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For what it's worth: evaluating revealed preferences for green certification

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In a case study that examines the outcomes of a flexible information-based policy, we observe how organizations obtain Leadership in Energy and Environmental Design certification. We use a regression discontinuity analysis to identify practices used to upgrade certification tiers. This analysis reveals preferences for green certification strategies and, we argue, intimates the perceived motivations for green certification. We distinguish practices that potentially confer private gains through returns to efficiency and productivity investments, from practices that only provide public benefits. Data show that organizations strategically certify to avoid high-cost resource use, appeal to key stakeholders, and communicate building and organization quality. Builders upgrading to the highest tiers are more likely to deploy practices with private gains. Results suggest a willingness to extend short time horizons associated with energy-efficiency investments in exchange for marketing benefits. Our discussion notes the capacity for certifications to mitigate market barriers associated with the energy-efficiency gap.

Keywords: green certification; signaling strategy; energy-efficiency gap; corporate sustainability; regression discontinuity

1. Introduction

Sustainable products have numerous qualities that are difficult for potential buyers and occupants to observe. Hidden building qualities potentially lead to a 'market for lemons' (Akerlof 1970) in which consumers cannot distinguish green or high-quality buildings from traditional or low-quality ones. These information asymmetries combine with other market failures and barriers (including externalities, high discount rates, and short time horizons), discouraging investment in sustainability overall. Policy interventions seek to mitigate this gap between efficient and actualized levels of investment in sustainability. Policies have traditionally been limited to building codes or other regulations, though flexible, market- and information-based instruments such as labels or certifications have become increasingly popular (Keohane, Revesz, and Stavins 1998). Despite decades of experience implementing these policies, we still lack fundamental understanding of the types of changes organizations make in order to comply (Koehler 2007). In this manuscript, we explore the types of practices induced by one prominent green certification in the building industry.

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Under flexible policy mechanisms and certifications, compliance is not strictly defined to a single pathway. We take the set of practices adopted to obtain certification as the 'certification pathway,' which can be observed empirically in a large quantitative study. To examine heterogeneous compliance pathways under a flexible policy mechanism requires high-resolution data from one empirical setting. This allows a direct answer to our research question, which asks how organizations prefer to certify green when pursuing compliance with a flexible policy mechanism. We do not examine differences between certified and uncertified projects, nor the sequences of decision protocols, which have been the subject of previous research (Corbett and Muthulingam 2007; Koehler 2007; Fischer and Lyon 2013).

We aim to describe certification pathways with the rich level of detail capable of providing meaningful insight for scholars and practitioners. Our data come from a proprietary database detailing all actions taken toward a common green building certification in the United States, though we note the prevalence of green building labels with similar requirements and characteristics around the world (Matisoff, Noonan, and Flowers 2016). Recent literature has highlighted the popularity of these green building programs, in part due to the premium rental and sale prices awarded for adoption in the United States (Devine and Kok 2015; Eichholtz, Kok, and Quigley 2010a), United Kingdom (Chegut *et al.* 2010), and Hong Kong (Yau 2012), among others. These studies identify *consumer* preferences for green building by revealing the *willingness-to-pay* premiums for certified green buildings. By contrast, our study examines *producer* preferences by revealing the types of practices builders are willing to adopt in pursuit of certification.

We structure our study as follows: first, our literature review demonstrates how the design of green building labels is intended to address market failures related to sustainability in the built environment. We then provide a detailed introduction to our empirical context before setting up hypotheses tested through our analysis. These hypotheses serve to structure our depiction of certification pathways in a theoretically meaningful way. One limitation of our approach, as described in the subsequent methods section, is that these data are not well suited for nuanced causal analysis. Rather, they provide a richer description of the actions taken to comply with a flexible information-based policy. Future work may build on these findings, as detailed in the discussion and conclusions.

2. Background and literature review

Green building certifications verify sustainable qualities, communicating this hidden information to stakeholders (Amacher, Koskela, and Ollikainen 2004; Eichholtz, Kok, and Quigley 2010a; Mason 2013; Reichardt 2014). That is, by certifying a building with a green label, owners quickly provide information to potential investors, tenants, consumers, and employees. This 'signaling' may reflect on both the building and its owner or occupant (Matisoff, Noonan, and Mazzolini 2014), communicating quality at apparently low costs (Eichholtz, Kok, and Quigley 2010a). By clearly distinguishing high- from low-quality buildings, certifications provide signaling benefits such as higher rental or sales prices for the property, improved occupancy rates, and greater tenant retention (Chegut *et al.* 2010). These signaling benefits incentivize otherwise cost-prohibitive green practices (Mason 2012).

2.1. *The case of LEED*

In particular, the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) label has gained significant traction in the United States. There, LEED certification labels as much as 5% of the new commercial buildings, and 30% of the new commercial office space in the 30 largest metropolitan areas (Kok and Holtermans 2014). The LEED program works by certifying specific building improvements that reduce the environmental footprint of a building. LEED certification is based on the sum of dozens of different green practices, for which firms earn 'credit' toward a composite score. LEED scores are then tiered into four certification levels. Because certification is simply based on the total number of credits attained, the pathway to certification is highly customizable. The tiered, flexible structure of the LEED label appears to have diffused to similar programs around the world (Matisoff, Noonan, and Flowers 2016).

With myriad certification pathways comes variance in environmental quality among certified buildings. Some LEED credits are thought to reduce a building's operating costs by increasing efficiency, or are thought to improve employee productivity and indoor environmental quality. Other practices accepted toward LEED certification offer no such return on investment, but improve environmental outcomes for the surrounding community. Sustainable practices that offer no returns may be worthwhile if certification is leveraged to provide stakeholders some indication that the organization occupying the building is of elite quality, has green values, and is socially responsible (Potoski and Prakash 2009). Throughout, we refer to credits conferring potential returns as having private (versus public) benefits.

