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Competing or complementary labels? Estimating spillovers in Chinese green building certification

Xia Li[1] | **Timothy Simcoe**[1,2]

[1]Questrom School of Business, Boston University, Boston, Massachusetts, USA

[2]National Bureau of Economic Research, Cambridge, Massachusetts, USA

Correspondence
Xia Li, Questrom School of Business, Boston University, 595 Commonwealth Avenue, Boston, MA 02215, USA.
Email: xiali7@bu.edu

Timothy Simcoe, Questrom School of Business, Boston University, 595 Commonwealth Avenue, Boston, MA 02215, USA.
Email: tsimcoe@bu.edu

Abstract

Research summary: Many markets have multiple voluntary certification programs that sellers use to signal product or organizational quality. We argue that there can be positive spillovers in adoption of "competing" certifications and propose a framework for understanding how such spillovers arise through three channels: suppliers, adopters, and users of various labels. Our empirical analysis demonstrates these effects in the context of Chinese green-building certification. Specifically, we measure spillovers from adoption of the Chinese Green Building Evaluation Label (GBEL) to adoption of the alternative LEED standard within the same city. To isolate the causal impact of GBEL on LEED adoption, we use local government subsidies as an instrumental variable. We find evidence of market-level spillovers through the supplier and user channels, but little evidence of building-level scope economies.

Managerial summary: Many markets have several voluntary certification programs that sellers can use to signal product or organizational quality. Although many scholars emphasize the potential for competition between labels, we argue that there can be positive spillovers in adoption of "competing" certification schemes and propose a framework for understanding how those spillovers arise through three channels: suppliers, adopters, and audience. Managers of nascent certification programs can use this framework as a roadmap for attracting various stakeholder groups. We use our framework to analyze the diffusion of Chinese green-building labels and find evidence of large positive spillovers through the supplier and audience channels. These results suggest that the risks of tipping toward a single standard may be small in practice.

KEYWORDS

differentiation, green building, multiple certifications, spillover, voluntary

1 | INTRODUCTION

Certification is a widely used tool for reducing information asymmetry between buyers and sellers when product quality is hard to assess (Biglaiser & Li, 2018; Houde, 2018; Stahl & Strausz, 2017) or when certain organizational behaviors are hidden (King, Lenox, & Terlaak, 2005). Voluntary certification programs can be found in sectors as diverse as finance, health, real estate, food, and energy (Dranove & Jin, 2010), and scholars have studied how certification can signal a wide variety of practices, ranging from environmental performance (King & Lenox, 2000) or social responsibility (Heyes & Martin, 2017) to hygiene (Jin & Leslie, 2003) and creditworthiness (Becker & Milbourn, 2010).

One recent and important strand of the literature analyzes competition between labels in markets with more than one voluntary certification program (Bottega & De Freitas, 2009; Fischer & Lyon, 2014, 2019; Heyes & Maxwell, 2004; Heyes & Martin, 2017).[1] It is not obvious, however, that any pair of similar labels serving the same market are substitutes. When there are multiple certification programs, sellers might credibly signal more product attributes or reach different groups of consumers. Labels can also be complements on the supply-side of the market if they promote capacity-building and create scale economies in input markets. Thus, although there is prior literature on the adoption and impacts of voluntary certification (Dranove & Jin, 2010; King & Toffel, 2007), the nature and extent of interactions among "rival" certification programs remains underexplored. This study addresses that gap in the literature by asking whether, why, and at what level of analysis voluntary certification programs serving the same market are complements or substitutes.

Our empirical context is the Chinese building sector. China is currently the largest market for new construction in the world and is expected to account for almost half of new construction globally in the coming 5–10 years (Yu, Evans, & Shi, 2014). In 2015, buildings accounted for one-third of total Chinese energy use (Yuan, Zhang, Liang, Wang, & Zuo, 2017) and also produced a large share of nonindustrial solid waste, water use, CO_2 emissions, and SO_2 emissions. Calculations based on prior estimates suggest converting half of the Chinese building

[1]In practice, not all labels are linked to a certification program. We use the terms interchangeably, however, with the understanding that our focus only includes labels certified by governments, NGOs, or industry associations.

stock from conventional to green would reduce carbon emissions by 250 million tonnes per year, which is close to the annual output of Spain.[2]

Two green-building labels are widely used within China. Green Building Evaluation Label (GBEL) is a government led voluntary certification scheme introduced in 2006 and used primarily within China. Leadership in Energy and Environmental Design (LEED) is an industry-led voluntary certification program managed by the U.S. Green Building Council. It was introduced in 1998 and has since become a global standard. Our empirical analysis measures the spillover effect of GBEL adoption (driven by state and municipal incentives) on the diffusion of LEED in the same geographic markets.

From a theoretical perspective, the sign and magnitude of these spillover effects is unclear. Following the literature on competition between labels (Fischer & Lyon, 2014; Heyes, Kapur, Kennedy, Martin, & Maxwell, 2020; Li & van't Veld, 2015), we might predict that GBEL and LEED adoption will be negatively correlated. Indeed, if builders, occupants, and the suppliers of green-building materials and services all derive large benefits from coordinating on a common standard (Simcoe & Toffel, 2014), the literature on standards adoption predicts that markets can "tip" toward a single dominant label (Farrell & Saloner, 1985; Katz and Shapiro, 1994). On the other hand, there are several forces that push in the opposite direction. Because these factors have received less attention in the literature, one contribution of this article is to propose a conceptual framework describing several mechanisms that could produce positive spillovers.

Our conceptual framework emphasizes three channels—corresponding to three types of stakeholder – that can generate cross-label complementarities in certification. The first channel operates through suppliers. Widespread adoption of a label may stimulate the supply of related goods and services, which can lead to lower input prices and provide legitimacy for key players (Corbett & Kirsch, 2004; King & Lenox, 2001). If similar inputs are used by different labels, this mechanism can produce market-level synergies in certification. The second channel operates through adopters (i.e., firms that use the labels). Adopters may use more than one label when overlapping requirements lead to building-level economies of scope. That is, adopting one label may reduce the marginal cost of adopting a second label by more than it reduces the marginal benefits. Finally, the third channel operates through users (i.e., the audience for a label). Adoption of one certification program might stimulate demand for a "rival" label by increasing consumer awareness and the perceived legitimacy of certification in general, particularly when the labels measure different aspects of product quality.

Measuring spillovers due to any of these channels is difficult for two reasons. First, according to our theory, adoption decisions are jointly determined—the use of label A influences label B, and vice versa. Second, causal spillover effects are easily conflated with the impact of unobserved variables (e.g., growth in the overall demand for green building) that may influence the adoption of all certification programs. To overcome these challenges requires an instrumental variable that shifts the incentives to adopt one label (but not the other) and is uncorrelated with any omitted variables. We use provincial and city level government financial subsidies to adopt GBEL as an instrument to estimate the spillover from GBEL to LEED adoption. Our results indicate positive spillovers with an elasticity of 0.23, which implies that doubling the rate of GBEL certification leads to a roughly 20% increase in LEED adoption.

[2]Carbon emissions from the building sector in China is around 2Gt (2,000,000,000 t) in 2016 (CABEE, 2018; Jiang, Yan, Guo, & Hu, 2018). Studies have shown that on average buildings with a LEED label were 25–30% more energy efficient than conventional buildings (Kats, 2003) and 250,000,000 t = (2,000,000,000 * 0.5 * 0.25).

