Competing or Complementary Labels? Estimating Spillovers in Chinese Green Building Certification*

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ABSTRACT

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 the adoption of "competing" certification programs, 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 Leadership in Energy and Environmental Design (LEED) standard within the same region. 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.

KEYWORDS

Multiple Certifications; Spillover; Green Building; Voluntary; Differentiation

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INTRODUCTION

Certification is a widely used tool for reducing information asymmetry between buyers and sellers when product quality is hard to assess (Biglaiser and Li, 2018; Houde, 2018; Stahl and Strausz, 2016) or when certain organizational behaviors are hidden (King, Lenox, and Terlaak, 2005). Voluntary certification programs can be found in sectors as diverse as finance, health, real estate, food, and energy (Dranove and Jin, 2010), and scholars have studied how certification can signal a wide variety of practices, ranging from environmental performance (King and Lenox, 2000) or social responsibility (Heyes and Martin, 2017) to hygiene (Jin and Leslie, 2003) and creditworthiness (Becker and Milbourn, 2010).

One recent and important strand of the literature analyzes competition between labels in markets with more than one voluntary certification program (Bottega and De Freitas, 2009; Fischer and Lyon, 2014 and 2019; Heyes and Maxwell, 2004; Heyes and 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. Adoption of one label could also increase consumers' general awareness of certain dimensions of product quality, and thereby stimulate adoption of other similar labels. Thus, although there is prior literature on the adoption and impacts of voluntary certification (Dranove and Jin, 2010; King and 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 five to ten years (Yu, Evans and Shi, 2014). In 2015, buildings accounted for one-third of total Chinese energy use (Yuan, Zhang, Liang, Wang, and Zuo, 2017) and also produced a large share of non-industrial solid waste, water use, CO_2 emissions, and SO_2 emissions. Given the vasqt scale of Chinese construction and real estate markets, curtailing energy consumption and using green materials are potentially important tools for addressing climate change and other environmental externalities.

Two green-building labels are widely used within China. Green Building Evaluation Label (GBEL) is a government led voluntary certification scheme introduced in 2007 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. LEED 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, 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 and Toffel, 2014), the literature on standards adoption predicts that markets can even "tip" towards a single dominant label (Katz and Shapiro 1985; Farrell and Saloner 1985). On the other hand, there are several forces that push in the opposite direction. Because these

[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.

factors have received less attention in the literature, one contribution of this paper is to propose a conceptual framework that describes several mechanisms that could produce positive spillovers.

Our conceptual framework emphasizes three channels – corresponding to three types of stakeholder – that can generate market or building level economies of scope 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, so adopting one label reduces the marginal cost of adopting another. Finally, the third channel operates through users (i.e. the audience for a label). When increased adoption of one certification program raises public awareness of the general issues it is meant to address, that can produce an increase in the total demand for related dimensions of quality, some of which may be more salient in the design of alternative labels.

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 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 percent increase in LEED adoption.

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. For users, we show that spillovers are larger for cities that are "greener" in other dimensions, which suggests an increased general awareness of green building in cities where there is greater latent demand for environmental quality. We find little evidence spillovers via the adopter channel. In particular, very few buildings adopt both GBEL and LEED, which suggests 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 (Delmas and Toffel, 2008; Fischer and Lyon, 2014 and 2019; Jiang and Bansal, 2003; Lanahan and Armanios, 2018; Heyes and Maxwell, 2004) 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." Second, our paper contributes to a literature that explores factors leading firms to participate in self-regulatory institutions (Chan & Wong, 2006; Corbett and Kirsch, 2004; King and Toffel; 2007; Short & Toffel, 2007). 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, our research sheds light upon the importance of government policy towards voluntary certification by analyzing the interaction between a Chinese government voluntary program (GBEL) and an industry self-regulatory label (LEED). Our main empirical results show how government subsidies for GBEL adoption had a positive impact on the diffusion of both labels.

THEORETICAL FRAMEWORK

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 (Shapiro, 1982; Merges, Menell, and Lemley, 2012), and third-party certification (Biglaiser and Li, 2018; Houde, 2018). We focus on certification, which is typically conducted by Non-Government 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 and Jin, 2010) certification is used to facilitate trade in a wide variety of settings. Many markets even 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 and Terlaak, 2001; Delmas and Toffel, 2008; Jiang and Bansal, 2003) or buyers (Lanahan and Armanios, 2018). Certification programs can also differentiate themselves vertically, by adopting different levels of stringency (Lerner and Tirole, 2006; Prado, 2013). For the most part, however, prior literature has assumed multiple certifications serving the same market compete with each other. For example, there are formal models of competition between government and NGO labels (Heyes and Maxwell, 2004), government and for-profit labels (Bottega and De Freitas, 2009), industry and NGO labels (Fischer and Lyon, 2014 and 2019), and between rival NGOs (Heyes and 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 or competitors. At a high-level, the theoretical mechanism we propose is that different labels serving a common market can benefit from scope economies whenever they utilize a common pool of resources. Under that assumption, 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 certification programs resemble a multi-sided platform (Lerner and 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.

