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Taking the LEED? Analyzing Spatial Variations in Market Penetration Rates of Eco-Labeled Properties

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Abstract

This paper investigates the impact of policies to promote the adoption of LEED-certified buildings across CBSA in the United States. Drawing upon a unique database that combines data from a large number of sources and using a number of regression procedures, the determinants of the proportion LEED-certified space for more than 170 CBSA in the US is modeled. LEED-certified space still accounts for a relatively small proportion of commercial stock in all markets. The average proportion is less than 1%. There is no conclusive evidence of a positive impact of policy intervention on the levels of LEED-certified space. However, after accounting for bias introduced by non-random assignment of policies, we find preliminary evidence of a positive impact of city-level green building incentives. There is a significant positive association between market size and indicators of economic vitality on proportions of LEED-certified space.

Introduction

Albeit from a low base, over the past decade there has been exponential growth in the number of buildings obtaining eco-labels in the United States. The development of real estate eco-labeling schemes, such as the USGBC's LEED rating system and the US EPA's Energy Star program, has reflected growing awareness of the environmental and social impacts of the use and construction of real estate both within the real estate industry and among the general public. Similar shifts are also occurring in many other developed economies. Following the invention and innovation stages, the diffusion of buildings with superior environmental performance is critical to reducing the environmental impact of commercial real estate. However, despite the increased awareness and understanding of the costs and benefits of sustainable design, the distribution of eco-labeled buildings has not been uniform across major US cities, In particular, the relative contribution of increasing regulation, growing financial incentives and expanding market demand from investors and occupiers remains relatively poorly understood.

Focusing particularly on the role of local incentives and regulations, the purpose of this research is to investigate spatial variations in the adoption of eco-labeled buildings across the US. As such, the paper explores the locational determinants of eco-labeled buildings across cities in the United States. We investigate whether local demand and supply of LEED-certified buildings is associated with certain market characteristics. The study incorporates data on local real estate market characteristics and industry composition in addition to demographic and socio-economic factors.

The Adoption of Eco-labels

Jaffe, Newell and Stavins (2005) categorize policies to decrease the environmental impact of production and consumption into three types. Market-based approaches tend to use financial incentives to encourage market participants to adopt new technologies and/or change their business practices. Minimum performance standards may also be used to specify maximum emissions. Finally, technology standards may be imposed that require market participants to employ particular technologies or processes. Although it is commonly accepted that market-based solutions that rely on incentives are likely to be a least costly means of encouraging adoption compared to mandatory regulatory approaches, in reality a portfolio of policies is often introduced. State and local governments often use a range of sticks and carrots to encourage the diffusion of products and processes that produce superior environmental performance.

Eco-labeling of properties is playing a role in promoting the voluntary adoption of more environmentally responsible buildings. For instance, states attempting to improve the environmental performance of their building stock often procure themselves and provide incentives to buildings with a LEED rating. The proximate objective of eco-labels is to provide information to buyers about products' environmental performance in order to influence their consumption choices, suppliers' production outputs and, consequently, the quantity of GHG emissions. In the commercial real estate market, eco-labels provide information on the environmental performance of a building to investors and tenants. While an eco-label and superior environmental performance are not necessarily synonymous, eco-labels can be particularly important for credence products, where due to the highs costs to the buyer of measuring and monitoring performance, sub-optimal allocation of resources can result. Given the credence good attributes of commercial property, it is typically not possible or feasible for market participants to directly measure the desired characteristics, for example the degree of energy efficiency of a building.

As discussed above, the mechanism by which environmental labels can produce a net environmental improvement is by changes to the relative demand and supply of labeled and non-labeled goods. Assuming that environmental performance is a salient attribute for consumers, environmental labeling enables consumers to discriminate between products according to their environmental impact resulting in increased demand for products with reduced environmental impact and in price differentials for labeled products. Price premiums, in turn, provide an economic incentive for producers to innovate and incur any additional production costs associated with obtaining the environmental label. However, since rebound effects are often complex, it can be difficult to quantify impacts on GHG emissions.

In many product markets with credence good characteristics, it is common for third parties to emerge in order to provide independent verification. Although eco-labels are usually awarded by Not-For-Profit organizations, these organizations have tended to be formed by a synthesis of government and private sector actions. As such, they provide a classic example of government intervention to remedy potential market failure and to correct a "paradox of underinvestment" (Jaffe and Stavins, 1994). Voluntary environmental labels can be interpreted as a method of reducing the negative externality produced by information asymmetry often associated with credence goods. Of course, market under-provision of products with superior environmental performance can occur for other reasons. Slow diffusion of products with superior environmental performance is typically attributed imperfect information, split incentives, risk aversion, high discount rates, inherent cost and revenue uncertainties and skills shortages *inter alia*. However, it is also possible that there is no market failure. Sanstad, Hanemann and Auffhammer (2006) pointed out that many of these issues are normal features of markets. They argue that apparent irrational underinvestment may reflect measurement error, the omission of relevant costs and other analytical failures. Nevertheless, it is generally accepted that government policies to stimulate demand and supply may foster faster adoption by creating a virtuous circle whereby suppliers' production costs are reduced by 'learning by doing' and information is generated for potential users on the existence, nature and performance of new technologies.