Turning to mechanisms, we find evidence of positive spillovers from GBEL to LEED through both the supplier and the user channel. For suppliers, using the instruments described above, we show that GBEL adoption is associated with an increase in the supply of LEED Accredited Professionals (APs). This result adds to a prior literature showing how diffusion of LEED techniques is driven by peer effects, local community characteristics, and human capital (Cidell, 2009; Kahn & Vaughn, 2009; York, Vedula, & Lenox, 2018). For users, we show that the effect of GBEL subsidies on LEED adoption is larger in "greener" cities, which suggests that spillovers are mediated by latent demand for environmental quality. Finally, we find little evidence of spillovers via the adopter channel. In particular, very few buildings adopt both GBEL and LEED, indicating that building level scope economies are not an important factor in this setting.

Our contributions are as follows. First, to the best of our knowledge, this is the first study to theorize and empirically test for spillovers among multiple voluntary certification programs. Thus, we contribute to the literature on certification and ecolabeling (Delmas & Grant, 2010; Doremus, 2019; Fischer & Lyon, 2014, 2019; Heyes et al., 2020) by providing causal estimates of a positive market-level spillover between two labels. Understanding the interaction between certification programs is important because it can help clarify their overall impact: if labels are complements at the market level, then policies to encourage adoption of one program can attract more participants to the other; if they are substitutes, the same policies may be viewed as "picking winners." Thus, although most models of ecolabel competition focus on demand-side competition in equilibrium (Heyes & Martin, 2017; Li & van't Veld, 2015; Poret, 2019), we draw attention to a set of supply-side factors that are more familiar in the literature on the diffusion of green building practices (Jones, York, Vedula, Conger, & Lenox, 2019; Matisoff, Noonan, & Flowers, 2016).

Second, our article contributes to a literature that explores factors leading firms to participate in self-regulatory institutions (Corbett & Kirsch, 2004; King & Toffel, 2007; Ostrom, 1990; Prado, 2013). In particular, we provide a framework for analyzing alternative mechanisms that could lead to positive spillovers in the adoption of voluntary certification programs. Our framework and our findings contribute to institutional theory by illustrating how shared resources and latent demand can stimulate adoption of multiple certification schemes at the regional level.

Finally, we contribute to the literature on green building. Several studies have shown that energy-efficient buildings realize higher rental prices and occupancy rates (Eichholtz, Kok, & Quigley, 2010, 2013), and there are a number of studies that examine the diffusion of certified green building practices (Corbett & Muthulingam, 2007; Kahn & Vaughn, 2009; Kok, McGraw, & Quigley, 2011; Kok & Jennen, 2012; Simcoe & Toffel, 2014; York & Lenox, 2014). None of the prior research, however, has sought to estimate a causal spillover between labels.

2 | THEORETICAL FRAMEWORK

2.1 | Certification spillovers

George Akerlof (1970) showed how information asymmetries can prevent trade in markets where sellers, but not buyers, observe product quality. Potential solutions to this problem include warranties (Akerlof, 1970), signaling (Spence, 1973), brands and trademarks (Merges, Menell, & Lemley, 2012; Shapiro, 1982), and third-party certification (Biglaiser & Li, 2018;

Houde, 2018). We focus on certification, which is typically conducted by NonGovernment Organizations (NGOs), industry associations, or governments. Certification agents systematically measure product or practice quality and disclose that information to their clients. Because this "hard" information is more precise and comparable than word of mouth, warranties, or brand names (Dranove & Jin, 2010) certification is used to facilitate trade in a wide variety of settings.

Many markets feature multiple certification programs. For example, the financial rating agencies Standard & Poor's, Fitch Group, and Moody's all grade many of the same securities, and the web site Ecolabel Index (http://www.ecolabelindex.com) tracks over 458 ecolabels that often cover similar issues in the same markets. Scholars have proposed several explanations for the presence of multiple certification programs serving a single market. Horizontally differentiated certification programs, which measure different product or service attributes, often target different groups of sellers (Delmas & Terlaak, 2001; Delmas & Toffel, 2008; Jiang & Bansal, 2003) or buyers (Lanahan & Armanios, 2018). Certification programs can also differentiate themselves vertically, by adopting different levels of stringency (Lerner & Tirole, 2006; Prado, 2013). For the most part, however, the literature on certification has assumed multiple labels serving the same market compete with each other. For example, there are formal models of competition between international organization and NGO labels (Heyes & Maxwell, 2004), government and for-profit labels (Bottega & De Freitas, 2009), industry and NGO labels (Fischer & Lyon, 2014, 2019), and between rival NGOs (Heyes & Martin, 2017).

Although the literature on competition between labels yields several important insights, we argue that in many cases, certification programs serving the same market can be viewed as complements rather than substitutes. At a high-level, the theoretical mechanism we propose is that different labels serving a common market can benefit from economies of scale and scope whenever they utilize a common pool of resources. When that is the case, the growth of one certification program may increase the marginal benefits (or reduce the marginal costs) of adopting another, leading to complementarities in aggregate demand.

In order to sharpen this argument, we build on the idea that certifications resemble a multi-sided platform (Lerner & Tirole, 2006), where adoption by one group confers benefits on all others. Simcoe and Toffel (2014) propose that there are three broad groups (or "sides") for most quality certification programs: suppliers, adopters, and users. Suppliers provide inputs that are required or recommended by certification programs, as well as expert advice on the certification process. Adopters use voluntary certification as a quality signal for their products or services. Users are the final customers whose perceptions of product quality, and hence willingness to pay, are influenced by certification. For example, in "fair trade" certification of agricultural products the suppliers are typically small farms and specialized commodity brokers; the adopters are major brands that label their products; and the users comprise retail distribution channels and individual consumers. In the context of green building certification, suppliers sell specialized construction materials and services, adopters own properties, and users pay the rent or the mortgage.

Whereas prior literature emphasized that the success of a single certification program relies on coordinated adoption by suppliers, adopters, and users, we extend that framework to multiple certifications, and argue that each group constitutes a distinct channel for positive spillovers between related labels. Figure 1 illustrates the idea that there are three main loci for positive spillovers and suggests the mechanisms that can operate within each group.

For suppliers, increased adoption of one certification program may produce scale economies, increased entry and competition (Simcoe & Toffel, 2014), or greater legitimacy (Corbett & Kirsch, 2004; King & Lenox, 2001). As long as key inputs are not specific to a particular

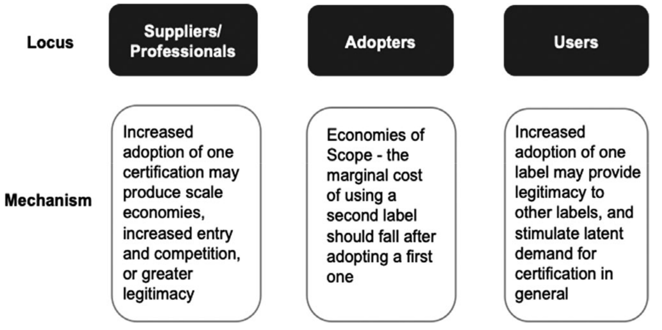


FIGURE 1 Positive spillover effect between multiple voluntary certification programs

certification program, lower input prices and greater legitimacy should stimulate adoption of all labels in a given market, leading to market-level economies of scope. For adopters, if there is overlap in the business practices measured by two certification programs, then the marginal cost of using a second label should fall after adopting a first one. As long as marginal costs decline faster than marginal benefits, this will lead some adopters to use two labels at once (a strategy that we call multi-labeling). Finally, from the user perspective, increased adoption of one certification program may provide legitimacy to certification in general and stimulate latent demand for particular aspects of product quality, such as environmental impact or social responsibility (Bottega & De Freitas, 2009; Fischer & Lyon, 2014, 2019; Heyes et al., 2020). This can increase the demand for all goods that exhibit similar quality characteristics, including those certified under different labels. Combining these insights, we expect that increased adoption of one voluntary certification program can stimulate adoption of another label in the same market:

> **Proposition 1.** *Increased adoption of one voluntary certification program can increase the adoption of another similar certification program in the same market.*[3]

We expect each of the mechanisms behind P1 to be more salient early in the development of the certification market, when adopters are deciding whether to certify at all, rather than selecting between well-established labels. The logic is that when relatively few products are labeled, spillovers can make a second label more attractive at the extensive margin (i.e., relative to no certification), even when adopters typically use one label or the other.[4]

The remainder of this section unpacks the supplier, adopter and user channels in greater detail and describes how each type of spillover might be measured. In order to be precise, and to help link the theoretical arguments to our empirical setting, we consider a hypothetical project *i*, in market *m*, that can choose to certify using LEED, GBEL, neither or both. We let $Li \in \{0,1\}$ and $Gi \in \{0,1\}$ denote the decision of a focal project to adopt LEED or GBEL

[3]Although we conform to the stylistic convention of enumerating several propositions, we do not wish to convey the impression that these statements are prior predictions about the sign or magnitude of any spillover effects. As noted in the introduction, there are plausible theories that generate opposite predictions. Thus, our propositions might properly be labeled "explanations" (King, Goldfarb, & Simcoe, forthcoming) since their main purpose is to propose a set of conditions that are *sufficient* to account for the patterns we observe in the data.

[4]In online Appendix A, we formalize this idea in the context of a simple logit demand system.

respectively, and S_m represent the stock of GBEL certified buildings in the same market as the focal project. With these assumptions, we can write the net benefits (payoffs) from certification as

$$\pi(L_i, G_i; S_m) = B(L, G; S) - C(L, G; S)$$

where the function B represents gross benefits of certification and C the associated costs.

2.2 | Supplier spillovers

Different voluntary certification programs serving the same market often require adopters to use similar inputs. For example, some green-building materials may help a project qualify for multiple certifications. Similarly, architects and consultants are often qualified to work on multiple standards. More generally, as long as some of the inputs linked to certification are not specialized to a particular label, the growth of one certification program may catalyze adoption of another program by promoting entry and competition in shared input markets. Stated in terms of our simplified payoff function, supplier spillovers occur when $\pi(L, G; S)$ is super-modular in (L,S) through the cost function, or equivalently

$$\frac{d[\mathrm{C}(1,0;\mathrm{S}_m) - \mathrm{C}(0,0;\mathrm{S}_m)]}{d\mathrm{S}_m} < 0$$

The underlying mechanisms that can generate supplier spillovers include helping to solve coordination problems; promoting entry and competition; and providing legitimacy for suppliers and professionals in nascent markets. Although many of these mechanisms are familiar in the literature on diffusion of green building practices (e.g., Corbett & Muthulingam, 2007; Kahn & Vaughn, 2009; Kok et al., 2011; Kok & Jennen, 2012; Simcoe & Toffel, 2014; York et al., 2018), they have typically been studied as drivers of diffusion rather than channels for spillovers between labels. For example, Simcoe and Toffel (2014) describe how a new certification program may face "chicken and egg" coordination problems when first introduced: adopters wait for suppliers who can help them manage the uncertainty associated with a new label, while suppliers wait for signs of robust demand before committing to the market. If suppliers realize some economies of scope across related certification programs, however, then increased adoption of one label—spurred by government policies or other factors—may help another label overcome these initial barriers to adoption. Supplier spillovers can also arise if increased adoption of one certification program increases the density of suppliers and professionals (Cidell, 2009), and therefore increases their legitimacy (Corbett & Kirsch, 2004). Finally, supplier spillovers might be a form of pecuniary externality. If the growth of one certification program leads to increased entry and competition, and hence lower prices in shared input markets, then adoption of related labels may increase simply because the costs of adoption decline. For all these reasons, we hypothesize:

> **Proposition 2.** *Increased adoption of one voluntary certification program can cause increased adoption of a second certification program by stimulating the supply of shared inputs, such as professional services, within the same market.*

2.3 | Adopter spillovers

Adopters often view alternative certification programs as substitutes, and select a single label based on their own particular needs. Nevertheless, there are some settings where firms use multiple labels on their products. For example, many agricultural products have multiple organic and fair-trade labels. Wood and paper products are often certified by both the Forest Stewardship Council and the Program for the Endorsement of Forest Certification (Auld, Gulbrandsen, & McDermott, 2008). We use the term "multi-labeling" to describe products that simultaneously adopt multiple certifications.[5]

Multi-labeling is often driven by firm or project level economies of scope.[6] If different certification programs have some shared requirements, then the marginal cost of adopting a second label will decline once a firm makes the investments required to achieve its first label. As long as the marginal costs of a second certification decline by more than the marginal benefit (i.e., scope economies are large relative to any reduction in signaling benefits) then project-level economies of scope can be a source of positive spillovers between labels. Formally, this is equivalent to the assuming that $\pi(L_i, G_i; S_m)$ is super-modular in (L,G),

$$\pi(1,1;S_m) - \pi(0,1;S_m) > \pi(1,0;S_m) - \pi(0,0;S_m).$$

If one label's requirements are a strict subset of a second label, then adopting both provides no new information relative to adopting the more stringent certification. Thus, the returns to multi-labeling are greater when certification programs are horizontally as opposed to vertically differentiated (Fischer & Lyon, 2014; Li & van't Veld, 2015; Heyes and Martin, 2017; Rysman, Simcoe, and Wang, 2018). In practice, however, consumers may not understand the difference between two standards (Harbaugh et al., 2011), so even vertically differentiated labels can offer some scope for multi-labeling. Adopters might also multi-label if they are uncertain about which standard will dominate in the long run and wish to hedge that risk. Nevertheless, we expect horizontally differentiated certification programs to be more conducive to multi-labeling in general, because the signal produced by adopting both labels provides strictly more information than adopting either label individually. This leads us to propose:

> **Proposition 3.** *Project-level economies of scope in the adoption of horizontally differentiated certification programs is associated with increased multi-labelling.*

2.4 | User spillovers

Whereas supplier and adopter spillovers are both supply-side mechanisms, demand-side factors can also produce complementarity in label adoption. User spillovers occur when increased adoption of one certification program leads to greater willingness-to-pay for products that utilize other similar labels. Although demand-side externalities are well-known from the literature

[5]The term multi-labeling is adapted from the literature on multi-sided platforms, where an agent who adopts multiple competing platforms is said to be "multi-homing" (Armstrong, 2006).

[6]In this article, we focus on certification decisions at the product/project level, but decisions to use one versus many labels might also be taken at the firm-level for an entire product/project portfolio. This is an interesting topic that we leave for future research.

on product interoperability (e.g., Katz and Shapiro, 1994), the mechanisms are likely to be different for eco-labels. In particular, we hypothesize that increased adoption of an initial certification program can help legitimize eco-labels in general, thereby making end-users more sensitive to social and environmental quality and unlocking latent demand for other certification programs. Formally, the user spillover channel implies that $\pi(L,G;S)$ is super-modular in (L,S) through the gross benefits function

$$\frac{d[\mathrm{B}(1,0;\mathrm{S}_m)-\mathrm{B}(0,0;\mathrm{S}_m)]}{d\mathrm{S}_m}>0.$$

Our conception of user spillovers assumes that there is a latent demand (i.e., unrealized willingness-to-pay) for products that address a particular class of problems. For example, the desire for green buildings is linked to specific problems such as energy use, access to transit, and sustainably sourced materials. Building on the idea that adoption of certification is conditioned by regional institutional logics (Lee & Lounsbury, 2015; Marquis & Lounsbury, 2007; Thornton & Ocasio, 1999; York et al., 2018), we argue that demand for the entire bundle of "green" attributes will be positively correlated across regions. Moreover, in markets with high latent demand, users may seek to distinguish themselves as the "first in category" user of a new label, building practice, or certification level. These efforts by users (and also, potentially, adopters) to distinguish their projects can lead to greater variety in their choice of labels, as well as greater overall adoption.[7] Customers and users may also encourage local governments to set policies that favor certification in general, without favoring any particular label. The idea that adoption of one label can legitimize certification in general, spurring increased user interest and unlocking latent demand for alternative labels, suggests that we should observe greater complementarity in markets where customers share a strong taste for quality. This leads us to predict.