Such variance presents unique challenges to scholarly understanding of certification outcomes in the built environment. There has been much debate about the value of green certification, with unclear evidence on energy intensity of certified spaces (Brounen, Kok, and Quigley 2012; Chegut *et al.* 2010), in addition to the aforementioned attention to market premiums from signaling green. Yet a variety of other environmental outcomes are not captured by these assessments. What are organizations willing to do to gain signaling benefits? A better understanding of certification pathway heterogeneity may shed light on the nuanced relationships between certification, market premiums, and energy efficiency.

Prior research on certification pathways has only identified broad patterns suggesting that certification can signal both building and organization quality (Matisoff, Noonan, and Mazzolini 2014; Corbett and Muthulingam 2007), treating certification behavior as a 'black-box' process. We use a proprietary data-set from the USGBC to examine building-level certification choices to examine variation in certification pathways across organizations. Such high-resolution analysis has been limited to a handful of studies. Cidell and Beata (2009) aggregate buildings into large EPA regions, and sum credits by broad categories to explain regional differences in the use of general types of green practices. Others have used these data for small-*n* studies (Da Silva and Ruwanpura 2009) or have not sought to explain trends in certification pathways (Wu *et al.* 2016). By opening the black box of green certification pathways, we contribute to a growing body of knowledge that seeks to understand strategic approaches to, and motivations for, environmental certification.

2.2. *Certification pathways*

When pursuing certification, builders can target a specific LEED score, a tier, a set of environmental improvements they find desirable, and/or a set of environmental improvements their stakeholders will find desirable. An owner's preferred LEED credits may address environmental externalities related to energy, water, air quality, and land use in the built environment. These externalities are often coupled to information asymmetries. For instance, potential buyers cannot determine whether a building used sustainably harvested wood throughout construction, at any point, and can only ascertain whether the building design is energy efficient by assessing utility bills during occupancy. The credits that cannot be verified, such as sustainable forestry products, provide no occupant benefits, but do contribute to public goods, such as biodiversity. Credits that can be verified often provide private benefits to the occupant by reducing utility costs or by increasing productivity through enhancements to the indoor environment. Market premiums may accrue due to consumer preferences for either (Brounen and Kok 2011).

We distinguish between LEED credits that provide purely public goods versus those that could confer private benefits to the building occupant in Table 1. In this table, private benefits are operationalized as either cost-saving measures or measures that improve the user experience. The remaining LEED credits, which do not confer private benefits despite measured environmental mitigation, are classified as public.

Cost-saving credits are identified with respect to many practices. First, they may provide private returns by lowering electric utility costs through envelop efficiency, commissioned energy planning, and on-site renewable production. Second, efficient landscaping, low-flow internal water use, and innovative wastewater technology may similarly reduce water bills. Third, some credits lower costs in less obvious ways. Innovation and design credits frequently represent additional efficiency efforts in our data; reuse of materials during renovations avoid purchasing costs; reduction of rooftop heat island effects lowers the cooling cost of the building; reduction of light pollution limits wasted power for lighting; and indoor system controls for lighting and temperature provide comfortable conditions with minimal intervention.

Table 1. LEED credit categorization by two forms of private returns. Credits are considered to generate private returns when it could be argued that they reduce resource (utility) costs, or improve occupant (user) experience in a way that enhances productivity. The number of points available for each credit is included to the right.

Private returns: cost-saving		Private returns: user experience		Purely public returns	
Optimize energy performance	10	Air delivery monitoring	1	Refrigerant management	1
On-site renewable energy	3	Increased ventilation	1	Green power purchasing	1
Enhanced commissioning	1	Low-emitting materials	4	Construction air quality	2
Measurement & verification	1	Thermal comfort	2	Indoor chemicals	1
Controllability of systems	2	Daylight and views	2	Construction waste	2
Innovation and design	4	Development density	1	Renewable materials	1
LEED AP	1	Alternative transit	4	Certified wood	1
Building reuse	3			Site selection	1
Materials reuse	3			Brownfield	1
Regional materials	2			Habitat protection	2
Water-efficient landscape	2			Stormwater design	2
Wastewater technologies	1			Non-roof heat island	1
Water-use reduction	2				
Rooftop heat island	1				
Light pollution reduction	1				

User experience credits, on the other hand, enhance productivity by improving indoor environmental conditions. Green buildings emphasize indoor air quality through low-emitting materials and improved ventilation. High-quality interiors may also provide thermal comfort and controls, views of the outdoors, and lighting improvements. Neighborhood characteristics including development density, walkability, and access to alternative transit may also be preferred by users. Credits in this category are thought to reduce employee absences, attract better-quality employees, enhance retention, and improve employee productivity (Turban and Greening 1996; Lanfranchi and Pekovic 2014). Though not every credit listed in the cost-saving or user experience category yields a return for every building, we distinguish credits by their *potential* to provide a return. Our analysis will examine certification pathways at the individual credit level and in terms of these aggregate categories.

Notably, some in the building industry assert that there are no returns to the individual practices that constitute LEED certification. Because potential returns may be small compared to upfront costs, and because returns are delivered over a long time horizon, these building owners may discount potential private returns entirely. The emphasis on short time horizons and the use of high discount rates has been identified as a key contributor to the energy-efficiency gap (Hirst and Brown 1990). From this perspective, the only gains of certification come from market premiums.

