontinuous value of LEED certification at the thresholds. Assuming that environmental quality or building performance rises continuously in LEED scores, this approach quantifies the discontinuous jump associated with the “signaling value” (or non-building performance value). In other words, it can be viewed as a quantitative measure of signaling effect for each score (for certain owner types).¹

¹ This assumption relies on the design of the LEED NC certification scheme, where thresholds are based on proportions of the base points available and that attained scores rely on a bundle of attributes that all positively contribute to environmental performance. This allows the construction of a signaling factor,

The identification of this signaling effect is sensitive to the designation of how wide of a neighborhood of scores around the each threshold will be dropped. Dropping fewer scores keeps more information for the generation of kernel density, but the counterfactual density may be influenced by projects that over-shot thresholds. Thus, the measured signaling effect is likely to be underestimated. Dropping more scores captures more of the signaling effect, but leaves less information for the generation of kernel density, possibly biasing the estimates. This study drops three scores for each tier (i.e., the threshold score, one above, and one below) as the default. Dropping one score (the threshold only) and five scores (the threshold, two above and two below) are reported as sensitivity checks.

After identifying the intensity of signaling for each LEED score, the second stage of the study then turns to identify the mechanism behind the signaling effect. A regression model that explains the relationship between the signaling effect and municipal regulations², and the global Moran's I that identifies the spatial dependence of the signaling effect, are estimated for this purpose. For the regression model, it can be written as:

$$\text{Signaling factor} = \alpha + (\text{Regulation})\beta_1 + (\text{Owner type})\beta_2 + (\text{Reg} \times \text{type})\beta_2 + (\text{Number counts})\beta_3 + (\text{Num} \times \text{type})\beta_4 + \varepsilon$$

which applies on average or in aggregate, although it cannot calculate signaling for a particular building (i.e., on a case-by-case basis).

² Regulations are limited to municipal regulations for two reasons. First, the cross-sectional model would have no variation in national-level regulations. Second, local regulations are where there is the most variation in policies (Matisoff et al., 2016).

where the *Signaling factor* denotes the corresponding signaling factor for each observation (i.e., LEED building project) according to the owner type classification and the scores achieved. *Regulation* is a dummy variable that takes on the value of unity if the observation is located in a city with municipal standards. *Owner type* denotes the dummy variable for each owner type. *Reg × type* refers to the interaction terms between *Regulation* and *Owner type*. *Number counts* denotes the total number of LEED buildings in the municipal jurisdiction of the observation, and *Num × type* refers to the interaction terms between *Number counts* and *Owner type*. Note that only positive signaling factors (i.e., when the original densities are larger than the counterfactual ones) are assigned in this process. Signaling factors with negative signs are coded as zeros to avoid exaggerating (i.e., double counting) the signaling effect of thresholds.

The global Moran's *I* is used to measure the spatial correlation of signaling effect in this study. The first step is to assign signaling factors to each LEED-certified building based on owner type. Again, only positive signaling factors are assigned in this process. The global Moran's Index (Moran's *I*), which is an index to reflect the level of spatial correlation (Moran, 1950), is then calculated to identify the spatial dependence of signaling factors. Moran's *I* is defined as:

$$Moran's\ I = \frac{n}{\sum_{i=1}^n \sum_{j=1}^n \omega_{ij}} \frac{\sum_{i=1}^n \sum_{j=1}^n \omega_{ij} (X_i - \bar{X})(X_j - \bar{X})}{\sum_{i=1}^n (X_i - \bar{X})^2}$$

Where *n* is the number of spatial units, ω_{ij} denotes the element of spatial weights between observations *i* and *j*, *X* is the variable of interest (the signaling factor in this case) and $\bar{X}$ is the mean of *X*. Spatial weight ω reflects how “neighbors” are defined. For example, it can be a dummy variable showing whether two units are directly contiguous,

or it can be the inverse distance/squared inverse distance between observations, reflecting the gradient of influence by distance. In this study, the method of inverse distance is used to calculate the global Moran's I . Contiguity is not applicable here because nearly no LEED buildings are adjacent to each other. In normal cases, Moran's I ranges from -1 to 1, where -1 represents the case of perfectly dispersed, 1 illustrates perfectly clustered, and zero means purely random. But in some extreme cases, such as when the variable X is strongly skewed or when ω_{ij} is extremely small, Moran's I can exceed the bound of -1 and 1.