> **Proposition 4.** *Complementarity in the adoption of related certification programs will be stronger in markets with greater latent demand for products or practices that address the shared goals of those certification programs.*

3 | INSTITUTIONAL CONTEXT

Our empirical analysis examines the diffusion of two green building certification programs, GBEL and LEED, using panel data from Chinese real estate markets. Khanna, Romankiewicz, Feng, and Zhou (2014) provide a detailed description of the two programs.

GBEL is a government led voluntary program developed by the Chinese Ministry of Urban and Rural Development (MOHURD).[8] It was introduced in 2006. Most GBEL certified buildings are multi-unit residential structures or public buildings, such as offices, hotels or retail outlets. MOHURD estimates that the cost of GBEL certification range from $4.50 to $29 per square

[7]We do not include endogenous product differentiation by adopters (Fischer & Lyon, 2019; Rysman et al., 2018) as a fourth channel within our theoretical framework because it is a type of strategic complementarity (Bulow, Geanakoplos, & Klemperer, 1985) as opposed to a spillover effect. In other words, competition among adopters of one label can alter the *relative* payoff from selecting an alternative, but not its underlying costs and benefits. In terms of our simplified payoff function, incentives for endogenous differentiation arise when $\frac{d[\mathrm{B}(1,0;S_m)-\mathrm{B}(0,1;S_m)]}{dS_m}>0$.

[8]GBEL is often called "China Three Star" because it uses a three-tier rating system.

TABLE 1 GBEL and LEED comparison

	ESGB	LEED
Launch of standard	2006	1998
First certification in China	2008	2005[a]
Standard setter	MOHURD (government-led voluntary program)	USGBC (nongovernment, multi-stakeholder international program)
Coverage	China	160 countries
Credit-based system	Yes (based on total points summed over all categories)	Yes (require minimum credits within each category)
Types of buildings	2	21
Rating categories	Land, energy, water, resources/material efficiency, indoor environmental quality, and operational management	Sustainable site, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design, and regional priority
Multi-tiers	1 star, 2 stars, 3 stars	Certified, silver, gold, and platinum

[a]LEED was introduced in China in 2003 but first certification was in 2005.

meter for residential buildings and from \$5.50 to \$71 per square meter for public buildings, depending on the certification level. MOHURD also suggests these costs can be recovered through energy savings within 2–6 years.[9]

LEED is an international standard with multi-stakeholder engagement created and managed by the US Green Building Council (USGBC).[10] Whereas GBEL certifies two major types of building (residential and commercial), LEED has rating systems for 21 different building categories. Within each category, LEED offer four tiers of certification: Certified, Silver, Gold, and Platinum. The costs of LEED certification vary by project type and certification level. Against those costs, prior literature has found that LEED certification produces substantial financial and environmental benefits (Eichholtz et al., 2010; Kats, 2003; Newsham, Sandra, & Benjamin, 2009; Sabapathy, Ragavan, Vijendra, & Nataraja, 2010). In addition to managing the LEED standard, USGBC offers professional accreditation under the "LEED AP" brand for various types of building-industry professionals (e.g., architects, designers, and contractors) to certify their advanced knowledge of green building practices.

Table 1 compares GBEL and LEED along several key dimensions. Both standards prioritize environmental benefits over industry profit. Both programs are multi-tier labels that award points for adopting green building practices in a handful of categories. Five of the point categories used by LEED and GBEL overlap.[11] Within each category, however, the nature of the credits differs between the two programs. For example, GBEL prioritizes

[9]http://www.gbmap.org/article1.php?id=355.

[10]Between 1998 and 2019, more than 79,000 projects across 160 countries and territories have been registered or certified using LEED. (http://leed.usgbc.org/leed.html).

[11]The overlapping point categories are land, energy, water, resources/material efficiency, and indoor environmental quality. The sixth category for GBEL is focused on operational management, whereas LEED emphasizes innovation, design, and regional priority.

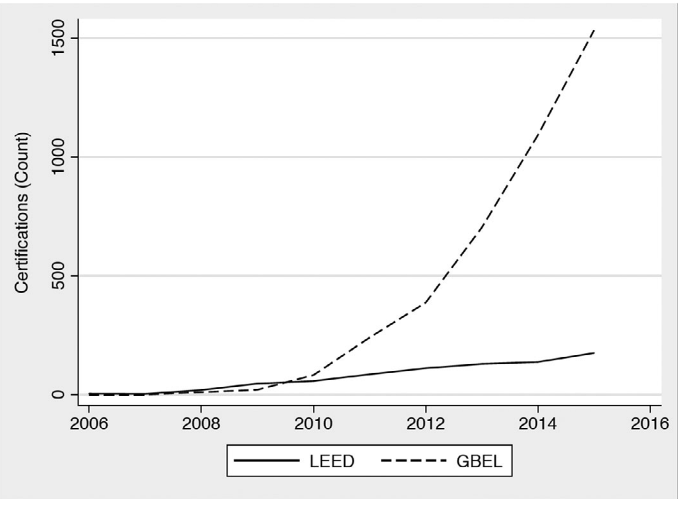


FIGURE 2 Annual green building certifications in China from 2006 to 2015

energy efficiency technology and conservation measures, while LEED also emphasizes other practices such as renewable energy and performance verification (Geng, Dong, Xue, & Fu, 2012).

Despite their similarities, LEED and GBEL exhibit elements of both horizontal and vertical differentiation. LEED's global brand makes it a prestigious international standard, and for that reason it is used by far more Chinese buildings than alternative labels such as UK's BREEAM, Germany's DGBN, or Singapore's Green Mark (Lee, 2012; Shen & Faure, 2020). On the other hand, LEED is controversial. Because LEED ratings are based on total points, a project may reach a high certification tier even though it scores poorly in important categories such as energy and water consumption. GBEL requires projects to meet the minimum rating or credits within each category (Khanna et al., 2014). LEED also awards points for predicted energy savings, whereas GBEL credits are based on actual energy usage measured 1 year after construction (Geng et al., 2012).

Although our theory suggests that builders decide to use LEED and/or GBEL by weighing adoption costs and benefits (net of spillovers), we do not have strong priors about their relative appeal. Figure 2 shows that, overall, Chinese builders favored LEED prior to 2010 but then shifted toward GBEL.[12] This switch partly reflects government policy, and specifically the inclusion of GBEL within China's 12th Five Year Guideline (2011–2015) on environmental and energy efficiency goals.[13] Under those guidelines, the Chinese government provides builders with a number of incentives to adopt GBEL, including financial subsidies to GBEL buildings, prizes, and better conditions on loans. Between 2012 and 2015, seven provincial-level administrative units and three prefecture-level cities also introduced *local* financial subsidies for GBEL

[12]Nevertheless, by July 2018, there were 1,470 Chinese LEED certified projects, making China the largest market for LEED certification outside the United States. We provide more information below on adoption by building type (residential versus commercial) and owner type (Chinese versus foreign).