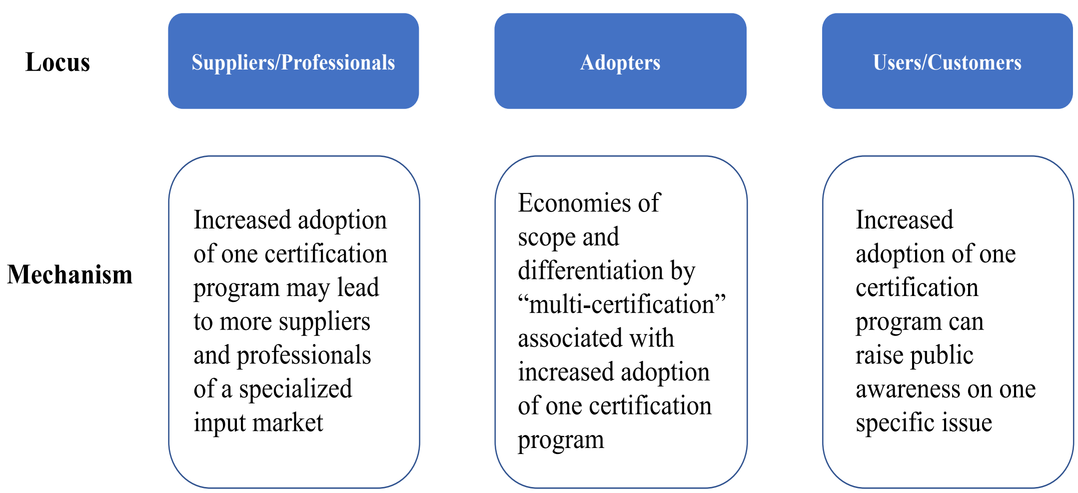
Whereas prior literature has emphasized that the success of a single certification program relies on coordinated adoption by suppliers, adopters and users, we extend that framework to multiple certification programs, and argue that each group constitutes a distinct channel for positive spillovers between 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, or greater legitimacy (Corbett & Kirsch, 2004; King & Lenox, 2001). As long as key inputs are not specific to a particular 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, there are two sources of positive spillovers. First, 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. Second, as more firms adopt a first label, some may want to further differentiate by adopting two labels at once (a strategy that we call multi-labelling).

Finally, from the user perspective, increased adoption of one certification program may raise general awareness about particular aspects of quality, such as environmental impact or social responsibility. This can increase the demand for all goods that exhibit similar quality characteristics, including those certified under a different label. Combining these insights, we expect that

Figure 1. Positive Spillover Effect between Multiple Voluntary Certification Programs



increased adoption of one voluntary certification program can stimulate adoption of another label in the same market:

> *Proposition 1(P1): Increased adoption of one voluntary certification program can increase the adoption of another similar certification program in the same market.*[2]

In the remainder of this section, we unpack the supplier, adopter and user channels in greater detail and describe how each type of spillover might be measured. In the interest of precision, *Online Appendix A* provides a formal statement of each of the propositions.

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.

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. Simcoe and Toffel (2014) describe how a new label 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, 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 (P2): Increased adoption of one voluntary certification program can increase the supply of key inputs, such as professional services, for similar certification programs operating in the same market.*

Adopter spillovers

Adopters often view alternative certification programs as substitutes, and select a single label based on their own particular needs (Delmas and Toffel, 2008). 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 (FSC) and the Program for the Endorsement of Forest

[2] 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 labelled "explanations" (King, Goldfarb and 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.

Certification (PEFC). We use the term "multi-labelling" to describe products that simultaneously adopt multiple certifications.[3]

Multi-labelling is driven by firm or project level economies of scope.[4] 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. This does not mean that costs of adopting the second label fall to zero – additional resources are still required. Thus, a necessary condition for multi-labelling is that the marginal benefits of acquiring an additional label exceed the marginal costs.

The benefits of multi-labelling are greater when certification programs are horizontally as opposed to vertically differentiated, where vertical differentiation refers to the stringency of the certification scheme (Fischer and Lyon, 2014; Li and van't Veld, 2015; Hayes and Martin, 2017; Rysman, Simcoe, and Wang, 2018). If one certification program has requirements that are a *strict* subset of a second certification program, then there is no information provided by adopting both, relative to adopting the label with more requirements. In that case, there is no incentive for multi-labelling. Horizontally differentiated certification programs have requirements that only partially overlap and may therefore appeal to different users. Adopting a pair of horizontally differentiated labels will send a different signal from adopting either individual label on its own. Thus, for horizontally differentiated certification programs, as long as the marginal benefits of gaining a second certification decline more slowly than the marginal costs (i.e., scope economies are large relative to any reduction in signaling benefits), then *ceteris paribus*, an increase in the adoption of one voluntary certification program should lead to more adoption of related labels in the same market. This leads us to proposition:

> *Proposition 3 (P3): Economies of scope in the adoption of multiple voluntary certification programs is associated with increased multi-labelling.*

User spillovers

Whereas supplier and adopter spillovers are both supply-side mechanisms, it is also possible for demand-side factors to produce complementarity in the adoption of related certification programs. User spillovers occur when increased adoption of one certification program raises public awareness and interest in the general problem addressed by related labels (e.g. health, environmental, or social responsibility) thereby stimulating demand for products or projects that utilize other similar labels. For instance, increased adoption of the EU organic label may raise public awareness of the benefits of organic products in general, and thereby stimulate demand for other organic certifications such as Demeter International.