Result and Discussion

1. Identifying Signaling Factors

The first part of this study identifies the signaling factor for each score by owner type. As mentioned in the Method section, the signaling factor reflects the weight of non-building performance value in the decision process. Table 1 summarizes the calculated *Signaling factor* by owner type. For each owner type, three scenarios of generating signaling factors are used: (1) only the threshold score of each certificate tier (scores of 26, 33, 39, and 52) are replaced by kernel estimates; (2) three scores (the threshold score, one above and one below) are replaced for each certificate tier; and (3) five scores (the threshold, two above and two below) are replaced. The dotted lines denote the threshold for each certificate tier.

Table 1 Signaling Factors by Score and by Owner Type, for Various Scenarios

% of subsample	Governments			Non-profits			For-profits		
		45.6			22.7			31.7	
Score\Scenario	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
24			-			-			-
25		-	-		-	-		-	-
26	0.62	0.79	0.90	0.59	0.72	0.80	0.52	0.64	0.66
27		0.32	0.44		0.48	0.57		0.27	0.33
28			-0.03			0.18			0.23
31			-0.61			-0.39			-0.92
32		-0.57	-0.68		-0.87	-0.52		-1.26	-1.60
33	0.48	0.72	0.88	0.51	0.67	0.78	0.52	0.57	0.60
34		0.46	0.69		0.56	0.75		0.11	0.42
35			0.48			0.54			0.60
37			-0.33			-0.30			-0.10
38		-1.36	-1.34		-3.49	-1.78		-8.76	-6.36
39	0.56	0.77	0.84	0.53	0.64	0.71	0.48	0.60	0.58
40		0.51	0.59		0.48	0.54		0.59	0.56
41			-0.11			0.02			0.14
50			-0.72			-			-
51		-	-		-	-		-	-
52	0.60	0.81	0.88	0.50	0.65	0.69	0.63	0.79	0.75
53		0.52	0.55		0.56	0.60		0.65	0.67
54			-0.26			0.01			0.25

Note: the signaling factor is marked as '-' if the original density at that score is 0.

The interpretation of Table 1 focuses on the second scenario (shaded columns) that replaces three scores for each threshold. Comparing Scenario (1) and (2), it is clear that the signaling effect is stronger in Scenario (2) for all owner types. Given the fact that building owners sometimes overshoot when aiming for the threshold, it is expected that replacing more scores around the thresholds captures more signaling effect. Thus,

Scenario (2) is preferred to Scenario (1). In comparing Scenario (2) and (3), Scenario (2) is preferred for mainly two reasons. First, the negative signs for scores above thresholds (e.g., 28, 41) are signs of over-estimation. By definition, a negative signaling factor means that the actual density at which score is smaller than the counterfactual kernel estimate. Negative signaling factors are expected for scores just below thresholds, because it provides evidence that non-building performance value often makes those just-below scores less preferable. But this theoretical explanation does not necessarily apply to scores just-above thresholds. No theory suggests that building owners would rather achieve a lower score than they otherwise would have, because of non-building performance value. Thus, these negatives on the right-hand side of the thresholds are viewed as a result of replacing too many scores' densities by kernel estimates. In addition, the magnitude of signaling factors in Scenario (3) is not significantly larger than that in Scenario (2). Therefore, Scenario (2) is preferred to Scenario (1) and (3). Still, the result for Scenario (1) and (3) is reported as sensitivity checks.