[13]China's Five-Year Plans are a series of social and economic development initiatives issued since 1953. It plays an important role in mapping strategies for economic development, setting growth targets, and launching reforms. The name Five Year Plan was changed to Five Year Guideline since 2006.

adoption.[14] Khanna et al. (2014) report that several cities require 85% of all new government buildings obtain GBEL certification. Our empirical strategy exploits the fact that not all provinces and cities offer subsidies, and the ones that do provide subsidies introduced them at different points in time.

4 | DATA AND METHODOLOGY

This section describes our data and empirical methodology, and Online Appendix B provides additional details on data sources, cleaning, and merging.

4.1 | Data

Our data comprise a balanced panel of 657 Chinese cities observed from 2005 to 2015.[15] The primary outcome variables measure annual adoption of the two voluntary certification programs: GBEL and LEED. For each city, we hand collect and translate GBEL certification data from MOHURD to obtain an annual count of new certifications. For LEED, we collect data on new certifications, registrations and APs (again, at the city-year level) from the USGBC. We use certification instead of registration data in the analysis. Although registration typically precedes certification by several years, and may be a good indicator of "intent to invest" in green building practices, we view certification as a better measure of actual investments.

A key explanatory variable in our study measures provincial or city level financial subsidies to adopt GBEL. We hand collect this information from MOHURD and local government websites, and use it to create two variables. The first is an indicator variable (*SUBSIDY*) that equals one for all years following the adoption of a local financial subsidy. The second variable (*SUBYEAR*) is a time-trend that equals zero prior to the adoption of any subsidy, and $y - t_i$ after adoption, where y is the calendar year and t_i the year when a subsidy was introduced in city i.

For a subset of 115 cities, we have measures of local demand for environmental amenities that are useful for examining Proposition 4. Specifically, we use the "China Green Low-Carbon City Index" (Ohshita et al., 2017) as a variable (*GRINDEX*) that captures local taste for green products.[16] Finally, we merged information on city population, land area, and construction activity collected from MOHURD into the panel. For continuous variables, we use the transformation $ln(1 + X)$ throughout the analysis, given the highly skewed distribution of city size.[17] Table 2 reports means, *SD*s, and partial correlations for the main variables used in our analysis. Notably, the table shows that around 7% of the city-year observations have adopted local subsidies for GBEL between 2005 and 2015.

[14]China has 34 provincial-level administrative units: 23 provinces, 4 municipalities, 5 autonomous regions, and 2 special administrative regions. Jiangsu, Shaanxi, and Shanghai have provided provincial level subsidies since 2012; Guangdong, Shandong, and Beijing provided subsidies since 2013; and Jilin has provided subsidies since 2014. The prefecture-level cities providing subsidies by 2015 are Luoyang, Xi'an, and Qingdao.

[15]The central government sets more stringent energy efficiency targets under the 13th Five Year Plan (2016–2020) and some cities/provinces require all new buildings to certify under GBEL starting in 2016.

[16]A city's green building activity counts for just 2 out of 100 total points in this index.

[17]In a series of robustness checks, we show that our main results largely hold in a specification where the primary outcome and explanatory variables enter in levels instead of logs.

TABLE 2 Summary statistics and correlations

Variable	Mean	*SD*	Type of variation	lnGBEL	lnLEED	SUBSIDY	SUBYEAR	lnArea	lnPop	lnGR INDEX
lnGBEL	0.1457	0.5057	i, t	1						
lnLEED	0.0291	0.2184	i, t	0.5922	1					
SUBSIDY	0.0687	0.2535	i, t	0.2878	0.1532	1				
SUBYEAR	0.0820	0.3968	i, t	0.2805	0.1381	0.7629	1			
lnArea	3.5886	0.9294	i, t	0.4974	0.3725	0.1617	0.1302	1		
lnPop	4.1829	0.8946	i, t	0.3672	0.3214	0.1722	0.1401	0.6976	1	
lnGRINDEX	3.7888	0.1825	i	0.1501	0.2004	0.1013	0.0758	0.1245	0.1531	1

Our data have several limitations. Perhaps most important, we do not know the total number of new buildings in each city. This implies that although we can count LEED and GBEL certifications, we do not know the number of uncertified buildings. That is one of the main reasons for conducting our analysis at the city-year level, rather than analyzing the certification choices of individual projects.

4.2 | Methodology

Measuring causal spillovers between voluntary certification programs is challenging for two reasons. First, adoption decisions are jointly determined, so causality flows in both directions. If adoption of GBEL stimulates adoption of LEED, and vice versa, a simple regression will estimate some combination of those two effects. Second, what appear to be spillover effects might actually be the impact of unobserved factors that stimulate adoption of both programs. For instance, growth in the overall demand for green building may promote adoption of both LEED and GBEL, leading to a spurious correlation in a simple regression model of spillovers.

In an experimental setting, we might overcome these challenges by randomly assigning different cities to build a particular number of GBEL (or LEED) certified buildings, and then measuring how adoption of LEED (or GBEL) co-varies with that random treatment. In observational studies, an alternative methodology is to seek an instrumental variable (denoted by Z) that is correlated with GBEL adoption and, by assumption, uncorrelated with (or equivalently, exogenous to) LEED adoption. Our analysis will use local financial subsidies to adopt GBEL as an instrument.

To make these ideas precise, consider the following two-way fixed effects regression:

$$LEED_{it} = \alpha_i + \lambda_t + \beta GBEL_{it} + \theta X_{it} + \varepsilon_{it} \tag{1}$$

where i indexes cities, and t indexes years; α_i is a city fixed effect that absorbs all observed and unobserved time-invariant city characteristics; λ_t is a set of year dummies that absorbs time-varying factors common to all cities, such as central government subsidies to adopt GBEL; and X_{it} are a vector of time-varying control variables such as population and the physical area encompassed by an urban district. The coefficient β measures the spillover effect of GBEL certification on LEED adoption (as in P1) at the city level. In practice, because we take logs of both $LEED_{it}$ and $GBEL_{it}$, the parameter β is an elasticity.

It is well known that when $GBEL_{it}$ is correlated with the residual (ε_{it}), for example because of omitted variables, then OLS estimation of (1) will yield biased estimates. To obtain consistent estimates of the spillover parameter, we instrument for $GBEL_{it}$ using our measures of local government subsidies. That is, we let Z_{it} be the vector ($SUBSIDY_{it}$, $SUBYEAR_{it}$) and estimate the following "first stage" regression:

$$GBEL_{it} = \alpha_i + \lambda_t + \pi Z_{it} + \delta X_{it} + \eta_{it} \tag{2}$$

Valid instrumental variables must satisfy two conditions. First, the instruments must be "relevant." Intuitively, this can be verified by estimating (2) and checking that the coefficient π is statistically significant. In our setting, these "first stage" estimates also hold substantive interest. In particular, when Z includes only the indicator $SUBSIDY_{it}$, Equation (2) is a difference-in-differences regression that measures the impact of local financial subsidies on GBEL adoption by comparing cities with and without subsidies before versus after those subsidies were enacted.

The second necessary condition for a valid instrumental variable is that it must be exogenous (or, equivalently, must satisfy the "exclusion restriction"). This implies that the instruments Z_{it} are uncorrelated with the residuals ε_{it}, and is a maintained assumption (i.e., it cannot be tested using the data). The logic behind our instruments is that provincial or city level financial subsidies targeting GBEL should have no *direct* impact on LEED adoption. This does not imply, however, that the subsidies are *uncorrelated* with potential LEED adoption. Indeed, we will show that GBEL subsidies are associated with LEED adoption, and under the assumed exclusion restriction, we attribute that correlation entirely to spillovers from GBEL to LEED.