This conception of user spillovers assumes that the latent demand for certain quality attributes is linked to broader social awareness of a particular class of problems. For example, the desire for green buildings is linked to specific problems such as energy use, access to transit, sustainably sourced materials, and air quality. Different certification programs typically place different weight on each of the specific problems within a broader domain. At the market-level, however, we expect that demand for the entire bundle of "green" attributes to be positively correlated.

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[3] The term multi-labelling 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).

[4] In this paper, 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.

Thus, adoption of one label that addresses a subset of these issues can stimulate demand for related certification programs that address other issues within the same broad problem domain.

Scholars have argued that the adoption of certification programs is conditioned by regional institutional logics (Thornton and Ocasio, 1999; Lee and Lounsbury, 2015; Marquis and Lounsbury, 2007; York, Vedula, and Lenox, 2018), and that the costs and benefits of adopting the same certification will vary across regions. The user spillover mechanism described above suggests that we should observe greater complementarity in markets where customers share a strong taste for quality, as measured by a particular group of labels that address a common problem. In such markets, the adoption of one label may lead customers to pay greater attention to other labels, leading to greater benefits for an adopter that embraces any related certification. Customers may also encourage local governments to adopt policies that favor investments that are not specific to any particular label (and in that sense, user spillovers are not strictly a "demand side" channel). In either case, the adoption of one certification program leads users to favor certification as a general solution to a broad class of problems, thereby creating a more favorable environment for the adoption of related labels.

Proposition 4 (P4): 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.

Before describing our empirical context, it is important to mention a key scope condition that applies to each of our hypotheses. We believe that positive spillovers in the adoption of multiple voluntary certification programs are more likely in markets where most products are not yet certified, so that producers are not (yet) choosing from a set of well-established labels. In markets with several mature certification programs, there may be some scope for multi-labelling. But in general, the supplier and user-spillover mechanisms described above will be stronger when adopters' default choice is to remain uncertified.

INSTITUTIONAL CONTEXT

Our empirical analysis examines the adoption of two green building certification programs using panel data from Chinese real estate markets. The first program, GBEL, is a government led voluntary scheme. The second, LEED, is a global industry-led self-regulatory certification program. *Figure 2* shows the number Chinese buildings certified under each label between 2006 and 2015. Although adoption of both labels is increasing over time, the introduction of government policies and subsidies targeting GBEL around 2012 is associated with a rapid increase in its share of total certification.

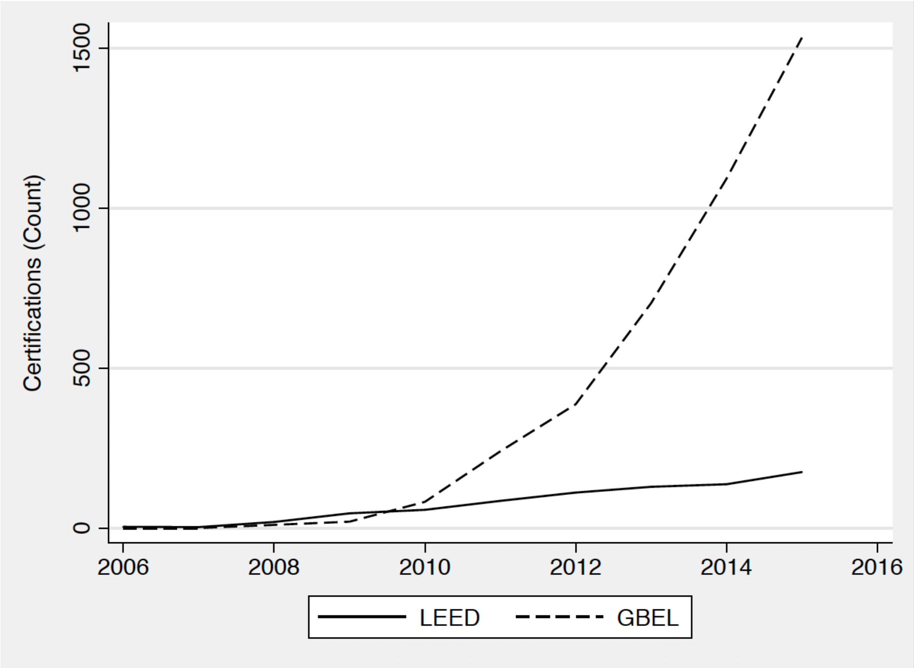
GBEL

GBEL was developed by the Chinese Ministry of Urban and Rural Development (MOHURD) and introduced in 2006. The program is often referred to as "China Three Star" because it uses a three-tier rating system. Most GBEL certified buildings are multi-unit residential structures or public buildings, such as offices, hotels or retail outlets within a larger building.[5]

Although the costs of adopting any green building standard can vary widely across projects, MOHURD estimates that the cost of GBEL certification range from $4.50 to $29 per square meter for residential buildings and from $5.50 to $71 per square meter for public buildings, depending

[5] Although GBEL can also be used to certify industrial buildings, its scope (i.e. the diversity of building types covered by the rating system) is not as broad as LEED.