Typically, eco-labels are awarded by a third party to products with a reduced environmental impact compared with other products in the same product group. In the US, the two most common voluntary programs are LEED and Energy Star. The LEED Green Building Rating System, developed by the U.S. Green Building Council, consists of set of standards for the assessment of environmentally sustainable construction. Similar eco-labeling schemes are Green Star (Australia), BREEAM (UK), CASBEE (Japan), Haute Qualité Environnementale (France) and Deutsche Gesellschaft fur Nachhaltiges Bauen (Germany). Typically, the rating systems focus on six broad categories related to: sustainability of location, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and innovation and design process.

There are different levels of LEED accreditation based upon a scoring founded upon the six major categories listed above. The thresholds are mainly absolute in the sense that all buildings put forward that meet the required standards are certified. In LEED v2.2 for new construction and major renovations for commercial premises, buildings may qualify for four levels of certification. Certified, Silver, Gold and Platinum. The Energy Star scheme involves an assessment of buildings' energy performance. Buildings are awarded a score out of 100. In contrast to the LEED program, Energy Star is a measure of *relative* energy efficiency and environmental performance. Only buildings that are in the top quartile of buildings put forward are eligible for Energy Star accreditation. In terms of the US commercial real estate market, office properties have tended to dominate both the LEED and Energy Star in terms of space and numbers (Nelson, 2007).

There is a substantial body of commentary and evidence that occupiers of and investors in buildings with sustainable attributes can obtain a range of benefits. Most pertinent to this paper, owners, developers and occupiers may be eligible for a growing variety of incentives (subsidies, tax reliefs and reduced regulatory barriers) offered in some states and cities. Commonly cited benefits to occupiers include reduced utility costs, improved business performance (lower staff turnover, absenteeism, higher outputs *inter alia*) and marketing benefits. Investors may gain from higher occupancy rates, lower utility costs, reduced rates of depreciation and protection from regulatory obsolescence. In turn, it is also expected that buildings with superior environmental performance may attract a lower risk premium. However, convincing research on some of these benefits e.g. improved productivity, remains elusive (Miller, Pogue, Gough and Davis, 2009).

In the real estate literature, a body of revealed preference studies are emerging that broadly confirm occupiers' and investors' willingness to pay a premium for eco-labeled buildings. The majority of these studies have been conducted on LEED Green Building Rating System and the Environmental Protection Agency's Energy Star system which are two schemes that have been developed for the commercial real estate sector in the United States (see Eichholtz, Kok and Quigley, 2010, Wiley; Benefield and Johnson, 2010; Fuerst and McAllister, 2011; and Miller, Spivey and Florance, 2008). However, it is important to bear in mind that, given the emerging nature of the market shift, sample sizes have typically been small. In addition, price effects are likely to change as supply and demand adjust. Furthermore, effects may be different in residential markets. A study of the Tokyo residential market finds a significant price discount for eco-labeled condominiums (see Yoshida and Suguira, 2011)..

Related Literature

In order to provide some context to our discussion of related research, it is worth highlighting some of the methodological issues involved in measuring the impact of policy interventions on the diffusion of eco-labeled buildings. A key issue is controlling for potential confounding factors in order to avoid identifying a spurious relationship between market penetration of eco-labeled buildings and policy interventions. Cross-sectional econometric models need to include possible confounders such as wealth or rates of new supply as covariates. For instance, in wealthy cities there may be more demand for eco-labeled buildings and more 'supply' of green incentives and regulations. However, the limitations of a cross-sectional analysis due to limited chronological information should be explicitly acknowledged. Time series or panel data enable 'before-after' analyses of policy interventions to be conducted. It is generally considered, although contested, that 'before-after' studies will provide more robust inferences regarding causal relationships (see Rubin, 1974). A further issue is that the share of eco-labeled buildings in the overall commercial real estate market has been changing dramatically. As a result, data tends to become obsolete fairly rapidly.

As outlined below, in the United States, more than 50 cities and a growing number of states have incorporated standards based on the LEED rating system into their legislation and building codes. One of the first studies analyzing the spatial distribution of eco-labeled buildings is Kahn and Vaughn (2009) who use zip code level data in California to investigate the spatial distribution of both LEED registered buildings and hybrid vehicles with a view towards identifying spatial clusters of "green" consumers. Applying a maximum likelihood estimation and a measure of community environmentalism based on revealed preference political data, the authors find that 'green' consumers tend to cluster together even when controlling for age, race, income, and geographical fixed effects.

Focusing on occupier demand, Eichholtz, Kok and Quigley (2009) focused on the components of the occupier demand for eco-labeled offices. Using data on more than 3,100 tenants in 1,180 eco-labeled office buildings, and on a control sample of approximately 8,000 tenants in 4,000 conventional office buildings, they suggest that economic composition may influence adoption of eco-labeled buildings. They find that a substantial number of firms in the oil and the financial services industry are among the largest occupiers of eco-labeled office buildings. Their empirical analysis showed that mining and construction companies, as well as government and government-related organizations, are systematically more likely to lease eco-labeled office space rather than conventional space when compared to corporate tenants in other industries. All else equal, their analysis suggest that cities with above average exposure to these economic sectors are likely to have higher concentrations of eco-labeled buildings.