2.3. Green signals and LEED tiers

Green certifications signal potential buyers and tenants that a building and its owner are of high quality. In this section, we detail how the structure of the program, which is one case among numerous related green building programs around the world, functions to signal both building and owner quality. The LEED certification scheme only awards points after environmental impacts are improved, so that the building's true environmental quality varies continuously with each LEED additional credit. However, the tiered structure of LEED means that *signals of building and organizational quality* only change at the thresholds between certification levels. Moving from one tier to the next requires the adoption of at least one new environmental practice, though organizational quality may not improve. By contrast, the signal of both building and organizational quality increases with this change in tier.

Builders can leverage LEED certification as simply an indicator of energy-efficient design (Eichholtz, Kok, and Quigley 2010b). LEED buildings have been observed to consume nearly 30% less electricity compared to real estate establishments matched on a wide array of covariates (Asensio and Delmas 2017).[1] Other performance advantages associated with different LEED credits include, for example, indoor environmental quality that makes the building a more desirable place to work and increases worker productivity (Cole 1998; Cidell and Beata 2009). These private benefits to sustainable practices accrue even without certification, though, perhaps not surprisingly, rental and sales premiums tend to increase with certification (Eichholtz, Kok, and Quigley 2010b). While designers could reap some benefits from green building without certification, information barriers may limit market returns to efficiency (Jaffe and Stavins 1994; Sallee 2014). Labeling through LEED allows owners to reduce information asymmetry between producers and stakeholders by verifying improved building performance with a simplified signal of building quality (Mason 2013; Majumdar and Zhang 2009; Fuerst and McAllister 2011).

While building quality improvements often provide returns with or without signaling, organizational quality must be labeled to provide returns (Matisoff, Noonan, and Mazzolini 2014; Corbett and Muthulingam 2007). LEED can signal qualities of the owner organization, signaling quality management, strong owner values, positive environmental externalities, and even product quality. Past work observes that LEED can signal employees, as firms occupying LEED buildings attract higher quality employees (Eichholtz, Kok, and Quigley 2010a). Further, Lanfranchi and Pekovic (2014) find that employees working for firms with green certification feel more useful and equitably recognized, and are more likely to work uncompensated overtime. LEED's signal of environmental quality may be important for investors (Saha and Darnton 2005), consumers (Sen and Bhattacharya 2001), employees (Turban and Greening 1996), or other stakeholders (Wood 1991). This is consistent with the theory that demonstration of corporate social responsibility (CSR) to stakeholders is linked to increased economic performance (Amacher, Koskela, and Ollikainen 2004; Lyon and Maxwell 2008), as perceptions of facility quality impact the owner, and the owner's goods and services. When LEED certification can be leveraged to signal organization quality, additional investments in sustainable practices may become worthwhile, whether those practices have tangible private benefits or not (Devine and Kok 2015).

Which practices are worthwhile at the margin between one level of signaling and the next? Analysis of certification pathways may indicate what builders hope to gain by going green, revealing latent preferences for green certification and signals. We frame our description and analysis of LEED certification with a suite of hypotheses, presented in the next section. Throughout, we argue that potential signaling benefits drive owners to these increased certification levels, and that the corresponding environmental practices adopted are selected to specifically appease key stakeholder groups.

3. Hypotheses: expected signaling strategies

The LEED certification program verifies building improvements in dozens of categories, corresponding to many types of environmental impacts across an immense set of available certification pathways. To give structure to the analysis of strategic certification, without losing the high resolution of credit-level data, we focus analysis on two dimensions. First, we examine the extent to which builders leverage credits with potential private benefits, as operationalized in Table 1. Second, we examine strategies used to upgrade to higher LEED tiers, to send stronger signals of building or organizational quality (Harbaugh and Rasmusen 2018). This approach opens the black box of green certification while reflecting on broader themes of interest to researchers and program managers. Our hypotheses test expectations that organizations strategically certify to (1) avoid high resource costs, (2) appeal to key stakeholders, and (3) signal that the building or owner is of high quality.

3.1. LEED as cost avoidance

All LEED credits mitigate externalities in some fashion, though some also provide private benefits, such that owners and occupants can experience the improvements through reduced utility costs and improved user (occupant) experience. Our first hypothesis states that builders leverage LEED to avoid high resource costs. Because the returns from efficient resource use increase when the costs of those resources are high, we anticipate high utility costs to be associated with greater energy efficiency (Ito 2014).

H1a: Energy-efficiency credits are more popular in states with high electricity prices.

We expect similar trends relating water prices and water efficiency (Arrow 1966). While electricity rates vary by state and utility provider, water prices tend to be higher in urban areas with higher stormwater and wastewater management costs (Roy *et al.* 2003). If supported, we take these as evidence that certification is strategically leveraged to avoid high resource costs.

H1b: Water-efficiency credits are more popular in urban areas with high water prices.

3.2. Customization for stakeholder appeal

If certification is motivated by potential signaling benefits, it is important to recognize that stakeholders must value the types of qualities signaled to be willing to pay market premiums (Spence 1973). This should imply some degree of pathway customization to stakeholder preferences. Our black-box understanding of certification inhibited estimation of this customization until now. We can observe tailored approaches to certification by relating information about the owner sector and industry to the LEED credits adopted.

LEED buildings serve many functions**,** which have variable design needs, and provide services to diverse consumers. For example, a LEED-certified apartment building may be more desirable to prospective tenants if the design emphasizes efficiency and indoor environmental quality. Hospitals and hotels may use similar strategies in appealing to their patients and guests. These owners target stakeholders that require improved user experience, alongside at least some emphasis on cost reductions.

H2a: Residential buildings obtain more credits with private benefits for tenants.