Figure 2. Annual Green Building Certifications in China from 2006 to 2015



on the certification level. MOHURD also estimates that these certification costs can be recovered through energy cost savings within 2-6 years.[6]

Figure 2 shows that Chinese builders favored LEED prior to 2010, but then shifted towards GBEL. 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.[7] Under those guidelines, the Chinese government provides builders with a number of incentives to adopt GBEL, including financial subsidies to all GBEL buildings equal or above two stars, prizes, and better conditions on loans. Between 2012 and 2015, seven provincial-level administrative units and three cities introduced local financial subsidies for GBEL adoption.[8] 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.

LEED

LEED is an industry self-regulatory standard created and managed by the US Green Building Council (USGBC). Between 1998 and 2019, more than 79,000 projects across 160 countries and territories have been registered or certified using LEED, making it the world's most widely adopted green building certification.[9] The first Chinese LEED certification took place in 2005.

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

[7] 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.

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

[9] http://leed.usgbc.org/leed.html

By July 2018, however, there were 1,470 Chinese LEED certified projects, and according to the USGBC China had surpassed Canada as the largest market for LEED certification outside the United States.

LEED is a multi-tier label featuring four levels of certification: Certified, Silver, Gold, and Platinum.[10] As with GBEL, the costs of LEED certification vary by project types and certification levels. While there are modest registration and certification fees, the major expense of LEED certification is associated with designing and adopting green technologies (Simcoe and Toffel, 2014). Against these costs, prior literature suggests that LEED adoption has both financial and environmental benefits (Kats 2003; Eichholtz, Kok, and Quigley, 2010; Newsham, Sandra, and Benjamin, 2009; Sabapathy, Ragavan, Vijendra, and Nataraja, 2010).

In addition to certifying buildings, the LEED brand is associated with a professional accreditation program for various types of building-industry professionals (e.g. architects, designers, contractors) to certify their advanced knowledge in green building practices and expertise in a particular LEED rating system.

Khanna et al (2014) provide a detailed comparison of the LEED and GBEL rating criteria. Five of their six rating categories used by these two labels are very similar: 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. Lee (2012) compares five green building standards including LEED and GBEL, and suggests that despite the variations in default parameters among the five different schemes, market positions of certified buildings are comparable.

DATA AND METHODOLOGY

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

Data

Our data comprise a balanced panel of 657 Chinese cities observed from 2005 to 2015.[11] 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 professional accreditations (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.

[10] Because both programs have multiple tiers, it is difficult to say whether GBEL or LEED is more stringent. For detailed comparison between LEED and GBEL, please refer to Khanna, Romankiewicz, Feng, and Zhou (2014).

[11] 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 achieve the green building standard so data after 2016 might not be a good fit for the research design.

For a sub-sample of 115 cities, we also 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. A city's green building activity counts for just 2 out of 100 total points in this index.

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.[12] *Table 1* reports means, standard deviations 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.

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.

Methodology

Measuring causal spillovers between voluntary certification programs is challenging for two reasons. First, according to our theory, 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

Table 1. Summary Statistics and Correlations

Variable	Mean	Std.	Type of Variation	lnGBEL	lnLEED	SUBSIDY	SUB-YEAR	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

[12] 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.

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:

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

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 the 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:

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

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 as associated with LEED adoption, and under the assumed exclusion restriction, attribute that correlation entirely to spillovers from GBEL to LEED.

Although it is not possible to test the exclusion restriction directly, we offer two observations in support of our instruments. First, because our regressions include city fixed-effects, we have controlled for any time-invariant factors that might produce an unwanted correlation between the instruments and the residuals. Second, in *Online Appendix C* we compare observable characteristics of provinces that do and do not adopt financial subsidies. Although provinces with financial subsidies are somewhat larger and wealthier, the demographic disparities are not dramatic. Moreover, there is no statistically significant correlation between *GRINDEX* and provincial subsidies. It remains possible that time-varying factors, such as growth in the demand for green buildings, is correlated with both GBEL subsidies and LEED adoption. We cannot control for these factors without exhausting the degrees of freedom in our data. This concern is alleviated to some extent, however, by the fact that most subsidies are implemented at the provincial level, where we see only minor differences between adopting and non-adopting provinces.

In addition to estimating spillover effects, we also conduct a set of analyses that provide evidence on the various channels described in Propositions 2 through 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 professional accreditations in a local market year. This outcome measures the supply of a key input – professional services – tied to the green building process. Next, to examine the adopter channel (P3), we go to the building level data, and compare the probability of multi-labeling versus single-labelling 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 Low-Carbon City Index. Specifically, we estimate the difference-in-differences regression

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

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).[13] In this 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.

RESULTS

Descriptive evidence

Table 2 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 non-residential (i.e. offices, retailers, or hotels), whereas GBEL certified projects are evenly split between residential and non-residential. 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 inter-label competition taking place for Chinese-owned non-residential buildings.