At the state level, Fuerst (2009) examined the distribution of Energy Star and LEED certified buildings across the United States. To equalize size effects among the states and focusing on a state rather than metropolitan level, he estimated a 'location quotient' - the ratio of a state's share in the respective eco-certification program to its population share in total US population. Thus, a quotient larger than 1 indicated that the share of a state in eco-labeling is higher than its population share would suggest and vice versa. Using this approach, Fuerst (2008) identified particular concentrations of LEED buildings in Washington D.C. and Oregon. Focusing on the metropolitan areas rather than states, Simons, Choi and Simons (2009) also investigated the market penetration of Energy Star and LEED labeled buildings in US metropolitan areas. Confirming previous research, compared to the retail sector, they find much higher levels of penetration in office markets both in relative and absolute terms. With 19 out of a total of 534 office buildings (3.53%), Hawaii was identified as having the highest relative penetration of eco-labeled offices. In absolute terms, Los Angeles was the largest market for eco-labeled offices with 244 from a total of 15,335 office buildings (1.59%).

Fuerst (2009) also finds that the share of corporate clients and private developers relative to government bodies seeking LEED certification has increased steadily since its inception. The share of private developers and corporate clients has increased considerably from 46% in the 2000-02 to 60% in the most recent 2006-08 period. The growth of the share of private developers from 3% to 26% is particularly notable as this indicates that certification appears to be seen as a valuable investment by an increasing number of developers. Given the exponential growth of certified buildings described above, this trend becomes even more notable when considered on an absolute basis (i.e. number of projects certified for private developers in each period).

Looking at the role of policy intervention in adoption, Kok, McGraw and Quigley (2011) examined trends in the number and volume of LEED and Energy Star certified buildings in 48 US metropolitan areas for the period 1995-2010. Their time series data on market size, rents, prices, vacancy rates for 'competitive' buildings in the various markets was obtained from a private real estate research organization (CBRE-EA). They suggested that the nature of the sampling created a selection bias resulting in an upward bias in the estimated penetration rates. They found high penetration rates with Energy Star certified space accounting for 30% of the total office *space* (as monitored by CBRE-EA). The corresponding figures for LEED space was 11% of all the office space.

Hypothesizing that the market penetration would be a function of a blend of climatic, socio-economic, real estate market and policy variables (including regulation and incentives), Kok, McGraw and Quigley (2011) first investigated which variables were significant at a cross-sectional level. They identified positive relationships between the penetration of eco-labeled buildings and income, size of real estate market, rental levels, energy prices, the presence of LEED accredited professionals, political allegiance and the presence of incentives. They acknowledged the problem of small samples, provided no indication of statistical significance and were obviously aware of the distinctions between association and causation. In order to test for the explanatory power of these variables more robustly, they also used multivariate econometric procedures to model the dynamic relationship between market penetration and metropolitan characteristics. They found mixed and sometimes inconsistent results. In most model specifications, they found that indicators of economic and real estate market vitality had a significantly positive relationship with market penetration. Although they identified positive effects of LEED incentives, they omitted potentially important variables. For instance, in their model including local policies encouraging LEED, the potentially confounding factor of high income jointly causing policy and market adoption is not included. Further, it is not clear from the discussion how or whether they have accounted for another confounding factor - variation in the rate of new building.

Focusing on California, Simcoe and Toffel (2011) investigated the effect of local municipal procurement policies on the adoption of LEED buildings and the growth of LEED-accredited professionals. They used a Coarsened Exact Matching approach to identify a sample of matched controls which they then compared to policy adopters and their neighbors. They found that policy adopters tended to be larger, greener, richer and better educated than potential controls. In policy adopters and the neighboring municipalities, they estimated an increase in LEED registered buildings of 84% and 69% respectively. Using a difference-in-difference (before-after) approach to model the dynamic relationship between policy adoption and LEED registrations, they concluded that there was no statistically significant difference between the adopters and control cities in the period *prior to* policy adoption. However, they found that adopters gradually diverge in terms of LEED adoption *following* a policy change. This gradual divergence over a period of 2-4 years is consistent with development lags in new build.

Choi (2010) examined the effect of different types of incentives (technical support, financial support and expedited administrative procedures) and policies (standards) on market penetration rates for 103 US cities. Applying four model specifications on cross-sectional data, the presence of a regulatory requirement was consistently found to have had a positive effect on market penetration rates. For the incentives, only expedited administrative procedures were found to have a significantly positive effect. It is notable that income was only positive when a regulation dummy was omitted. This suggests that the presence of a required standard and income are correlated.

In the CSR literature, Bansal and Roth (2000) proposed three types of motive profiles that can individually or together stimulate a higher level of CSR commitment - the caring profile, the competitive profile and the concerned profile. In the caring profile, it is a championing effort by organizational leadership which is the key driver of a firm's CSR commitment. In the competitive profile, firms are motivated by straightforward direct business advantages such as reduced costs or improved revenues. The concerned profile is characterized in terms of a pre-emptive, collective response by a group of market participants in an industry that allocates resources to CSR performance in order to obtain reputational benefits and/or reduced regulatory risks. These contrasting motives illustrate some of the difficulties of generalizing about socio-economic drivers of variations in penetration rates of LEED-certified buildings. In some cases, demand and supply may be linked to championing efforts mediated by local, political salience. In other markets, demand may come from companies whose motivation is defensive.

Data and Methodology

Study Area and Data Sources

The study area for our analysis includes 177 core based statistical areas (CBSA) in the United States. The CBSA was selected as the level of analysis to allow for the collection of data from diverse sources with common geographic boundaries. The CBSA also provides an appropriate level of analysis to estimate the effect of government regulations and incentives for eco-labeled buildings on production.