By contrast, government agencies may want to signal community stakeholders more broadly, emphasizing public goods rather than private gains. By adopting practices that improve the ambient rather than indoor environment, LEED adopters can appeal to stakeholders who may never enter the building. We argue that this is more important for organizations with a greater number of external stakeholders. This includes government agencies, but may also pertain to large private developments, which accrue much public attention. Owners of these buildings provide public benefits as a signal of elite status (Potoski and Prakash 2009).

H2b: Government buildings obtain more credits that have purely public benefits.

The logic linking owners and stakeholders through the certification pathway could be applied to test numerous hypotheses. Based on the data analyzed, we are able to do so for many types of building owners and industries. We present the highlights in the results and discussion.

3.3. Signaling through strategic upgrades

Under information asymmetry, practices must be bundled to certification to generate a signal (Spence 1973), particularly if the benefits are purely pubic goods (Kotchen 2006, 2013).

Though two buildings may have nearly identical environmental footprints, one may obtain an extra credit, upgrading to a higher certification tier, and signaling far greener than its peer (Harbaugh and Rasmusen 2018). To enjoy the benefits of green *signaling* (rather than just environmental impacts), many are induced to make additional improvements, obtaining just enough credits to upgrade to a higher level of LEED, as shown by Matisoff, Noonan, and Mazzolini (2014). That work demonstrates certain ownership types that are more likely to participate in this upgrading for signal benefits. Those making upgrades for signaling are henceforth termed ‘signalers.’

We here assert that systematic differences should also exist in sustainable practices chosen between signalers and non-signalers. Identifying marginal credits chosen to carry a firm to a higher certification tier can demonstrate how organizations value green signals. The probability of obtaining any particular LEED credit increases continuously and monotonically with the number of credits obtained. But, careful assessment can reveal disproportionate jumps in likelihood of adopting particular credits around LEED tier thresholds. We take these discontinuities as a measure of revealed preferences for specific LEED practices among those who upgrade (Chetty *et al.* 2011; Allen *et al.* 2017). As detailed above, these preferences may be associated with key stakeholder expectations. This conceptualization allows us to understand these marginal credit choices as highly related to the signaler’s motivation for, and perceived value of, green signaling.

Credits that do not yield private returns ordinarily may be bundled to green labels that indicate high firm and product quality, making adoption strategic. By providing exclusive status in exchange for public good provision (Potoski and Prakash 2005), credits providing only public benefits become more attractive components of certification pathways. Thus, we might expect that – regardless of a builder’s preferred mix of credits with private or public benefits – these signalers would favor public-benefit credits for upgrading. Those attaining the greener signals, likely valued more by their stakeholders, may tend to use public-benefit credits. An alternative hypothesis may be that signalers favor credits with more private benefits. For instance, organizations facing greater quality competition, such as for-profit firms, may be more likely to pursue private-return credits when they upgrade to obtain signaling benefits (Matisoff, Noonan, and Mazzolini 2014).

H3: Credits providing only public benefits are more common among ‘signalers’ than otherwise similar non-signalers.

Certifications have been shown to incentivize greater energy efficiency in the face of short time horizons and high discount rates that correspond to the energy-efficiency gap (Hirst and Brown 1990). When efficiency measures are especially high cost, these mitigation practices have returns that only emerge over a much longer time horizon. Firms may not wish to adopt higher-cost efficiency measures unless they certify at a higher level, because they are averse to these long-term investments with relatively low returns (Gillingham, Newell, and Palmer 2009). For LEED to foster the highest degrees of energy efficiency, some signaling benefits must be associated with efficiency credits that provide modest returns. If so, we anticipate that some signalers will upgrade through efficiency measures.

H4: Credits with low or long-run returns are more common among ‘signalers.’

The expectations in Hypotheses 3 and 4 are only partially opposed to one another. There may be some organization types that become signalers through different strategies. Or, some certification thresholds may justify different types of investment. We explore this further in our analysis, results, and discussion. In the next section, we describe our data, which is uniquely situated to answer the questions presented. Then, we develop a methodology for identifying the marginal credit obtained toward certification before testing hypotheses.

4. Data

The USGBC Green Building Information Gateway for the LEED New Construction version 2.2 certification program is the primary source of data for this study. Though data for other versions of LEED could be used, we restrict analysis to a single version for consistent comparison among green building pathways selected by designers. This version of the LEED standard allows a building to achieve up to 69 total points, with thresholds at 26, 33, 39, and 52 points representing the Certified, Silver, Gold, and Platinum tiers of certification, respectively. These thresholds correspond to 40%, 50%, 60%, and 80% of available 'base' points (which exclude innovation credits), rather than corresponding to natural cut-points in sustainable design. Under this system, builders must strategically pick and choose sustainable design practices until the desired certification level is reached.

Data include all information for nearly 3,000 LEED-certified buildings, including categorical information on building owner, use, location, size, and whether the project was publicly or confidentially certified. We pair each LEED observation with local average electricity price data from the Energy Information Administration. This allows tests for a relationship between energy prices and the adoption of energy-efficiency LEED credits. Water prices, typically higher in urban areas, are proxied with an ordinal measure of development density provided by the USGBC. This measure ranges on a seven-point scale from very rural to large metropolitan area.

Data also include building scorecards, reporting precisely which of the 69 possible LEED points were attained as part of certification. In addition to the raw information about practices adopted for certification, we sum the number of adopted credits in each of the categories delineated in Table 1, for each building in the database. For much of our analysis, we assess differences in the shares of credits associated with public or private benefits; we do this when we wish to control for differences across tiers. In other parts of our analysis, we assess differences in the number of credits adopted, in order to examine the tiers themselves. This prepares us to answer our original research question by first describing general trends in LEED certification pathways, then conducting analysis that reveals preferences for certain types of signaling strategies.