Table 2. Green Buildings by Building Type between 2006 and 2015

	LEED (n=670)*		GBEL (n=4067)	
	Residential	**Non-Residential**	**Residential**	**Non-Residential**
Chinese	3.6%	45.8%	47.5%	51.6%
International	0.6%	50.0%	0.1%	0.8%

Note: *The total LEED certification number is actually 776. However, some building information is confidential and are not included in the analysis here.

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

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.[14] This pattern is illustrated in *Figure 3,* which graphs the total square meters of LEED certified space by owner type. By 2015, roughly 75 percent of the LEED certified space was Chinese owned.

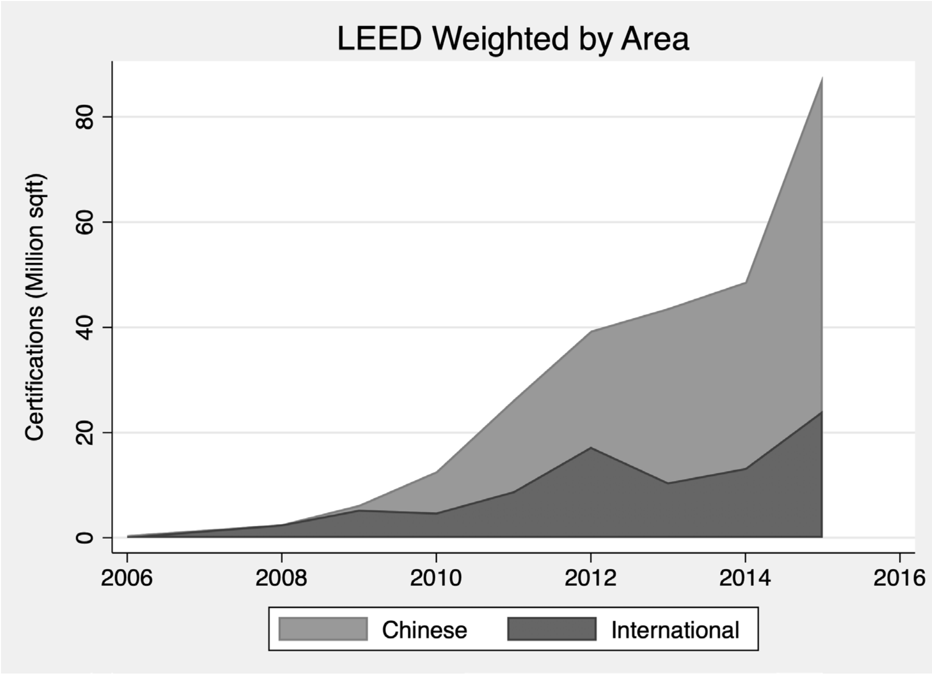
Overall, the descriptive evidence paints a mixed picture. The dominance of LEED and GBEL in their respective "segments" is consistent with the view that these labels are viewed as substitutes, at least at the building level. However, both labels account for a meaningful share of Chinese owned non-residential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

Spillovers in the adoption of green building labels

SPILLOVER EFFECT OF GBEL ON LEED

Table 3 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.[15] For example, the coefficient in the first column indicates that GBEL certifications increased by 28 percent after local financial incentives were adopted. *Figure 4* plots the coefficients and standard errors from an event study specification corresponding to this difference-in-differences

Figure 3. LEED Certification by Ownership – Weighted by Area



[14] 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.

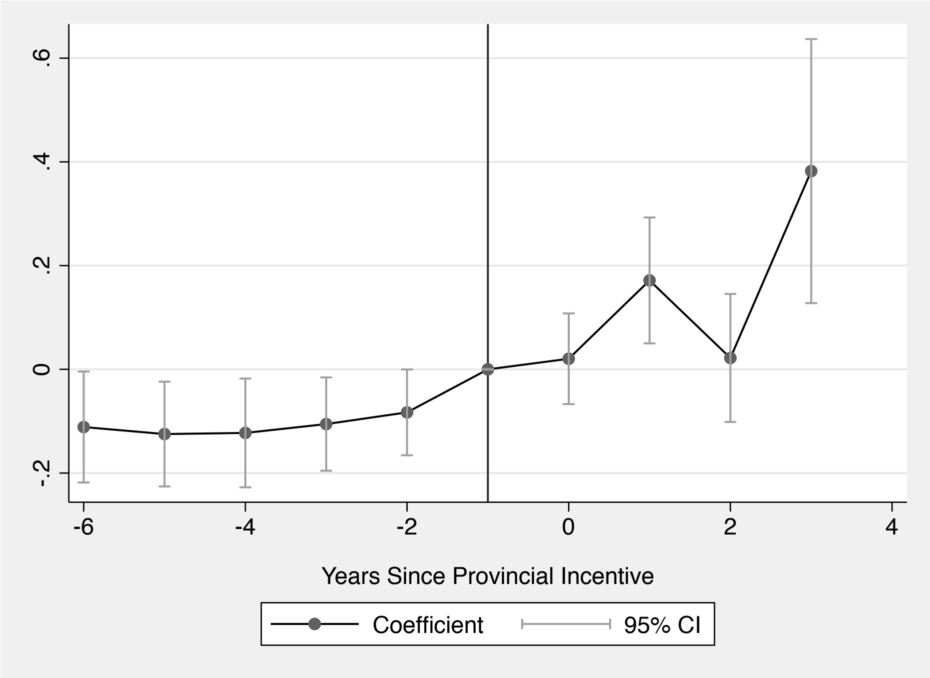
[15] When both instruments are included, the first-stage F-statistic is 15.68, which exceeds the F>10 rule of thumb for IV relevance proposed by Staiger and Stock (1997).