To analyze the effect of green building policies on market penetration, a database of regulations, incentives, and planning initiatives was created. The Green Building Regulation Database (GBRD) contains detailed information on green building policies for all 177 CBSAs included in the analysis. For each CBSA, the following information was gathered:

- Green Building Standards – design standards relating to the attainment of an eco-label certification (such as LEED); the applicability of the standard with respect to building size, type, and ownership (public or private); whether the standard was mandatory; the type and level of certification required; and the year adopted.
- Green Building Incentive – any incentives relating to green building construction, including expedited permitting, fee reductions, etc.; the applicability of the incentive with respect to building size, type, and ownership (public or private); the type and level of certification required to qualify for the incentive; and the year adopted.
- Sustainability Plan – any planning initiative or climate action plan that affects buildings, the type of real estate implicated, and the year adopted.
- Energy Conservation and Renewable Energy – any incentive or requirement for energy conservation programs and/or renewable energy systems on buildings.

The GBRD was developed using a three-step methodology. First, an online review of municipal planning, building, and sustainability agencies was conducted to determine the presence of the green building policies described above. Second, if a policy was indicated, a the applicable building code, zoning code, or local law was comprehensively reviewed to collect the required policy information. Finally, where sufficient information could not be gathered (such as year of policy adoption, for instance), a survey of the relevant municipal planning, building, or sustainability official was conducted by phone and email. This process was conducted between January 2010 and February 2011.

In addition, state-level policies where included in the database. These policies represent green building and energy efficiency regulations and incentives (tax incentives, subsidies, grants, municipal loans/bonds) offered by state governments. This information was collected from the Database of State Incentives for Renewables and Efficiency, a project of the North Carolina Solar Center and the Interstate Renewable Energy Council.

Methodology

Locational determinants have been studied in a number of sectors, from affordable housing (Freeman 2004; Oakley 2008; Rohe and Freeman 2001) to manufacturing and logistics facilities (Bartik 1985; Cheng and Stough 2006; Coughlin and Segev 2000; Smith and Florida 1994). We would expect that the "green" commercial real estate market share in a given city would be influenced by a number of factors, including economic conditions, climate, local real estate market conditions, the regulatory and political environment, demographic and socioeconomic variables, industry composition, and physical characteristics of the city and its commercial building stock. Eco-labeled building decisions would also tend to be driven by the extent of the eco-labeled building inventory that is already in place (DeCoster and Strange 1993). This may occur for two reasons. First, developers would choose to build "green" out of a fear of being at a competitive disadvantage to the existing supply of office space. Second, greater numbers of existing eco-labeled buildings in a particular city would suggest lower (additional) development costs for sustainable design elements, thus lower the marginal cost of an eco-labeled building vis-à-vis a traditional building.

To estimate the locational determinants of eco-labeled buildings, we test three reduced-form model specifications using ordinary least squares, robust regression and fractional logit. The linear regression model specification is given by:

$$PL = \alpha + \beta_1 ECON_i + \beta_2 RE_i + \beta_3 RP_i + \beta_4 SE_i + \beta_5 IND_i + \beta_6 BUILD_i + \beta_7 + \varepsilon$$

where the dependent variable (PL) is the proportion of LEED-certified office space (in sq.ft.) in a market at the end of 2010 and ε is the error term. The independent variables (and data sources) are:

Economic Climate (ECON): gross metropolitan product (Bureau of Labor Statistics);

Real Estate Market Conditions (RE): median price per square foot, median rental rate per square foot, vacancy rate (CoStar);

Regulatory and Political Environment (RP): mayor's political party affiliation and margin of victory, eco-labeled building regulations/mandates (GBRD), government incentives for eco-labeled building (GBRD).

Demographic and Socioeconomic Characteristics (SE): median age, per capita income (year 1995), per capita income growth (years 1995-2005), total population (year 1995), population growth (years 1995-2005), education level (U.S. Census);

Industry Composition (IND): proportion in NAICS codes 23, 52, 53, 54, 55, and 92 (financial sector, construction, and government) (Bureau of Labor Statistics);

Physical Characteristics (BUILD): average building size, total commercial rentable square footage (CoStar), percent urbanized area, population density (population per square mile) (U.S. Census);

Climate (CL): average annual temperature (National Oceanic and Atmospheric Administration), heating degree days (National Climatic Data Center), climate zone (ASHRAE), CO2 emissions per capita (NASA/Department of Energy).

Robust regression

An inspection of summary statistics reveals that our dataset contains a number of notable outliers both regarding the fraction of which might be influential in the estimation of coefficients. Further examination of leverage diagnostics such as the Cook's distance measure of the least squares estimations provides further evidence of influential outliers. To address this issue, we supplement the estimates from the OLS regression with robust regression. This method uses Huber and Tukey biweights to mitigate the impact of outliers on regressions coefficients in the estimation (Huber, 1964 and Rousseeuw and Leroy, 1987). In this framework, outliers are defined via a Cook's distance measure which reflects the leverage of any given observation in the estimation process. All observations with Cook's distances larger than 1 obtain a zero weight in the estimation. Verardi and Croux (2009) express this efficient M-estimator computed by robust regression in the following manner:

$$\rho(u) = \begin{cases} 1 - \left[1 - \left(\frac{u}{k}\right)^2\right]^3 & \text{if } |u| \leq k \\ 1 & \text{if } |u| > k \end{cases}$$

The iterative algorithm used in our specification follows a Huber (p) function with the following standard specification:

$$\rho(u) = \begin{cases} \frac{1}{2}(u)^2 & \text{if } |u| \leq c \\ c\,|u| - \frac{1}{2}c^2 & \text{if } |u| > c \end{cases}$$

Although this method of estimating robust regressions has not been without criticism This is mainly because it does not completely control all bad leverage observations in empirical applications and is prone to missing potential clusters of outliers in some cases (see for example Rousseeuw and Van Zomeren, 1990). However, we use this technique as a reasonably reliable and simple robustness check of our coefficient estimates.