4.1. Descriptive statistics

Table 2 displays descriptive statistics for the data, focusing on distributions of obtained credits which potentially provide private benefits. For various owner and use categories of LEED buildings, the table shows mean LEED score and mean percent of score from credits associated with private benefits (*%Private*). Statistically significant differences in subsample and population means are indicated. Notably, homes and hotels appear to attain above average credits conferring private returns. Schools, hospitals, government facilities, and confidentially certified projects score below average in terms of credits with private returns. Large buildings also appear to attain fewer private return credits (as seen in Table 3).

We compare prices and the adoption of LEED credits with private returns, observed as the total number of credits attained, the number of credits attained in LEED's Energy and Atmosphere (EA) and Water Efficiency (WE) categories, the total credits obtained that confer private returns, the total credits obtained that only provide public benefits, and the share of credits obtained that confer private returns (*%Private*). Each of these variables is correlated to some extent with energy prices and urban density (a proxy for

Table 2. Means of LEED project points and percent of score from credits with private returns, with tests for significant differences of subsample means compared to the overall sample.

(Sub) Sample	*N*	*LEED score*	*%Private*
All	2981	38.36	68.76
Government	1694	38.67***	68.56**
For-profit	554	37.21***	69.11
Non-profit	496	38.82*	68.98
Other owner	237	37.91	68.98
Confidential	581	37.44***	68.19***
Signaler	1432	37.16***	68.71
Civic	419	38.20	69.06
Commercial	653	38.96***	68.70
Education	653	38.77*	68.43*
Healthcare	164	36.54***	67.79**
Hospitality	66	36.75**	70.77**
Industrial	110	38.02	68.63
Residential	170	38.12	71.00***
Retail	108	35.75***	68.47

Note: *, **, and *** for p-value <0.1, 0.05, and 0.01, respectively.

water prices). Correlation values and indications of statistically significant covariance are listed in Table 3. Investment in EA credits, which mostly confer private returns, is positively correlated with local electricity prices.

Urban developments tend to have more EA and WE credits, but lower LEED scores overall. This may indicate that urban projects have lower LEED scores, obtaining fewer credits overall. That the results are negative and significant for credits with both private and purely public benefits, yet the result for *%Private* is insignificant, suggests that urban developments do not vary systematically from rural developments in terms of prioritization of returns.

We test whether certification pathways are customized to building types with respect to each credit category. With so many credits on the LEED scorecard, this process demands hundreds of *t*-tests to reveal statistically significant differences in pathway strategy. We report a few of the highlights of these tests (Table 4), which compare subsample means to the full population. This table focuses on our interest in credit

Table 3. LEED credits correlated to building setting, including measures of resource costs.

	Electricity price	Urban density	Building size
Energy & atmosphere	0.083***	0.035*	−0.047***
Water efficiency	−0.028	0.117***	−0.035*
LEED score	0.037*	−0.077***	0.025
Credit count: private returns	0.085***	−0.055***	0.020
%Private	0.125***	0.024	−0.044**
No ROI	0.001	−0.096***	0.077***

Note: *, **, *** for p-value <0.1, 0.05, and 0.01, respectively.

attainment patterns among residences, government facilities, and other groups within the data, such as confidentially certified buildings.

In Table 4, we observe that government projects score on average 0.25 higher than the general population mean LEED score (Table 2), yet they tend to achieve fewer credits for Innovation & Design and Sustainable Sites. They perform especially poorly in public transportation credits, and rarely attain building reuse and materials reuse credits. High LEED scores for government agencies rely on Energy and Atmosphere, Indoor Environmental Quality, Materials and Resources, and Water Efficiency credits. They tend to earn fewer *user experience* points and more *cost-saving* points.

By comparison, firms appear to use the opposite strategy, scoring low where government buildings tend to score high, and vice versa. Schools place most focus on indoor environments and user experience, affirming that school certification is used to improve student health and comfort. Industrial projects place very little emphasis on the indoor environment, but emphasize water efficiency. Residential buildings emphasize efficiency and user experience, though they have lower overall LEED scores compared to other buildings.

5. Methodology: regression discontinuity analysis

To assess strategic signaling decisions, we narrow analysis to the thresholds between LEED certification levels. We observe differences in signalers compared to those who do not upgrade, by employing a regression discontinuity test from Porter (2003). This approach reveals preferences (Allen *et al.* 2017) for green certification by indicating the marginal green practices pursued for signaling purposes. By assuming that, on average, builders obtain LEED credits until the marginal utility of the credit equals the marginal cost of the credit, we can observe the additional value from signaling at a higher tier as related to jumps in credit attainment at thresholds. That is, we assume that owner investments in green practices amount to what a green signal is worth to the owner. Because building quality and environmental impacts change only modestly with each additional credit, significant jumps in propensity to attain a credit at a threshold reveal preferences for signaling.

Table 4. Mean credits earned by various owner organizations and difference from population mean. *T*-statistics are listed in parentheses.