The negative signaling factors in Table 1 indicate that building owners tend to avoid achieving scores that are just below the thresholds. An alternative definition of signaling factors, which avoids negative values, replaces the denominator with the kernel estimates. The result for the alternative definition follows the same pattern displayed in Table 1. The interpretation of the regression results for these two definitions is identical, too. This study keeps the current definition for a more straightforward interpretation.

Comparing signaling factors by owner types provides a view of how owner type affects behaviors. The signaling factors for government agencies are significantly higher than those for non-profit organizations and for-profit firms. Nearly 80 percent of

government buildings that are right at the thresholds only achieve the thresholds for non-building performance reasons. One possible source of this strong non-building performance value is the legislative mandates that require government buildings to go green (May & Koski, 2007) and attain a certain certification tier. The next section tests this hypothesis. Agencies that seek to comply at minimal cost will attain just above thresholds and appear like they are seeking a (non-building performance) signal. When the government agencies are the only owner type that is required to achieve certain certificate tier (even if it is not cost-effective), a higher signaling effect for them is expected.

Non-profit organizations generally signal more than for-profit firms do, except for those in the Platinum certificate tier. Under the assumption that for-profit firms care more about profitability, this result implies that for-profit firms either do not value this signaling as much as governments/non-profit organizations at lower certificate tiers, or they do not think the payoff is large enough to overcome the costs and risks. At the Platinum level, the possible benefit of signaling seems to be high enough for for-profit firms to be willing to take the risk and signal as much as governments and non-profit organizations do. Conversely, non-profit owners tend to overshoot the Platinum threshold more than other owners, driving down their signaling factor and suggesting that these organizations are trying to maximize environmental performance and marketing signals are secondary. Non-profits at the top-tier Platinum level may be more like those niche, green consumers (Fuerst et al., 2016). At the Platinum level, governments and for-profit firms may not have that priority or luxury and hence bunch at the threshold. Also, this could be a result of thin data. Only 4.5 percent (64 out of 1,416) of the certified for-

profits choose to pursue for the Platinum, which is much lower than that for non-profits (9 percent).

2. The sources of signaling for different owner types

The second part of this study introduces the results in the first part into the inquiry of the sources of non-building performance value by owner type. The global Moran's I , and the regression model of signaling on municipal regulation, is introduced for this purpose. The global Moran's I is first used to see whether the signaling factor (i.e., the effect of non-building performance value) is spatially clustered. This study assigns the signaling factor to every LEED-NC building by the owner type and scores achieved. As mentioned in the Method section, only signaling factors with positive signs are assigned. (Observations with negative signaling factors are all assigned a value of zero.) The global Moran's I of the signaling factor, which reflects the status of spatial dependence, is then calculated. The results are shown in Table 2.

Table 2 Spatial Clustering (global Moran's I) of Signaling Factors

	Threshold scores	All types	Governments	Non-profits	For-profits
Signaling factor1	26, 33, 39, 52	0.101 **	0.090 *	0.282 *	0.285
Signaling factor2	26, 27, 33, 34, 39, 40, 52, 53	0.288 ***	0.297 ***	0.283 *	0.545 ***

Signaling factor3	26, 27, 28, 33, 34, 25, 39, 40, 41, 52, 53, 54	0.396 ***	0.380 ***	0.230	0.558 ***
Signaling dummy1	26, 33, 39, 52	0.082 *	0.066	0.270	0.299 *
Signaling dummy2	26, 27, 33, 34, 39, 40, 52, 53	0.332 ***	0.342 ***	0.263	0.467 **
Signaling dummy3	26, 27, 28, 33, 34, 25, 39, 40, 41, 52, 53, 54	0.337 ***	0.349 ***	0.159	0.424 **

*p < .10. **p < .05. ***p < .01.

The first three rows in Table 2 show the global Moran's *I* by scenarios of the signaling factor for each owner type. The following three rows indicate the global Moran's *I* for "Signaling dummies," which takes a value of unity for all observations attaining a score at or just above a threshold. This study focuses on the results of Scenario 2 (shaded rows) and lists the other two scenarios as sensitivity checks. The signaling factors for all observations show strong evidence of spatial clustering. The result by owner type shows that the clustering mainly exists for both government agencies and for-profit firms. For governments, the significant spatial clustering in signaling is evident across the nation, spanning jurisdictions that require greener government buildings and those that do not.