Fractional logit estimation

In addition to OLS and robust regression, we apply a fractional logit model to better account for the fact that the dependent variable is a non-negative value limited strictly at 100%. Initially proposed by Papke and Wooldridge (1996), fractional logit models are better suited for modeling fractional dependent variables bounded by zero and one than other functional forms. A potential drawback of the least-squares estimation is that non-linearities in the data are ignored. The fractional response values predicted directly by quasi-maximum likelihood estimation (QMLE) lie within the unit interval. The conditional mean assumption of the dependent variable y_i on covariates x_i are then

$$E\left(y_i \middle| \mathbf{x_i}\right) = G\left(\mathbf{x_i \beta}\right)$$

where G is the logistic CDF (Cumulative Distribution Function) and $y_i \in [0,1]$. Papke and Wooldridge (1996) assume a logistic distribution

$$E\left(y_i \middle| \mathbf{x_i}\right) = \frac{\exp\left(\mathbf{x_i \beta}\right)}{1 + \exp\left(\mathbf{x_i \beta}\right)}$$

and propose the following Bernoulli log-likelihood function

$$l_i(\boldsymbol{\beta}) \equiv y_i \log\left[G\left(\mathbf{x_i \beta}\right)\right] + \left(1 - y_i\right) \log\left[1 - G\left(\mathbf{x_i \beta}\right)\right]$$

to obtain consistent parameter estimates with QMLE. The non-binary, non-normal response distribution assumed in fractional logit estimations, makes it suitable for modeling it with a Generalized Linear Models (GLM) framework.

Treatment effects model

A further concern in our analysis is a potential selectivity and/or endogeneity bias. If markets with a high percentage of green buildings are found to have more incentives and regulations in place that aim to promote the diffusion of green buildings in these markets, it is impossible to conclude – at least in a cross-sectional setting - whether the high percentage of green space preceded the existence of these policies. More importantly, this would seriously put into question the strong assumption of our single-equation models that the introduction of these policies is completely random and independent of the percentage of green commercial space in these markets (for a thorough discussion of selectivity and omitted-variable biases, see e.g. Achen 1986 and Imbens 2004) . It seems more plausible that markets where these policy measures are in place today already had particularly high (or possibly particularly low) percentages of green commercial space even before these policies were introduced. This selectivity bias would then bias the results upwards or downwards depending on whether these policies were introduced to a greater extent in either green or non-green markets.

To address this issue, we estimate a two-stage treatment effects model which is a variation of the standard Heckman correction (see Heckman 1979). The specification takes the following form:

Stage 1

$$RP = \alpha + \beta_1 X_1 + \mu$$

Stage 2

$$PL = \alpha + \beta_1 ECON_i + \beta_2 REe_i + \beta_3 RP_i + \beta_4 SE_i + \beta_5 IND_i + \beta_6 BUILD_i + \beta_7 + \varepsilon$$

with

and X_1 being a vector of explanatory characteristics that predicts which municipalities and other administrative units will adopt 'green' policy measures. The first-stage is a maximum-likelihood probit estimation of the binary policy variable in question. Evidently, some of the factors affecting the adoption of green space also affect the diffusion of green space and are therefore included in both stages. All other factors in the specification are assumed to be strictly exogenous. A further assumption is that the respective error terms of the equations, u and ε follow a bivariate normal distribution. We test the validity of this assumption using a Wald test for independent equations. The null hypothesis of this test is that the MLE first-stage is independent of the structural equation of interest in the second stage.

Summary Data

This study draws on CoStar's comprehensive national database which includes approximately over 40 billion square feet of commercial space in more than two million properties making it the largest available real estate database in the United States. In an effort to provide details on the environmental performance of buildings, the CoStar Group began tagging LEED buildings around 2006. This enables researchers to identify numbers and LEED certified buildings in the database. Data on the commercial real estate markets is displayed in Tables 1 and 2. Information on total commercial space (retail, industrial, office and flex) was obtained from the CoStar database and reflects to status quo as of end of 2010.

Stock data were obtained for 177 Core Based Statistical Areas (CBSA) in the US. Our database covers a wide range of market sizes to test whether green buildings are in fact primarily a 'big city' phenomenon. The average quantity of commercial space in a CBSA is approximately 231 million square feet. Both New York and Los Angeles have over 2 billion square feet of commercial space in over 100,000 buildings each. Approximately 60% of the commercial space is in the largest 25 CBSA. At the other end of the scale, there are nine CBSA with less than 10 million square feet. There is some initial evidence to suggest that LEED-certified buildings tend to be concentrated in larger centers. Of the total LEED-labeled space (563 million square feet), 77% is located in the largest 25 CBSA. The correlation coefficient between total commercial space and proportion of LEED-certified space is positive and statistically significant (0.22).