	Building sector					
LEED credit category	All	Government	For-profit	Education	Industrial	Residential
Energy & atmosphere	7.51	7.76 (4.34)	6.97 (−3.98)	7.58 (0.53)	7.94 (1.28)	6.86 (−2.46)
Indoor environment	9.92	10.03 (3.19)	9.40 (−6.33)	10.25 (4.41)	8.65 (−6.33)	9.64 (−1.77)
Materials & resources	5.55	5.61 (2.13)	5.45 (−1.54)	5.59 (0.71)	5.68 (0.84)	5.08 (−3.84)
Innovation & design	3.96	3.89 (−3.90)	4.08 (3.01)	3.90 (−1.45)	4.15 (1.89)	4.22 (3.13)
Sustainable site selection	7.98	7.88 (−2.90)	7.94 (−0.46)	8.12 (2.03)	7.83 (−0.77)	9.09 (7.24)
Water efficiency	3.46	3.52 (3.50)	3.38 (−2.23)	3.34 (−3.69)	3.78 (3.62)	3.25 (−3.08)
Private returns	26.68	26.73 (0.66)	26.18 (−2.35)	26.81 (0.76)	26.37 (−0.64)	28.09 (3.34)
User experience	10.00	9.92 (−2.42)	9.81 (−2.45)	10.26 (3.78)	9.04 (−5.08)	10.55 (3.69)
Cost-saving	16.64	16.78 (2.06)	16.35 (−1.64)	16.49 (−1.00)	17.29 (1.63)	17.40 (2.16)
Number of buildings (*N*)	2,981	1,694	554	653	110	170

The dependent variable in this analysis is the probability of obtaining individual credits, or the propensity to obtain credits within certain groups. (We do not rely on shares, as in Tables 2–4, because we are specifically interested in additional credits rather than average mix of credits.) We may also use this test to identify which building owner sectors, industries, and years[2] are more likely to be 'signalers.' The regression discontinuity test assesses whether the trends in observed DV values above and below the threshold are 'smooth' at the threshold or whether there is a discontinuous 'jump' in the observed DV values on either side of the threshold. In the LEED setting, this corresponds to abnormally large jumps in credit adoption as buildings go from 32 to 33 points (for Silver certification), 38 to 39 points (for Gold certification), or 51 to 52 points (for Platinum certification).

More specifically, this test functions by estimating separate local regressions from the left and from the right of a given treatment threshold. Approaching from the left-hand side of the threshold, we find an expected value for the dependent variable. Another expected value at the threshold is found when approaching from the right-hand side. The magnitude of the difference between the expected values, α, reveals whether a project attribute is more or less likely to be observed among signalers than non-signalers just below that threshold. A positive α means that there is a disproportionately large increase in observations of its kind above the threshold. An α below zero would indicate a paucity of observations above the threshold. For example, an α of 0.23 would indicate that the probability of obtaining a LEED credit increases by 23 percentage points as a builder chooses to upgrade beyond the threshold under examination. When statistically significant, α reveals which practices are leveraged to obtain a higher certification tier, revealing stronger preferences for those technologies when signaling that benefits may be conferred in exchange.

The Porter (2003) approach has several advantages. First, we can observe shifts in the distribution at each individual LEED threshold, for any project characteristic. Second, we can statistically identify discontinuities that may not be visually apparent. For example, in Figure 1, it is not clear whether the share of credits attained that have private benefits (*%Private*) changes at all as LEED scores change from Certified to Silver, Silver to Gold, or Gold to Platinum. However, significant differences may exist. Third, by smoothing from both sides of the threshold, we control for differences in density of observations above and below the threshold, and additionally control for the loss of degrees of freedom when choosing pathways to higher LEED scores.

Analysis requires assumptions about the appropriate bandwidth chosen for local smoothing. Results are somewhat sensitive to this choice: larger bandwidths include more data and often have more precise fits. However, in a multi-tier setting, increasing the bandwidth risks bias by including data from regions of the distribution influenced by adjacent thresholds. This bias might obscure localized discontinuities. To this end, we opt for a three-point bandwidth at the Silver and Gold tiers (33 and 39 points, respectively), the smallest bandwidth that reliably describes patterns in the multitier framework. For the Platinum threshold (52 points), which is farther from (and less influenced by trends related to) other thresholds, we increase the bandwidth to four points. This, in part, compensates for the absence of any observations scoring 51 points, just a single credit shy of the Platinum tier. Further sensitivity tests in the Appendix (online supplemental data) use other bandwidths for each credit indicating robust results.

One drawback of this method is the amount of data required to estimate robust results. Without data on both sides of the threshold, no comparisons can be made using the regression discontinuity test. For instance, we can say nothing about certified versus

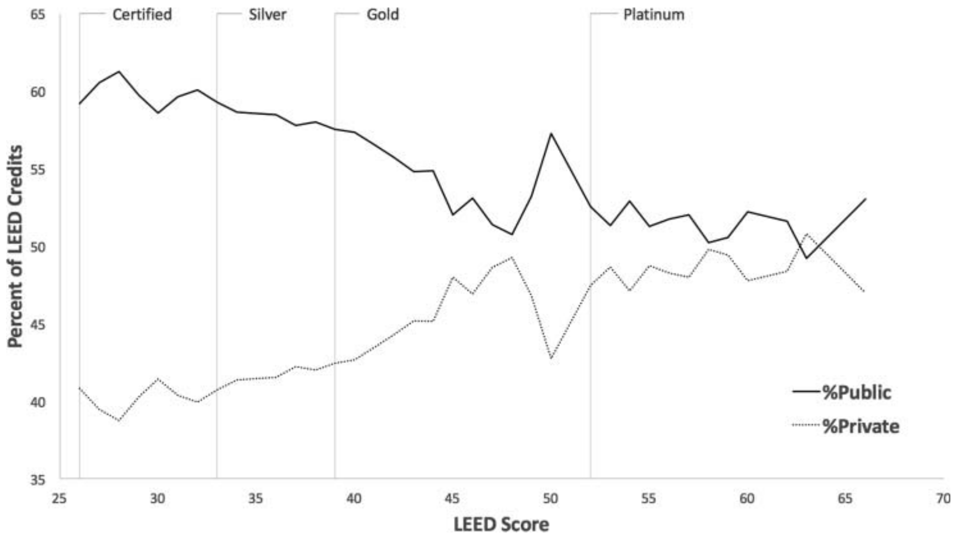

Figure 1. Achievement of LEED points associated with potential private returns versus purely public benefits, as a percentage of total LEED score.

uncertified building owners because uncertified projects have no score and do not appear in our data. If we wish to assess time as a set of year dummies, the data become too thin in most years and tiers conduct the test. Finally, an advanced and more causal analysis could leverage the results toward a difference-in-difference estimation that compares preferences between owner types. Yet, only the largest owner type (government buildings) provides enough data to conduct the test at any tier, and even that group is not large enough at the Platinum tier to conduct the regression discontinuity. Alternative approaches are needed to make these direct comparisons over time and ownership categories.