The spatial clustering of signaling is significant and strong for for-profit firms. Furthermore, the spatial correlations in Table 2 refer to the *Signaling factor* and the signaling dummy, revealing spatial correlations in non-building performance signals. The spatial clustering suggests several possible sources of the signaling effect for for-profit firms. The first possible explanation is localized demand for green buildings. By showing

that the non-building performance reason for pursuing LEED certification clusters more than LEED buildings per se, the results of this study are consistent with localized demand for greener buildings. Also, the signaling for for-profit owners might cluster in locally well-developed LEED markets. It may also reflect a localized supply, expertise, or clustering in building practices that emphasize non-building performance signaling, perhaps due to supply-side spillovers from public-sector mandates that have been previously observed (Simcoe & Toffel, 2014).

Another possible source of the non-building performance value for for-profit firms is the local competition. Although literature indicates that local governments competing with each other for the leadership in going green (Sharpe, 1970), it is generally expected that the competition among local firms is stronger than that between governments. To further explore conditions that support local clustering of non-building performance signals, local indicators of spatial autocorrelation (LISAs) are calculated per Anselin (1995) for for-profit-owned buildings. The local Moran statistic calculated for particular buildings is a local analog of the global Moran's I and can be used to identify outliers or "hot spots." Correlating local socioeconomic conditions (from the 2000 Census) with these LISAs can detect if spatial clustering of signaling factors tends to be particularly pronounced in certain areas. Among cities with four or more LEED projects, for-profit LEED projects with higher LISAs are located in places with lower populations, higher education, and higher incomes. The correlations between LISAs and logged population ($\rho=-0.65$, $p<0.01$), logged median household income ($\rho=0.39$, $p<0.01$), and the share of adults with college degrees ($\rho=0.30$, $p<0.04$) for those 51 for-profit-owned buildings are significant and substantial. "Hot spots" of spatially clustered signaling tend to be found in

smaller, wealthier, and more educated places, suggesting important roles for local markets in influencing non-building performance signaling.

The signaling of non-profit organizations shows far less clustering compared to other owners. There are three possible reasons for this. First, legal obligation for green buildings seldom applies to non-profit organizations. Second, they may care less about cost effectiveness and profit maximizing, so targeting thresholds may be less important for them. Finally, non-profit organizations may be less likely to compete locally, partly because of the nature of non-profits and partly because they may be more likely to have a local monopoly (and not compete with other nearby nonprofits).

To further identify the sources of non-building performance value for different owner types, a regression model is introduced to identify the relationship between the signaling effect and the implementation of municipal regulation. For this purpose, the signaling factor determined in the first part is assigned to all the observations, according to the owner type and the score achieved. As mentioned previously, only signaling factors with positive signs are assigned. (The rest are truncated to a value of zero.) The results of regressions are summarized in Table 3. The interpretation focuses on the results for the “Signaling Factor 2” column, which is determined based on the signaling factors in Scenario (2). The regression results for the signaling factor in Scenarios (1) and (3) are also listed as a sensitivity check. The result generally follows the same pattern across scenarios.

Table 3 Regression Results for Signaling Factors

Observation: 4,377

Dependent Variable	Signaling Factor 2 (truncated)	Signaling Factor 1 (truncated)	Signaling Factor 3 (truncated)
F-statistic (10, 4366)	5.15 ***	3.47 ***	3.94 ***
R-squared	0.0113	0.0073	0.0084
Regulation	-0.053 **	-0.065 ***	-0.058 **
Government	0.005	-0.010	0.022
Regulation*Gov	0.092 ***	0.106 ***	0.083 **
For-profit firm	-0.058 ***	-0.015	-0.038 **
Regulation*Profit	0.071 **	0.073 ***	0.059 *
LEED bldg counts	0.004 ***	0.003 **	0.004 **
LEED count*Gov	-0.002 **	-0.001 **	-0.002 **
LEED count*Profit	0.000	0.000	-0.001
Gov LEED bldg counts	-0.004 **	-0.003 *	-0.004 *
Profit LEED bldgs counts	-0.005 **	-0.005 **	-0.006 **
Constant	0.281 ***	0.139 ***	0.362 ***

*p < .10. **p < .05. ***p < .01.