It is important to acknowledge the problems associated with using the ratio of certified space to total commercial space in the analysis. For instance, the ranking shows that Lexington, KY has the largest proportion of LEED space but this is mainly due to the existence of one large certified industrial property (Toyota) with 7.7 million sq.ft. in an otherwise relatively small commercial market. Indeed, Lexington is below average in terms of the *number of LEED buildings* as a proportion of all buildings. In terms of floor space, the average proportion of LEED certified commercial floor space in the United States is small at 0.87%.

Table 1: LEED Space as a Proportion of Total Commercial Space: Top 25 All CBSA

Rank	CBSA	Total bldgs	LEED bldgs	LEED bldgs	Total Floorspace	Total LEED space	LEED floorspace
		N	N	%	square feet	square feet	%
1	LEXINGTON-FYET	4309	5	0.12%	90,091,299	8,007,440	8.89%
2	AMES	241	2	0.83%	6,254,816	497,576	7.96%
3	OLYMPIA	2196	14	0.64%	29,369,744	1,738,812	5.92%
4	EUGENE-SPRFLD	14688	6	0.04%	17,418,735	694,653	3.99%
5	DENVER	20806	93	0.45%	524,826,899	19,830,062	3.78%
6	ANDERSON	871	1	0.11%	20,219,655	760,000	3.76%
7	SEATTLE	28082	119	0.42%	657,388,530	24,584,211	3.74%
8	WACO	929	1	0.11%	22,847,574	750,000	3.28%
9	SAN FRANCISCO	48375	115	0.24%	923,333,765	29,805,797	3.23%
10	BOSTON	30046	99	0.33%	864,004,380	27,827,078	3.22%
11	WASHINGTON	33505	145	0.43%	957,889,304	30,134,464	3.15%
12	AUGUSTA	4750	4	0.08%	68,171,965	2,079,811	3.05%
13	SAVANNAH	2856	10	0.35%	59,718,174	1,666,900	2.79%
14	RENO	4002	9	0.22%	111,350,354	3,095,805	2.78%
15	MINNEAPOLIS	28744	78	0.27%	710,475,377	18,394,164	2.59%
16	DALLAS	49107	92	0.19%	1,474,845,969	37,826,092	2.56%
17	SACRAMENTO	18088	49	0.27%	376,798,258	9,626,524	2.55%
18	HOUSTON	36270	88	0.24%	1,114,936,343	27,831,345	2.50%
19	DURHAM	3452	17	0.49%	84,466,078	2,004,783	2.37%
20	STOCKTON	3713	6	0.16%	112,663,091	2,662,260	2.36%
21	PORTLAND	19917	91	0.46%	410,025,616	9,167,621	2.24%
22	CHICAGO	64258	138	0.21%	2,106,143,296	46,404,869	2.20%
23	BEND	1063	9	0.85%	15,655,974	323,785	2.07%
24	LANSING	6875	4	0.06%	104,090,274	2,033,000	1.95%
25	ATLANTA	46359	88	0.19%	1,247,363,020	24,054,386	1.93%

Table 2: LEED Space as a Proportion of Total Commercial Space; Top 25 Large CBSA
CBSAs over 100 million sq ft only

Rank	CBSA	Total bldgs	LEED bldgs	LEED bldgs	Total Floorspace	Total LEED Floorspace	LEED Floorspace
		N	N	%	square feet	square feet	%
1	DENVER	20,806	93	0.45%	524,826,899	19,830,062	3.78%
2	SEATTLE	28,082	119	0.42%	657,388,530	24,584,211	3.74%
3	SAN FRANCISCO	48,375	115	0.24%	923,333,765	29,805,797	3.23%
4	BOSTON	30,046	99	0.33%	864,004,380	27,827,078	3.22%
5	WASHINGTON	33,505	145	0.43%	957,889,304	30,134,464	3.15%
6	RENO	4,002	9	0.22%	111,350,354	3,095,805	2.78%
7	MINNEAPOLIS	28,744	78	0.27%	710,475,377	18,394,164	2.59%
8	DALLAS	49,107	92	0.19%	1,474,845,969	37,826,092	2.56%
9	SACRAMENTO	18,088	49	0.27%	376,798,258	9,626,524	2.55%
10	HOUSTON	36,270	88	0.24%	1,114,936,343	27,831,345	2.50%
11	STOCKTON	3,713	6	0.16%	112,663,091	2,662,260	2.36%
12	PORTLAND	19,917	91	0.46%	410,025,616	9,167,621	2.24%
13	CHICAGO	64,258	138	0.21%	2,106,143,296	46,404,869	2.20%
14	LANSING	6,875	4	0.06%	104,090,274	2,033,000	1.95%
15	ATLANTA	46,359	88	0.19%	1,247,363,020	24,054,386	1.93%
16	ALLENTOWN	5,792	14	0.24%	166,382,341	2,945,525	1.77%
17	SAN JOSE	17,989	41	0.23%	421,148,233	7,377,925	1.75%
18	CHARLOTTE	17,466	27	0.15%	425,157,646	7,418,582	1.74%
19	BALTIMORE	19,795	56	0.28%	483,283,085	7,776,553	1.61%
20	LOS ANGELES	109,744	159	0.14%	2,406,005,038	37,548,882	1.56%
21	SAN DIEGO	27,775	66	0.24%	463,095,975	7,130,443	1.54%
22	PHOENIX-MESA	28,615	44	0.15%	679,063,315	9,601,971	1.41%
23	NEW YORK	119,846	115	0.10%	2,932,995,228	35,953,792	1.23%
24	GRAND RAPID	9,624	41	0.43%	202,163,029	2,470,264	1.22%
25	RIVERSIDE	32,604	37	0.11%	766,436,510	8,978,284	1.17%