6. Results

In the above descriptive statistics, we observe evidence that LEED is used to avoid high-cost resource use, and appeal to key stakeholder groups, confirming our first two groups of hypotheses. Table 3 suggests that builders leverage more energy and water efficiency when prices for these utilities are high. Because owners appear to respond to prices through efficiency, we take these results as an overall confirmation that private returns exist and are recognized for at least some of the LEED credits. Notably, larger buildings appear to rely less heavily on private returns. This may suggest diseconomies of scale for some efficiency technologies, or that larger developments leverage LEED to appeal to more stakeholder groups.

Similarly, Table 4 reveals small, but statistically strong, differences in LEED certification pathways across owners and building uses. Taken together, these results confirm our hypotheses by demonstrating certification pathway customization to key stakeholder interests. But these cannot reveal which LEED credits are strategically selected for upgrading to gain signaling benefits. For this, we turn to our analysis of differences across LEED scores. From Figure 1, we see that builders select a combination of public and private credits at all LEED scores, rather than first exhausting one option, then upgrading with the other. The consistency of public and private shares over the distribution of LEED scores calls into question the assumptions of past literature, which presume one type of credit should be adopted first. It remains hard to know whether signaling upgrades are made by adopting practices that provide public goods, as expected by Hypothesis 3, or private goods, as expected by Hypothesis 4. Our regression discontinuity analysis tests Hypotheses 3 and 4, as seen in Table 5.

Significant discontinuities in credit attainment patterns reveal signaling strategies. The data suggest that some credits are especially likely to increase in popularity when building owners upgrade to higher certification tiers. As coded, signalers' strategies do not appear to leverage credits with private benefits overall. However, some individual credits and credit categories do show statistically significant differences in adoption patterns as buildings cross a certification threshold. At the Silver level, signalers are more likely to select credits for indoor environmental quality, innovation & design, and

Table 5. Regression discontinuity tests across LEED certification tiers. Note that α values were computed at bandwidth of 3 for thresholds at Silver and Gold; bandwidth of 4 was used for the Platinum threshold. Values for α correspond to the additional probability of obtaining a credit in order to obtain the listed certification tier, compared to observations just shy of the tier.

	α – Discontinuity magnitude at threshold		
Project attribute	Silver	Gold	Platinum
Private returns	0.068	0.168	8.691***
%Private	0.003	0.004	0.174***
Purely public returns	0.160	−0.240	−4.125***
%Public	0.005	0.006	−0.083***
User experience	−0.343	−0.124	0.393
Cost-saving	0.412	0.293	8.298***
Energy & atmosphere	0.224	−0.398	7.417***
Indoor environment	0.399**	−0.501***	−2.112***
Materials & resources	−0.812***	0.454***	0.688
Innovation & design	0.242*	0.180*	1.597***
Sustainable sites	−0.619***	0.304*	−3.720***
Water efficiency	0.662***	−0.004	−0.779***
Confidential	0.031	−0.066	−0.620***
Energy price	1.249**	0.071	6.309***
Certification year	−0.140	−0.164*	−1.463***
Government	−0.015	−0.051	−1.001***
For-profit	−0.119**	0.074**	0.177**
Nonprofit	0.140***	−0.017	0.754***
Other	−0.006	−0.007	0.069
Civic	0.127**	−0.159***	−0.775***
Commercial	0.096**	0.107**	0.241***
Education	−0.052	−0.022	0.037
Healthcare	0.054**	0.002	0.048
Hospitality	0.031**	−0.002	0.019
Industrial	0.063**	−0.042**	0.024
Residential	−0.255***	0.022	0.283***
Retail	−0.043	−0.031	0.024

Note: *, **, and *** for p-value <0.1, 0.05, and 0.01, respectively.

water efficiency. On the other hand, these buildings also tend to have significantly fewer materials & resources and sustainable sites credits, compared to those who do not upgrade from certified. The low-tier signalers appear drawn to credits with purely public benefits (in support of Hypothesis 3), but appear to avoid materials and thermal comfort credits.

At the higher tiers, different patterns emerge. Gold signalers more frequently leverage materials and site selection credits, but less often choose improvements to indoor environmental quality, including thermal comfort credits. When projects upgrade to platinum,[3] the focus on indoor environmental quality drops, and green power purchasing credits become over 70% less likely. To reach the highest tier, owners switch signaling strategies, increasing energy efficiency from the energy and atmosphere credits far beyond what is adopted in LEED Gold buildings. In fact, Platinum signalers obtain, on average, eight more credits from the private benefits category compared to those obtained by LEED buildings certified at the higher reaches of the Gold tier. In addition to the other results from various credits and categories, this confirms the expectations from Hypothesis 4.

Threshold discontinuities can be observed along various other project attributes. Past work identified these tendencies for owner type (Matisoff, Noonan, and Mazzolini 2014), which we replicate somewhat. We also divide the sample by building type: commercial office buildings tend to upgrade for signaling benefits at every level of certification, but civic buildings tend only to upgrade for Silver certification. Residential and industrial buildings are especially unlikely to be signalers. Education and retail facilities reveal no significant preferences for upgrading for signaling benefits, and may be motivated more by the environmental and efficiency impacts of certification compared to the signaling benefits.