Although it is not possible to test the exclusion restriction directly, we offer three observations in support of our instruments. First, we compare observable characteristics of provinces that do and do not adopt financial subsidies.[18] Although provinces with financial subsidies are somewhat larger and wealthier, the demographic disparities are not dramatic. More importantly, there is no statistically significant correlation between the green development index (*GRINDEX*) and the adoption of provincial subsidies. Second, because our regressions include city fixed-effects, we have controlled for any time-invariant factors that might produce a spurious correlation between the instruments and the residuals. It remains possible, however, that time-varying factors, such as local growth in the demand for green buildings, are correlated with both GBEL subsidies and LEED adoption. Thus, our third piece of evidence is based on comparing prepolicy certification trends for regions that do and do not adopt a local subsidy. These pretrend tests show that while GBEL certification begins to grow 1 year before adoption of a local subsidy, there is no significant difference between "treated" and "control" cities over the preceding 5 years.

In addition to estimating spillover effects, we also conduct a set of analyses that provide evidence on the various channels described in Propositions 2–4. In order to interrogate P2, we replace the outcome variable in (1) with a new variable, $LEEDAP_{it}$, which measures the number of LEED APs in a local market year. Because this outcome reflects the supply of professional services for the *nonsubsidized* label, a positive correlation between GBEL subsidies and new LEED APs is consistent with the presence of supplier spillovers. Next, to examine the adopter channel (P3), we go to the building level data, and compare the probability of multi-labeling versus single-labeling conditional on adopting either GBEL or LEED. Finally, to examine spillovers through the user channel (P4), we estimate a model that allows the impact of local GBEL subsidies to vary with a city's level of "environmentalism" as measured by the Low-Carbon City Index. Specifically, we estimate the difference-in-differences regression

$$CERT_{it} = \alpha_i + \lambda_t + \beta\, SUBSIDY_{it} + \delta SUBSIDY_{it} * GRINDEX_i + \theta X_{it} + \varepsilon_{it} \tag{3}$$

where the outcome $CERT_{it}$ is the annual count of GBEL or LEED certifications, and the city fixed effects absorb the main effect of the time-invariant "green score" (*GRINDEX*).[19] In this

[18]See Table C2 in online Appendix C. Local green building policies and financial subsidies are developed by the provincial Department of Housing and Urban Rural Development and the Department of Finance. Our investigation of the underlying politics indicates that the factors contributing to local government decisions on financial subsidies are complicated and hard to predict.

[19]Prior to estimating this model, we "center" the G_i by subtracting its mean value within the estimation sample from each observation. This implies that β estimates a sample average treatment effect, as opposed to the average treatment effect when G_i equals zero.

TABLE 3 Green buildings by building type between 2006 and 2015

	LEED (n = 670)[a]		GBEL (n = 4,067)	
	Residential	**Nonresidential**	**Residential**	**Nonresidential**
Chinese	3.6%	45.8%	47.5%	51.6%
International	0.6%	50.0%	0.1%	0.8%

[a]The total LEED certification number is actually 776. However, some building information is confidential and are not included in the analysis here.

specification, the coefficient β measures the impact of financial subsidies on the adoption of either GBEL or LEED, while δ indicates whether the impact of the financial subsidies varies with our proxy for the local demand for green amenities.

5 | RESULTS

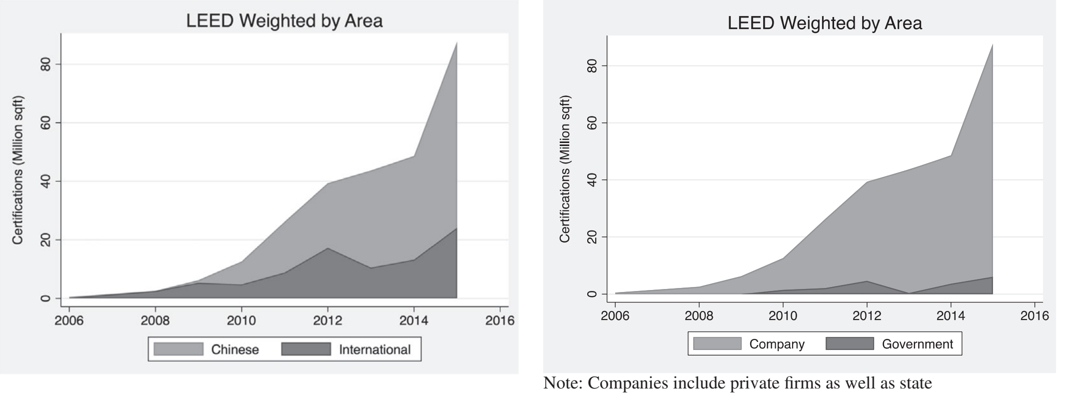
5.1 | Descriptive evidence

Table 3 provides descriptive evidence at the building level that observable project characteristics are correlated with builders' certification choices. Comparing across columns in this table, it is evident that most LEED certified buildings are nonresidential (i.e., offices, retailers, or hotels), whereas GBEL certified projects are evenly split between residential and nonresidential. Potential explanations include greater signaling benefits of LEED for international tenants of commercial buildings, or greater costs sensitivity for residential developers. Similarly, comparing across rows, we find that GBEL certified projects nearly all have Chinese owners, whereas LEED certified buildings are evenly split between Chinese and international owners. If we use these two characteristics to define a set of market segments, then GBEL and LEED appear to dominate in the residential and international segments respectively, with the most interlabel competition taking place for Chinese-owned nonresidential buildings.

One explanation for international owners' apparent preference for LEED is that they have prior experience with that label in other countries. Counting individual projects may, however, provide a misleading impression because many international projects are relatively small stores or offices, whereas Chinese-owned LEED projects tend to be entire buildings.[20] This pattern is illustrated in Figure 3, which graphs the total square meters of LEED certified space by owner type. As shown in Figure 3a, roughly 75% of the LEED certified space was Chinese owned by 2015. Figure 3b shows that most LEED buildings are owned or operated by companies, including state-owned enterprises, with the government share of LEED adoption varying between 0 and 10%.

Overall, the descriptive evidence paints a mixed picture. The dominance of LEED and GBEL in their respective "segments" is consistent with the view that these labels are viewed as substitutes, at least at the building level. However, both labels account for a meaningful share of Chinese owned nonresidential projects. To better understand the interactions between LEED and GBEL within local markets, we turn now to the regression analysis.

[20]Interestingly, many Chinese State-Owned Enterprises such as China National Offshore Oil Corporation, Bank of China, China National Offshore Oil Corporation, and China Life have their buildings certified only by LEED.



Note: Companies include private firms as well as state owned enterprises.

FIGURE 3 LEED certification by building type. (a) LEED projects owned by Chinese and international companies—weighted by area. (b) LEED projects owned by companies and governments—weighted by area. Companies include private firms as well as state owned enterprises

5.2 | Spillovers in the adoption of green building labels

5.2.1 | Spillover effect of GBEL on LEED

Table 4 presents estimates from our instrumental variable analysis of the impact of GBEL adoption on LEED certification in the same local market. In the first two columns, we report first-stage results based on Equation (2) for each instrument. The instruments are relevant.[21] For example, the coefficient in the first column indicates that GBEL certification increased by 28% after adoption of local financial incentives. Figure 4 plots the coefficients and standard errors from an event study specification corresponding to this difference-in-differences regression.[22] The figure shows that GBEL adoption begins to increase two-years prior to the enactment of subsidies, and then grows sharply after the subsidies are enacted. We interpret the uptick 2 years before subsidy adoption as an anticipation effect: builders certify ahead of the subsidy because they expect the financial incentives to arrive in the next year. We cannot reject the hypothesis that pretreatment coefficients for periods −6 through −2 are equal (i.e., there is no pretrend during that period), which we take as evidence against the idea that policy adoption is correlated with potential outcomes.[23] Overall, we find strong evidence of a link between financial subsidies and GBEL adoption, and little evidence that cities receiving a local subsidy were on a different GBEL-adoption path prior to the policy change.