For large CBSAs only, there are only five centers where LEED-certified space is over 3% of the total. Bearing in mind that confirmation bias due to preconceived theories makes it risky to draw inferences from these descriptive statistics, some preliminary observations can be made. The high ranking of west coast liberal cities such as Seattle, Portland and San Francisco is notable. On the east coast, a similar explanation may reflect Boston's high position. It is possible that the high position of Denver, Dallas and Houston may be linked to the economic importance of oil, gas and mining companies to their respective local economies – companies that typically value image benefits. On the other hand, Washington's position may be due to the procurement policies of government agencies. If nothing else, this rather speculative induction serves to highlight the complex range of factors that can determine differences in the diffusion of LEED certified buildings. The 25 CBSA with the lowest proportion of LEED certified space all have no LEED certified space. They tend to be small CBSA. Their average number of buildings is 1579 compared to the sample average of nearly 10,700. Typically, they have only 10% of the floor space of the average CBSA.

Results

In the next step, we seek to identify the major drivers of green commercial markets as reflected in the percentage of LEED-certified commercial floor space using three regression model specifications. To wit, we test whether there is any statistically significant association between the presence of incentives, frameworks and regulations and the proportion of LEED-certified commercial floor space in the market along with a series of other characteristics. Table 3 reports the results of these three single equation models. Across all models, there is a highly statistically significant positive association between market size and market penetration of LEED-certified buildings confirming the previously described *large-market bias* (see Burr 2008). The greater proportion of LEED- certified space in large cities may be due to a number of factors ranging from knowledge spillovers, imitation through observation, social learning to higher demand from large corporate tenants and greater versatility of large markets to respond to innovations. We also find that a negative impact of almost all climate zone compared to markets in Climate Zone 1 (South Florida). A notable exception is Climate Zone 7, which is also one of the more extreme climate zones. This seems plausible since the economic returns of LEED-certification, particularly in terms of energy efficiency[1], are likely to be higher in less moderate, i.e. tropical and arctic climates.

[1] Fuerst and McAllister (2011) report that their comprehensive dataset of green buildings contains nearly twice as much dual-certified space (i..e. both LEED and Energy Star certification) than LEED-only certified space.

Table 3 Single Equation Model Results

	OLS model[1]		Robust Regression		Fractional logit	
Constant	0.54		-0.44	**	-5.00	***
Market size	0.01	***	0.01	***	0.01	***
CO_2 emissions psf	-0.63	**	-11.69		-4.00	***
Climate zone 1	Omitted		Omitted		Omitted	
Climate zone 2	-0.88	*	0.18		-0.78	**
Climate zone 3	-0.96	**	0.15		-0.88	***
Climate zone 4	-0.87	*	0.08		-0.73	**
Climate zone 5	-0.50		0.36	***	-0.50	*
Climate zone 6	-1.09	**	0.25	*	-1.02	***
Climate zone 7	-0.35		0.99	***	0.28	
Employment growth 2001-08	3.86	**	4.47	***	2.89	**
% public sector 2008	2.66		0.09		0.56	
% financial sector 2008	-5.49		1.33		-1.64	
% of population with degree	7.56	***	1.99	***	5.89	***
Average electricity price	-0.08	***	-0.01		-0.91	***
Required	-0.11		0.08		-0.09	
Incentive	-0.18		0.04		-0.10	
Greenplan	-0.13		-0.13	*	-0.65	
Greenbuilding	-0.24		-0.02		-0.28	
Tax incentive	0.10		-0.08		0.21	
Democratic mayor	-0.14		-0.06		0.01	
Republican mayor	-0.17		0.04		-0.03	
Independent mayor	Omitted		Omitted		Omitted	

n	174	n	174	n	174
F(21, 148)	11.67	F(21, 147)	17.54	Log pseudo-likelihood	-6.83
Prob F	0.00	Prob F	0.00		
R-squared	0.33				

*** significant at 1% level

** significant at 5% level

* significant at 10% level

Policy variables
Required = city-level mandatory green building standard (e.g. LEED is required for new buildings)
Incentive= city-level green building incentive (e.g. expedited permitting, fee reductions for green)
Green plan = city-level sustainability or climate action plan
Greenbuilding = State-level green building program
Tax incentive -> State-level tax incentives (personal, corporate, or property)

A somewhat counterintuitive finding is the significant negative impact of CO_2 emissions per sq.ft. of commercial space, implying that commercial markets with a larger carbon footprint tend to have a higher percentage of green buildings. However, a more focused analysis would be required to confirm the validity of this finding. Another consistent result across all of the single equation models is a significantly positive association between employment growth over the last decade and market penetration of LEED-certified buildings. In the absence of data on new supply of commercial floor space, employment growth should provide a good proxy for economic vitality and a reasonable proxy for the relative level of new supply. It may not be unexpected that markets with greater growth in the workforce and/or supply of space also tended to have higher levels of LEED-certified space. At the extreme, a lack of demand may mean no new stock which would preclude new LEED-certified stock and stall the certification of existing stock. The proportion of the population with a degree, another indication of economic vitality, also has a consistent and statistically significant positive association with penetration levels. Consistent with previous research, cities with a larger percentage of highly educated and wealthy inhabitants tend to be greener. It is notable that the economic composition variables (% employed in public sector, % employed in financial sector) do not appear to have a significant effect on market penetration. This may simply reflect the diversity of motives of market participants. Further, political affiliation has no direct significant impact on levels of LEED-certified commercial space.