Table 3. GBEL Certification and LEED Certification – Panel Data Analysis

	First Stage		Reduced Form		Spillover Effect	
	lnGBEL	lnGBEL	lnLEED	lnLEED	OLS lnLEED	IV lnLEED
lnGBEL					0.18 (0.03)	0.23 (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 (0.06)	0.22 (0.06)	0.02 (0.02)	0.02 (0.02)	-0.01 (0.02)	-0.03 (0.02)
lnPop	-0.02 (0.01)	-0.02 (0.01)	0.00 (0.00)	0.00 (0.00)	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	6822	6822	6822	6822	6822	6822
R-Squared	0.2	0.2	0.04	0.04	0.24	

Notes: 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)



regression.[16] 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. Overall, we find strong evidence of a link between financial subsidies and GBEL adoption.

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 second and third columns in *Table 3* examine this "reduced form" relationship. In particular, the results in the third and fourth columns of *Table 3* show that LEED certification increases by around 7% ($p < .01$, column 3) following the adoption of local financial subsidies for GBEL certification.

The last two columns in *Table 3* 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 ($p < 0.01$). 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.[17] Overall, the estimates in *Table 3* 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 *Online Appendix C* we subject the results in *Table 3* to a number of robustness checks. First, we drop all cities that do not report any green building certification over our sample period. Second, we switch from a constant elasticity specification to a model that regresses a count of LEED certifications on a count of GBEL certifications. Third, we drop the time-varying controls for urban population and built area. Finally, we use LEED registrations (rather than certifications) as the outcome variable. For all of these alternative models, we find very similar results to those reported in *Table 3*.

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 4* presents these results (omitting the first stage estimates, which are identical to those in *Table 3*). 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 4* indicate that doubling the rate of GBEL adoption would increase LEED related human capital investment in the same market by 25 percent ($p < .01$). It is not surprising that in markets where LEED certification increases, we also observe an increase in LEED professional accreditation. This finding does, however, 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.

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 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 percent of all buildings certified under either LEED or GBEL, chose to adopt both labels.[18] 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 3*.

[17] The p-value for a DWH test for endogeneity test is 0.317, so we cannot reject the null hypothesis of exogeneity.

Table 4. GBEL Certification and LEED AP Registration

	Reduced Form		Spillover Effect	
	lnLEEDAP	lnLEEDAP	OLS lnLEEDAP	IV lnLEEDAP
lnGBEL			0.21 (0.04)	0.25 (0.09)
SUBSIDY	0.07 (0.03)			
SUBYEAR		0.05 (0.02)		
Control Variables				
lnArea	0.02 (0.02)	0.02 (0.02)	-0.02 (0.02)	-0.03 (0.03)
lnPop	-0.01 (0.01)	-0.01 (0.01)	0.00 (0.01)	0.00 (0.01)
Year Dummy	Yes	Yes	Yes	Yes
City Fixed Effects	Yes	Yes	Yes	Yes
Observations	6822	6822	6822	6822
R-Squared	0.03	0.03	0.17	

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

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-labelling and greater investments in environmental performance suggests that multi-labelling 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.

USER SPILLOVERS

Table 5 reports estimates from a pair of reduced form OLS regressions based on equation (3), which interacts the *SUBSIDY* indicator variable with the *GRINDEX* score.[19] The first column 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 percent increase in certification. Doubling the green index increases this elasticity by 172 percent (that is 0.74/0.43 = 1.72). For LEED, on the other hand, the *SUBSIDY* effect is only 16 percent, while doubling the green index increases the impact of subsidies by 560 percent. In practical terms, these two regressions suggest 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 supports our claim in P4 that positive spillovers can occur through the user channel when increased public awareness spurred by the adoption of one certification

[19] We use a smaller sample of cities for this analysis, due to the limited availability of the Green Score variable.

Table 5. Spillover in Different Cities

	lnGBEL	lnLEED
SUBSIDY	0.43 (0.15)	0.16 (0.09)
SUBSIDY * lnGRINDEX	0.74 (0.90)	0.91 (0.43)
Control Variables		
lnArea	0.33 (0.17)	-0.03 (0.10)
lnPop	-0.04 (0.05)	0.01 (0.03)
Year Dummy	Yes	Yes
City Fixed Effects	Yes	Yes
N	1063	1063
R-Squared	0.61	0.18

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

program interacts with latent demand to solve the underlying informational problem that motivates both labels.

DISCUSSION AND CONCLISIONS

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 related 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 these spillover effects are substantial: doubling the rate of GBEL adoption leads to a 20 percent 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-labelling.