If there are causal spillovers from GBEL to LEED adoption, then the financial subsidies for GBEL should also promote LEED adoption in the same markets. The third and fourth columns

[21]When both instruments are included, the first-stage F-statistic is 15.68, which exceeds the $F>10$ rule of thumb for IV relevance proposed by Staiger and Stock (1997).

[22]The specification is $GBEL_{it} = \alpha_i + \lambda_t + \sum_k \beta_k 1[y - t_i = k] + \varepsilon_{it}$, where k indexes years before/after local subsidies are implemented, the coefficients β_k are dynamic treatment effects, and we normalize $\beta_{-1}=0$.

[23]The F-statistic for the pretrend test is 1.00 (p-value = .41) so we cannot reject the hypothesis of equal pretrends in GBEL adoption. We also test for pre-trends in LEED adoption, and similarly cannot reject the hypothesis that the pre-subsidy event study coefficients are jointly equal to zero (the p-values are p = .24 for the normalization $\beta_{-2}=0$ and p = .34 when we set $\beta_{-1}=0$).

TABLE 4 GBEL certification and LEED certification—Panel data analysis

	First stage		Reduced form		Spillover effect	
					OLS	IV
	lnGBEL	lnGBEL	lnLEED	lnLEED	lnLEED	lnLEED
lnGBEL					0.18	0.23
					(0.03)	(0.07)
SUBSIDY	0.28		0.07			
	(0.07)		(0.03)			
SUBYEAR		0.17		0.04		
		(0.04)		(0.02)		
Control variables						
lnArea	0.22	0.22	0.02	0.02	−0.01	−0.03
	(0.06)	(0.06)	(0.02)	(0.02)	(0.02)	(0.02)
lnPop	−0.02	−0.02	0.00	0.00	0.00	0.00
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
First-stage *F*-stat	7					15.68
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,822	6,822	6,822	6,822	6,822	6,822
R-squared	0.2	0.2	0.04	0.04	0.24	

Note: Unit of analysis is a city-year. Robust standard errors clustered by city in parentheses.

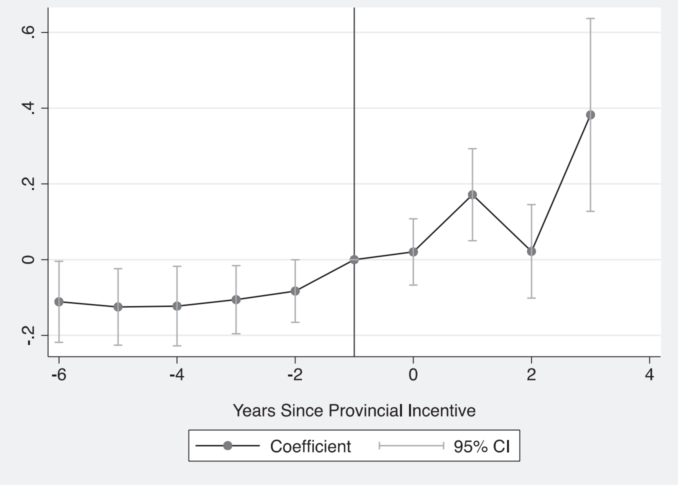


FIGURE 4 Event study—impact of GBEL subsidy on GBEL certification log(1 + GBEL)

in Table 4 examine this "reduced form" relationship. In particular, the results in the third and fourth columns of Table 4 show that LEED certification increases by around 7% (p <.01, column 3) following the adoption of local financial subsidies for GBEL certification. Note that in all of these models, the city-level fixed effects control for time-invariant unobserved heterogeneity, such as an especially strong international adopter or user presence at a particular location.

The last two columns in Table 4 report OLS and IV estimates of Equation (1), which measures causal spillovers from GBEL to LEED adoption. The OLS and IV estimates both indicate positive spillovers. The elasticity of 0.23 implies that doubling the rate of GBEL certification leads to a 23% increase in the rate of LEED adoption in the same market (p <.01). The similar size of the OLS and IV estimates suggests that GBEL adoption is exogenous to LEED certification, and indeed a Durbin–Wu–Hausman test cannot reject that hypothesis.[24] Overall, the estimates in Table 4 are consistent with P1, which claims that increased adoption of one voluntary certification program can have positive spillover effects that increase adoption of "rival" labels in the same market.

In Appendix C we subject the results in Table 4 to the following robustness checks: (a) drop all cities that report no green building certification during our sample period (Table C3); (b) switch from a constant elasticity specification to OLS in levels of LEED and GBEL adoption (Table C4); (c) drop the time-varying controls for urban population and built area (Table C5); (4) use LEED registrations (rather than certifications) as the outcome (Table C6); (5) use *amount* of local subsidy instead of a subsidy indicator as the instrumental variable (Table C7); (6) replicate the analysis using two additional outcome measures based on counting *only* Chinese-owned or internationally-owned LEED buildings (Table C8); and (7) drop individual cities, including Beijing and Shanghai, from the estimation sample (Table C9). Details of each analysis are provided in Online Appendix C. For all of the alternative models, we find very similar results to those reported in Table 4.

5.2.2 | Supplier spillovers

To examine whether spillovers operate via the supplier channel described in P2, we replace the outcome variable in Equation (1) with $LEEDAP_{it}$, which is a measure of supplier adoption. Table 5 presents these results (omitting the first stage estimates, which are identical to those in Table 4). For this new outcome variable, we find reduced form, OLS, and IV estimates that are extremely close to those for LEED certification. For example, the IV results in the final column of Table 5 indicate that doubling the rate of GBEL adoption would increase LEED related human capital investment in the same market by 25% (p <.01). This result shows that GBEL adoption causes LEED supplier entry—a necessary condition for existence of supplier spillovers—but does not demonstrate a causal link between supplier entry and LEED certification.[25] Nevertheless, the results in Table 5 provide evidence supporting the claim in P2 that there can be positive spillovers from one certification program to another that operate via shared input markets.

5.2.3 | Adopter spillovers

Our discussion of spillovers via the adopter channel (P3) describes how building-level scope economies in certification might lead to joint adoption of two or more labels. To examine this

[24]The p-value for a DWH test for endogeneity test is .317, so we cannot reject the null hypothesis of exogeneity.

[25]Estimating a causal link between APs and LEED certification would require another instrument, because those outcomes are simultaneously determined.

TABLE 5 GBEL certification and LEED AP registration

	Reduced form		Spillover effect	
			OLS	IV
	lnLEEDAP	lnLEEDAP	lnLEEDAP	lnLEEDAP
lnGBEL			0.21	0.25
			(0.04)	(0.09)
SUBSIDY	0.07			
	(0.03)			
SUBYEAR		0.05		
		(0.02)		
Control variables				
lnArea	0.02	0.02	−0.02	−0.03
	(0.02)	(0.02)	(0.02)	(0.03)
lnPop	−0.01	−0.01	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)
Year dummy	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Observations	6,822	6,822	6,822	6,822
R-squared	0.03	0.03	0.17	

Note: Unit of analysis is a city-year. Robust standard errors clustered by city in parentheses.

proposition, we matched building level data from MOHURD and USGBC and calculated the number of certified projects that use both labels. During our study period, only 72 projects, or 1.5% of all buildings certified under either LEED or GBEL, chose to adopt both labels.[26] Thus, it does not appear that building level scope economies are an important source of the spillover effect from GBEL to LEED adoption that we observed in Table 4.