Due to the existence of several interaction terms in the model, linear combinations of estimators are needed to further identify the effect for each owner type. Several interesting results of linear combinations of estimators for the Signaling Factor 2 are listed in Table 4.

Table 4 Result of Linear Combinations of Estimators for Signaling Factor

Dependent Variable: Signaling Factor 2 (truncated)	Coefficient
Reg + Reg*Gov	0.039 **
Reg + Reg*Profit	0.019
LEED_count + LEED count_Gov	0.000
LEED_count + LEED count_Profit	-0.001
LEED_count + LEED_count*Gov + LEED count_Gov	-0.002 **

LEED_count + LEED_count*Gov + LEED count_Profit	-0.003 *
LEED_count + LEED_count*Profit + LEED count_Gov	-0.001
LEED_count + LEED_count*Profit + LEED count_Profit	-0.001

*p < .10. **p < .05. ***p < .01.

Since dummy variables of government agency and for-profit firm are both introduced into the model, the main coefficients in Table 3 only reflect the effects for non-profit organizations. The negative sign of *Regulation* surprisingly indicates that for non-profit organizations, municipal regulations predict LEED buildings with five percentage points lower non-building performance signaling factor. Note that the negative effect here does not mean that non-profit owners score or adopt less with municipal regulations. It only implies that non-profit owners tend to invest more in building performance improvements, rather than marketing or tier-related signaling. One possible explanation is that the mandates create a richer, more skilled market for LEED certification. Non-profit owners could then learn from government adopters, thus finding better return on investment and so a greater emphasis on building or environmental performance.

Having one additional nonprofit organization with LEED certificate within the same municipal jurisdiction will increase the average signaling factor for nonprofit buildings by 0.4 percentage points. In other words, having more nonprofit organizations with LEED buildings in town makes a nonprofit organization more likely to pursue the next highest tier (largely due to the signaling reason). Additional LEED buildings for other owner types do not significantly affect the LEED signaling behavior of nonprofit organizations in the same metropolitan area.

Linear combinations are needed to appreciate the effects for other owner types. The results are listed in Table 4. For government agencies, the effect of regulation is confirmed. Municipal regulations increases government agencies' signaling factor by nearly four percentage points. Having an additional government agency with a LEED-certified building in town decreases the tendency of signaling for government agencies by 0.2 percentage points, while adding an additional for-profit firm with a LEED building decreases the tendency of signaling by 0.3 percentage points.

For for-profit firms, the effect of regulation is not significant. The result is as expected, since municipal regulations typically do not directly apply to for-profit owners. The effect of adding another for-profit building with LEED in a city is not significant either. This result is not consistent with a strong role for local competition, since more competition does not lead to more signaling. This is a fairly weak test, however, as marginal for-profit LEED buildings may not compete in the same sector or market as other LEED buildings in the city.

3. Study limitations

There are several limitations to this study. First, limited information provided by USGBC raises concerns about unobserved heterogeneity. Identifying the current unobserved information of each LEED building, such as the marginal cost of pursuing an extra credit or to the next highest tier, or many important factors that go into the design of buildings, would help further understand the behavior of LEED buildings. Current results in this study are general and unable to identify signaling motivations for specific projects.

Further, unobservables, such as other unmeasured local regulations or plans, are a concern insofar as they are correlated with both LEED adoption and the measure of *Regulation*. Future research should explore other measures of regulations, perhaps building on the DSIRE datasets.