This study contributes to a literature on voluntary certification that has emphasized competition between labels, but rarely considered potential economies of scope in the adoption of related certification programs. To our knowledge, it is the first study to examine spillovers effects in the adoption of multiple voluntary certification programs, either theoretically or empirically. Our analysis shows how "competing" labels may actually complement one another at the market level, even if they are rarely used together by the same individual adopter. This insight suggests several avenues for future research, such as examining whether markets are better served by differentiation within a certification program (e.g. through multi-tier schemes such as those used by LEED and GBEL) or through access to a "menu" of independently governed labels.

Our study also 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 and Powell, 1983) and strategic choice (King and Toffel, 2007). 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 and Tirole, 2003; Simcoe and Toffel, 2014) and guides our empirical analysis of Chinese green-building certification practices.

Finally, this study contributes to the literature on government voluntary programs, which are explicit arrangements between companies and regulators. Government voluntary programs encourage firms to set goals and undertake abatement efforts in return for financial or technical assistance. Prior literature suggests that government voluntary programs can impact all firms in affected industries, regardless of whether they choose to participate in a program (Lyon and Maxwell, 2008; Delmas and Montes-Sancho, 2010). 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 also expands that literature to encompass interactions between government voluntary programs and self-regulatory certification.

Of course, our analysis is subject to several limitations and boundary conditions that offer avenues for future research. Our empirical context features two standards that are both in a relatively early stage of adoption, judging by the fact that many buildings are not certified. 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 relatively mature, 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 towards increased use of multi-labelling 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.

Nevertheless, we believe our study has implications for policy. Voluntary certification is an important part of the overall toolkit for promoting environmentally sustainable business practices. Our findings suggest that 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, and also suggests that regulators consider subsidizing shared inputs directly as a method of promoting the adoption of multiple certification programs without "picking winners" when there are several downstream labels.

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Appendix A: Formal Statement of Hypotheses

A project chooses to certify using LEED, GBEL, neither or both. Let $L \in \{0,1\}$ and $G \in \{0,1\}$ denote the decision of a focal project to adopt LEED or GBEL respectively. Let S represent the stock of GBEL certified buildings in the same market as the focal project. We can write the net benefits (payoffs) from certification as

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

where the function B represents gross benefits of certification and C the associated costs. Using this notation, we can precisely state the hypotheses as follows:

Proposition 2 (Supplier Spillovers) is equivalent to assuming that $\pi(L, G; S)$ is super-modular in (L,S) through the cost function

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

Proposition 3 (Adopter Spillovers) is equivalent to assuming that $\pi(L, G; S)$ is super-modular in (L,G)

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

Proposition 4 (User Spillovers) is equivalent to assuming that $\pi(L, G; S)$ is super-modular in (L,S) through the gross benefits function

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

The text describes in greater detail a number of mechanisms that could generate these types of payoffs. Proposition 1 is simply a generalization of Propositions 2 through 4, noting that any of those different mechanisms could generate complementarities in the adoption of related voluntary certification schemes.

Appendix B: Data and Variable Construction

To compile a database of green buildings in China, we hand collect and translate GBEL certification data from MOHURD, and obtain the LEED certification and LEED AP data directly from the USGBC. We merge the two sets of data to obtain a comprehensive dataset of green building adoptions in China. We also collect demographic information from China Census. Our analysis use data on 657 cities with green buildings in China from 2005 to 2015. 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 achieve the green building standard so data after 2016 might not be a good fit for the research design.

LEED Certification: we obtained annual LEED certification data from the USGBC directly. We have the building level data including building name, building owner, year of certification, building type, certification type, located city, and certification rating level. Information of around 12% of LEED certified buildings is confidential. As we don't have some basic information such as the located city, building type, and rating level of these confidential buildings, they are not included in the empirical analysis.

GBEL Certification: we collect annual GBEL certification data from 2005 to 2015 from MOHURD[20]. We have the building level data including the building name, year of certification, building type, certification type, located province, and certification rating level. We translate all information from Chinese to English and search the cities where each project is located based on building names so that we can have a city-level panel data analysis. This is comparable with the LEED Certification data discussed above.

Green building policies and financial subsidies: we gather the national, provincial, and city level green building policy and financial subsidies from MOHURD and provincial government websites. A total of 7 provincial-level administrative units (China has 34 provincial-level administrative units: 23 provinces, 4 municipalities, 5 autonomous regions and 2 special administrative regions) in China have provided their own financial subsidies on GBEL adoption during the 12th FYP period. Four cities, including Luoyang, Xi'an, Qingdao, and Wuhan also provide city level financial subsidies. Because the provincial and city level financial subsidies do not reflect any firm's strategic decision, such "treatment" offers exogenous variation in firms' decision in adopting green building practice.

Construction activity: we collect yearly area of built district in each city from MOHURD.

*Demographic*s: for each city in the analysis, we obtain urban district population in different cities from MOHURD and China Census.

LEED AP: we collect the annual LEED AP data from the USGBC directly. We have the number of new LEED APs in China by city and by year from 2005 to 2015.