The small number of buildings that do adopt both labels appear different from the general population of certified projects. For example, the average GBEL certification level is 1.7 Stars, but increases to 2.6 Stars for buildings that also adopt LEED. This positive correlation between multi-labeling and greater investments in environmental performance suggests that multi-labeling can be used to provide a stronger "green signal" that differentiates these buildings from users of a single label, even if the multi-label mechanism is not widely used in our empirical setting.

5.2.4 | User spillovers

Table 6 reports estimates from a pair of reduced form OLS regressions based on Equation (3), which interacts the *SUBSIDY* indicator variable with the *GRINDEX* score.[27] The first column

[26]All of these projects are nonresidential buildings owned by Chinese firms or governments. Multi-labeling has also increased over time, with nearly half (35 projects) of these projects appearing in 2015, the final year in our sample.
[27]We use a smaller sample of cities for this analysis, due to the limited availability of the Green Score variable.

TABLE 6 Spillover effects in different cities

	lnGBEL	lnLEED
SUBSIDY	0.43	0.16
	(0.15)	(0.09)
SUBSIDY * lnGRINDEX	0.74	0.91
	(0.90)	(0.43)
Control variables		
lnArea	0.33	−0.03
	(0.17)	(0.10)
lnPop	−0.04	0.01
	(0.05)	(0.03)
Year dummy	Yes	Yes
City fixed effects	Yes	Yes
N	1,063	1,063
R-squared	0.61	0.18

Note: Unit of analysis is a city-year. Robust standard errors clustered by city in parentheses.

reports estimates for GBEL adoption, and the second column reports estimates for LEED adoption. Both models indicate that financial subsidies had a larger impact in "greener" cities. For GBEL, the estimated coefficient on *SUBSIDY*, which measures the impact of financial incentives at a city with the sample average *GRINDEX* score, indicates a 43% increase in certification. Doubling the green index increases this elasticity by 172% (i.e., 0.74/0.43 = 1.72). For LEED, on the other hand, the *SUBSIDY* effect is only 16%, while doubling the green index increases the impact of subsidies by 560%. In practical terms, these two regressions indicate that financial subsidies for GBEL had an across-the-board impact on GBEL adoption, whereas the positive spillovers to LEED were concentrated within cities that exhibited a larger green score. This pattern is consistent with our claim in P4 that positive spillovers can occur through the user channel when the adoption of one certification program stimulates latent demand for quality, leading to increased adoption of related labels.[28] In particular, these results reinforce the idea that demand-side spillovers through the user channel are not merely a function of the different market segments served by each label, but rather a function of tapping into latent demand for green building, which can be measured by either standard.

6 | DISCUSSION AND CONCLUSIONS

Our analysis of GBEL and LEED adoption in Chinese cities illustrates how the diffusion of one voluntary certification program can produce positive spillovers that encourage the adoption of

[28]As a point of comparison, Table C10 in online Appendix C estimates the same specification, replacing GRINDEX with INTINDEX, a proxy for each city's international orientation. The results show that although financial subsidies for GBEL adoption had a larger impact in cities with greater international orientation, the magnitude of the INTINDEX interaction term is small relative to the interaction with GRINDEX (though one should be cautious with this comparison, given that the two samples differ due to availability of the index measures).

"competing" labels. In particular, we exploit the staggered adoption of provincial and city level subsidies for GBEL to estimate spillover effects from GBEL to LEED. Our estimates suggest that spillover effects are substantial: doubling the rate of GBEL adoption leads to a 20% increase in LEED adoption within the same local market. In addition to measuring these spillovers, we provide evidence on underlying mechanisms. In the adoption of Chinese green-building labels, positive spillover effects appear to be driven by market level factors that operate through the "supplier" and "user" channels. We find little evidence of building level economies of scope that would lead to multi-labeling.

With respect to the question posed in the title – are the labels complements or substitutes?—our analysis suggests that GBEL and LEED complement one another at the market level, even if they are rarely used together at the building level. This insight provides several avenues for future research. For example, theories of ecolabel competition could seek to incorporate spillovers into a model of dynamic competition. New theory might also consider how competition changes when labels are viewed as intermediaries that must attract specialized input suppliers in addition to label adopters, particularly when labels are managed by different types of standard setting organizations. From a broader perspective, it is crucial to understand the conditions that determine whether co-existence of multiple certification programs in a market will lead to improvements in social and environmental performance as opposed to a "race to the bottom" (e.g., Doremus, 2019).

Our study contributes to the literature in several ways. First, to our knowledge, it is the only study to examine spillovers effects in the adoption of multiple voluntary certification programs. The results therefore contribute to a literature on eco-labeling certification that has emphasized competition among labels (Fischer & Lyon, 2014, 2019; Jiang & Bansal, 2003; Lanahan & Armanios, 2018), but rarely considered spillovers between them.

Second, our study contributes to the literature on self-regulatory institutions. Researchers have explored two major forces that lead firms to participate in self-regulatory institutions: institutionalization (DiMaggio & Powell, 1983) and strategic choice (King & Toffel, 2007; Prado, 2013). We propose a simple conceptual framework that emphasizes three different channels—supplier, adopter and user—that can influence the costs and benefits of self-regulatory action. Our framework helps link the literature on self-regulation to the literature on platforms (Rochet & Tirole, 2003; Simcoe & Toffel, 2014) and guides our empirical analysis of Chinese green-building certification practices.

Third, because we find that "competing" green building labels can be complements at the market level, our results suggest that policies stimulating the adoption of one green building standard can encourage the adoption of another. As such, the study adds a new dimension to the green building literature, where the importance of supply-side capacity building is well known (Cidell, 2009; Corbett & Muthulingam, 2007; Kahn & Vaughn, 2009; Kok et al., 2011; Kok & Jennen, 2012), but competition and complementarity have received less attention.

Fourth, we contribute to the literature on government voluntary programs. Prior literature suggests that government voluntary programs can impact all firms in affected industries, regardless of whether they choose to participate in a program (Delmas & Montes-Sancho, 2010; Lange, 2009; Lyon & Maxwell, 2008; Zhou, Bi, & Segerson, 2020). GBEL is a government voluntary program in China. Our finding that GBEL has a positive spillover effect on LEED is consistent with the prior literature, but expands that literature to encompass interactions between government voluntary program and self-regulatory certification.

Of course, our analysis is subject to several limitations. Our empirical context features two standards that are both in a relatively early stage of adoption. One of those standards is a relatively mature international certification program, and the other has the explicit support of the Chinese government. The scope for positive spillovers in the adoption of voluntary certification programs may be more limited in settings where one or both labels are well established within a market, where there is little parity between labels, or where neither label has explicit government support. Because our data ends in 2015, we are not able to examine whether the trend toward increased use of multi-labeling has accelerated. And perhaps most importantly, because we study label adoption rather than environmental performance, our outcome is only a rough proxy for the private or social benefits of certification.

Finally, our study has implications for both management and policy. Managers of standard setting organizations (e.g., at USGBC) and building developers may benefit from using our spillover framework as a roadmap for attracting various stakeholder groups. The results also suggest that market level complementarities can promote the co-existence of multiple labels, indicating to managers that the risks of tipping toward a single standard are lower in practice than the literature on standards adoption predicts. For policymakers, this study highlights how government incentives to adopt a particular standard – particularly in the early stages of the diffusion process—can work through various channels to encourage adoption of related certification programs that share common objectives or inputs. This policy multiplier effect merits further research, but also suggests that regulators consider subsidizing shared inputs directly as a method of promoting the adoption of multiple certification programs without "picking winners."

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DATA AVAILABILITY STATEMENT

Part of the data that support the findings of this study are available from USGBC. Data are available from the authors with the permission of USGBC.

ORCID

Xia Li https://orcid.org/0000-0001-6507-2302
Timothy Simcoe https://orcid.org/0000-0002-5950-660X

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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