Second, calculating the spatial dependence with data spanning a decade raises concern about using a cross-sectional analysis. Being the first analysis of this type, this study's cross-sectional approach gives important and novel evidence about geographic patterns rather than temporal dynamics. Examining only new construction certification helps focus the analysis on buildings as initially constructed, but it also overlooks other types of green building certification. Also, this study focuses on building owners rather than tenants, who may change over time and who may relate to non-building performance signals differently than original owners. Further investigation on the impact of tenants is needed. Of course, more direct measures of motivations for why each project pursued LEED certification as they did would be illuminating. The approach here has an advantage of leveraging an objective behavioral measure as the signal itself (i.e., points earned) rather than relying on survey data or case studies. Nonetheless, additional research with improved measures of the stakeholders and the "target audience" for LEED signals would complement this broader perspective.

Conclusion

Looking at certification behavior of thousands of new LEED buildings over a decade, the preponderance of buildings achieving scores just above thresholds reflects the

importance of non-building performance benefits generally. The effect of non-building performance values differs by owner type and by certificate tier. For all tiers except Platinum, government agencies and non-profit-organizations signal more than for-profit firms. This result generally confirms the hypothesis that governments and non-profit organizations rely on green marketing signals as much or more than profit-maximizers, because their different objectives afford them more opportunities for strategic investments and less pressure for financial returns and cost effectiveness of building performance. Once at the Platinum level, however, for-profit firms rarely pursue additional credits and tend to rely heavily on the signal of the tier itself. Of course, these general patterns in the data cannot directly account for particular green-building projects' benefits, costs, and risks from pursuing (non-building performance) signaling. A closer investigation of individual projects' approach to green signaling is warranted based on the strong pattern of projects bunching just above thresholds in the LEED tier system, across various owner types and local regulatory conditions.

Also, by checking the spatial clustering of the signaling factor, and by regressing the signaling factors on regulations, this analysis tests possible systemic sources of the non-building performance value in the pursuit of LEED. It is evident that government regulations are the main source of the non-building performance value for government agencies. For for-profit firms, the evidence does not point to local regulation or competition (in terms of more for-profit LEED buildings) as sources of non-building performance value. Localized demand drivers, such as higher education and incomes, are positively associated with spatially clustered signaling factors. Although these socioeconomic factors may not promote more non-building performance signaling

generally, they do play a role in establishing local conditions to support “hot spots” of green signaling. Further research is required to better understand for-profit builders’ behavior.

The results of this study have some policy applications. First, the clustering just above tier thresholds points to opportunities for information-based policies to provide incentives to build greener beyond what tiered signaling schemes or minimum standards for compliance provide. Information provision policies, for instance, may help accelerate peer effects in adopting green building practices. Second, better understanding the strategies behind the pursuit of LEED helps future regulatory design. The importance of non-building performance aspects of the signal apparent in LEED certification behavior supports “the development of public programs which try to highlight the strategic character of these investments” rather than the simply financial (Cooremans, 2011, p. 488). For example, taxes and subsidies might not be as effective for non-profit organizations as for profit firms, because non-profit organizations are not as responsive to the change of costs at thresholds. Also, the negative effect of *Regulation* in Table 3 suggests not that mandates for government buildings to be greener do not spillover to the private sector, but rather that private-sector projects in cities with those mandates tend to bunch less around thresholds. Insofar as that means a greater emphasis on building performance, this indicates that spillovers from procurement policies may get adapted by the private sector to make greener buildings. Finally, the existence of spatial clustering in signaling would possibly facilitate place-based policies to stimulate green buildings. By encouraging pilot projects in the region, such as providing technical assistance or subsidies to encourage new construction to achieve a higher certificate tier, the numbers

of achieving high certificate tiers, as well as adoption of LEED, may grow dramatically due to the spatial spillover. The analysis here points to these general policy themes as promising directions, but more research on local policy experimentation is needed to refine them into more practical recommendations in today's dynamic green building landscape.

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