7. Conclusions

The data provide a fresh glimpse into what types of practices are induced by information programs, by revealing preferences for signaling through strategic green certification. The descriptive statistics demonstrate varied certification pathways, defined as the overall set of practices adopted. Pathways appear customized to target specific stakeholder groups, with more public good provision by organizations with larger external stakeholder groups. Most research is only able to observe whether certification occurs, along with occasional metrics of environmental or financial performance. In contrast to some assertions that certification pathways are homogeneous or unstrategic, these results demonstrate that owners change building practices to minimize costs, signal key stakeholders, and accrue green signaling benefits. Lessons from this analysis have implications for builders seeking to strategically signal, policy-makers designing programs to address market failures, and scholars researching green labels and signaling. We address each of these in turn, and then acknowledge the limitations of our study, highlighting areas of potential research.

First, in regard to signaling strategies, our data show that efficient design practices are more popular under high resource prices. This suggests that, even when upfront costs are high, returns on investment in energy and water efficiency are an important factor in an organization's decision to 'go green.' However, not all LEED credits increase efficiency or otherwise provide a return. LEED's flexibility fosters variance in certification pathways, some of which may provide higher or faster returns. This gives builders opportunities to strategically reach certification through customized pathways, rather than adopting a singular 'best route.' Pathway selection can prioritize practices that appeal to stakeholders: schools can provide healthier environments for students, firms can differentiate themselves as innovators in a crowded industry, and home-owners can save on utilities, all within the same certification program. Such flexibility may be critical to encouraging widespread adoption among builders, but also creates highly variable environmental impacts from one LEED building to the next.

It appears that the signaling benefits of LEED certification may offset high discount rates for energy- and water-efficiency improvements (Sallee 2014; Jaffe and Stavins 1994; Gillingham, Newell, and Palmer 2009; Allcott and Greenstone 2012). By amplifying the visibility of building and organizational quality to key stakeholders, LEED certification expedites returns to enhanced efficiency, making even low-return and long time horizon practices more attractive to organizations that would not ordinarily pursue them. Tiered information-based program designs similar to LEED certification may therefore prove useful in reducing the energy-efficiency gap.

While the above suggests benefits to the design of LEED as an information-based policy instrument, a trade-off exists between flexibility and common understanding. When it comes to designing environmental certifications, variance in certification pathways may produce 'noisy' signals of quality, as those certified may be highly efficient, or not. The uncertainty in studies estimating the energy efficiency of LEED buildings may be explained by the fact that some LEED certification pathways prioritize public benefits, rather than efficiency. For example, governments and firms share few certification habits, yet both adopt the label widely. This variance makes it difficult to evaluate the effectiveness of the LEED label as a policy instrument.

Finally, some of our results challenge past findings on green signals. Signaling benefits do not incentivize all organizations equally. As Matisoff, Noonan, and Mazzolini (2014) demonstrate, some owner types are more willing than others to make upgrades in pursuit of green signaling. Our analysis finds that the types of practices used for upgrading signals also vary. Although upgrades to the highest certification tiers tend to come from energy efficiency, projects certifying at lower tiers are more willing to pursue credits that offer no potential private return. This supports our final hypothesis, but disagrees with previous assumptions that upgrades occur strictly through public good provision (Matisoff, Noonan, and Mazzolini 2014).

Our results are limited, however, in a few key arenas. First, though we can examine shifts in signaling across years, we have a limited means of operationalizing time in the discontinuity analysis. Alternative methods may examine this effect more closely, providing greater insight on whether organizations pay more or less attention to signaling benefits as LEED or other practices diffuse. Second, though we note that larger and publicly owned buildings provide greater public goods, this result is somewhat speculative. An alternative explanation is that other policies, such as tax incentives and building codes, apply selectively to these projects. This alternative would be consistent with recent work noting the regionally varied policy schemes promoting LEED (Matisoff, Noonan, and Flowers 2016). These additional policy interactions highlight a third limitation: though we discuss LEED as a voluntary certification and information-based policy, the possibility that compound policies interact to shift the motivation to certify calls to question the extent to which certification is truly voluntary. We leave to future research the question of whether voluntary and coerced certification pathways vary.

Overall, we present our findings on LEED certification pathways as a case study on what types of practices organizations are induced to adopt through certifications and information programs. Though LEED is designed in a manner similar to other standards worldwide, like BREEAM in the UK and Green Mark in Singapore, our data are limited to just one standard. Comparison across certification standards would provide greater insight on how organizations select environmental management techniques, but distinct designs and requirements provide challenges to research in quantitative settings. Future qualitative analysis across labels could shed light both on the true process by which pathways are selected, and evaluate how the designs of information and certification programs influence the types of practices adopted.

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Supplemental data

Supplemental data for this article can be accessed here.

Notes

1. Other estimates have found smaller effects on energy efficiency (Kats 2003), and a rebound effect has also been noted: Newsham, Mancini, and Birt (2009) observe greater energy use in about a third of commercial LEED buildings compared to general US commercial buildings, though others found this above-average use in less than a quarter of LEED buildings (Turner and Frankel 2008).
2. We take certification year as ordinal, rather than a set of dummies, in order to assess differences in average age of signaler projects rather than propensities to signal in particular years. Assessing as a set of dummies is plausible, but would only reveal whether signalers are more common in one year (compared all other years) on either side of the timeline.
3. As noted above, thin data at this tier limits our interpretation of results. However, we use a more robust bandwidth choice (4 points) to partially account for the thin data. The sensitivity of this analysis can be seen in the Appendix (online supplemental data).

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