Environmental preferences: we measure city level environmental sustainability by "China Green Low-Carbon City Index" of 114 cities co-assessed by Lawrence Berkeley National Laboratory, University of San Francisco, Innovative Green Development Program, and Energy Foundation China (Ohshita et al, 2017). It not only provides the total green low-carbon city score of each city, but also have scores on economy, energy/power, transport, industry, buildings, environment/land, policy/outreach of these cities.

The new combined data are not without drawbacks. First, we do not have information on GBEL registration data, which may better measure firms' intentions to build green, compared with certification data we obtain and use in the analysis. Second, we don't know detailed information of buildings that are not certified by either LEED or GBEL in different cities, and don't know the proportions of green certified buildings in different cities. As such, our key empirical analysis is at the city level instead of the building level.

In order to analyze multiple certification adoption, we match the building level data from MOHURD and USGBC. Both data sets are translated from Chinese to English (we translate the GBEL certification data while USGBC or LEED building applicants translate the LEED certified building names). The translation, which can be produced by pronunciation or meaning or neither, makes the building name matching very challenging. For instance, "北辰" can be translated into "Beichen" (pronunciation) or "North Star"(ancient Chinese meaning). Also, some building developer may assign an English name to their buildings with almost no relevance to the Chinese name, but the translator may not be aware this English name. For instance, a building developed by Zijin Group is called "W Square", but the Chinese name of the building is actually "Zhonghang Zijin." We have conducted several rounds of checks to minimize the building name discrepancies between the two sets of data, but due to the potential information lost in translation explained above, the total number of buildings adopting multiple certifications analyzed might be slightly underestimated.

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[20] http://www.cngb.org.cn/cms/view/index.action?sid=402888b44f81b20f014f81dd5b21000c

Appendix C: Supplemental Tables

Table C1. Robustness Check 1 - Sample with at least one green buildings

	First Stage		Reduced Form		Spillover Effect	
	lnGBEL	lnGBEL	lnLEED	lnLEED	OLS lnLEED	IV lnLEED
lnGBEL					0.21 (0.04)	0.29 (0.10)
SUBSIDY	0.41 (0.11)		0.12 (0.05)			
SUBYEAR		0.24 (0.06)		0.07 (0.03)		
Control Variables						
lnArea	0.22 (0.11)	0.22 (0.12)	0.01 (0.05)	0.01 (0.05)	-0.04 (0.04)	-0.06 (0.04)
lnPop	-0.02 (0.03)	-0.02 (0.03)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
City Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2466	2466	2466	2466	2466	2466
R-Squared	0.48	0.48	0.09	0.08	0.25	

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

Table C2. Robustness Check 2 – Green Building Counts instead of Logs

	First Stage		Reduced Form		Spillover Effect	
	GBEL Count	GBEL Count	LEED Count	LEED Count	OLS LEED Count	IV LEED Count
lnGBEL					0.15 (0.07)	0.12 (0.09)
SUBSIDY	1.48 (0.53)		0.24 (0.17)			
SUBYEAR		1.41 (0.50)		0.18 (0.14)		
Control Variables						
lnArea	0.06 (0.01)	0.06 (0.01)	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.00 (0.00)
lnPop	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
City Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6822	6822	6822	6822	6822	6179
R-Squared	0.30	0.31	0.10	0.10	0.31	

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

Table C3. Robustness Check 3 – Different Control Variables

	First Stage		Reduced Form		Spillover Effect	
	lnGBEL	lnGBEL	lnLEED	lnLEED	OLS lnLEED	IV lnLEED
lnGBEL					0.19 (0.03)	0.24 (0.07)
SUBSIDY	0.30 (0.07)		0.07 (0.03)			
SUBYEAR		0.18 (0.04)		0.04 (0.02)		
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
City Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6889	6889	6889	6889	6889	6889
R-Squared	0.19	0.19	0.04	0.04	0.24	

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

Table C4. Robustness Check 4 – GBEL Certification and LEED Registration

	First Stage		Reduced Form		Spillover Effect	
	lnGBEL	lnGBEL	lnLEEDReg	lnLEEDReg	OLS lnLEEDReg	IV lnLEEDReg
lnGBEL					0.22 (0.03)	0.21 (0.08)
SUBSIDY	0.28 (0.07)		0.07 (0.03)			
SUBYEAR		0.17 (0.04)		0.03 (0.01)		
Control Variables						
lnArea	0.22 (0.06)	0.22 (0.06)	0.06 (0.04)	0.06 (0.04)	0.01 (0.02)	0.02 (0.03)
lnPop	-0.02 (0.01)	-0.02 (0.01)	-0.01 (0.01)	-0.01 (0.01)	0.00 (0.01)	0.00 (0.01)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
City Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6822	6822	6822	6822	6822	6179
R-Squared	0.20	0.20	0.04	0.04	0.20	

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

Table C5. Comparison of observable characteristics of provinces that with and without subsidies

	Provinces with GBEL Subsidy	Provinces without GBEL Subsidy	T-stat
Green Development Index	78.93	79.87	1.04
GDP	1.85E+06	3.74E+06	2.81
Urban District Area	71217	54776	0.73
Urban District Population	1929	3613	2.58
Area of Built District	1377	2553	2.51
Observations	23	8	