Turning to the variables of interest, there is no evidence from any of the single equation models of a positive association between policies to promote the development of LEED-certified buildings. Indeed, the adoption of a Green Plan has a statistically significant negative effect in one of the models. However, in general, there is no statistically significant effect of any of the policy measures. This does not preclude the possibility of 'before-after' effects that cannot be captured in this cross-sectional framework. Where policies have been put into place only recently, they may not yet have had sufficient opportunity to influence the behavior of market participants and supply outcomes.

However, these single-equation results may be plagued by a potential endogeneity and sample selection bias as pointed out above. We address this issue with a series of two-stage treatment effects models. The resulting modeling estimates are displayed in Tables A2-A6. The vulnerability of these models to identification and specification problems is well documented in the extant literature (see for example Little and Rubin, 1987). A particularly crucial step in specifying a valid model is thus to justify the exclusion restrictions from the first stage. In the present study, economic theory provides little guidance for excluding variables contained in the choice model (first stage) in the outcome model (second stage). Hence, we include factors in the first stage that are expected to have an impact on the policy treatment variable and little or no direct impact on the proportion of LEED space in a market. Since it cannot be ruled out that many of the factors affecting the adoption of green policies also impact upon the supply of green buildings, we circumvent this problem by including factors in both stages or matching relevant first-stage regressors with similar but more directly related market measures that exhibit low correlation with the first stage regressors. An example of the latter is the CO_2 per capita variable in the first stage which is matched with a variable measuring CO_2 emissions per sq.ft of commercial space in the second stage. Average electricity price is included in both equations as an explanatory variable. Size is expected to matter in both equations but is measured differently in each equation, i.e. as the number of inhabitants in the policy equation and as inventory of commercial space in the LEED proportion equation. Educational attainment is expected to impact directly only on the policy variable based on the assumption that higher levels of education are associated with more support for environmental regulations as shown in previous empirical studies (e.g. Kahn 2002). It is only assumed to impact upon the fraction of green commercial space more indirectly via the second-stage socio-economic variables. Political variables, i.e. mayor's affiliation, was only included in the first-stage policy equation.

The likelihood-ratio test for the independence of equations shows for three of the five measured policy variables that there is significant evidence of selectivity. This may be an indication that the previously reported single-equation results were biased and that the treatment effects estimates are preferable. Consistent with the results of the single equation models, the presence of a Green Plan and tax incentives has a statistically significant negative association with the proportion of LEED-certified buildings in a metropolitan area. A time-series analysis of these factors is required to disentangle the dynamics of and interaction between these factors. However, the treatment effects models do confirm a statistically significant association between the presence of city-level green building incentives (e.g. expedited permitting or fee reductions for green projects) and the proportion of LEED-certified buildings in a market.

Conclusions

Since the environmental performance of the existing stock is critical, there has been increasing adoption of policy instruments that are attempting to increase the market diffusion of buildings with superior environmental performance. Consistent with many policy interventions in other policy areas, typical measures have involved a blend of economic rewards (such as tax benefits, subsidies), information provision, preferred procurement, technical assistance and regulatory requirements. The most problematic issue in this line of research is fundamentally concerned with endogeneity and/or selection bias. Essentially, the same characteristics of markets that adopt LEED-certified buildings at a higher rate may also be causing the same markets to adopt policies that promote LEED-certified buildings. It is not clear that previous research has controlled sufficiently for this joint causality problem.

Our results suggest that, when variations in economic vitality, climate zone and market size are taken into account, there is only very limited support for the hypothesis that 'green' policies have a significant positive effect on green building adoption in the current market. Due to the cross-sectional nature of this study, it is possible that this may simply be a product of the timing of policy adoption. There is clearly scope for robust 'before-after' research on the effects of policy intervention using appropriate econometric techniques such as a difference in differences (DID) approach or more advanced panel analysis methods. In addition, the tendency of large cities to have higher proportions of LEED-certified buildings may be due to spatial clustering effects due to concentrations of exemplars and knowledge externalities. This introduces scope to research on the spatial diffusion of LEED-certified buildings both over time and over space.

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Appendix

A1 Definitions of policy variables

Policy variables
Required = city-level mandatory green building standard (e.g. LEED is required for new buildings)
Incentive= city-level green building incentive (e.g. expedited permitting, fee reductions for green)
Green plan = city-level sustainability or climate action plan
Greenbuilding = State-level green building program
Tax incentive -> State-level tax incentives (personal, corporate, or property)

Table A2 Treatment Effect Model Results for Tax Incentives

ML Treatment Effects Model		
Tax incentives		
Stage 1		
Constant	0.03	
CO_2 per capita	-0.01	
Population 2005	-0.01	
Democratic mayor	-0.11	
Republican mayor	-0.14	
Average electricity price	-0.07	**
% of population with degree	-6.03	***
Stage 2		
Constant	-0.01	
Market size	0.01	***
Vacancy rate	3.16	
GDP per capita	0.02	
CO_2 emissions psf	-1.51	
Climate zone 1	Omitted	
Climate zone 2	-1.27	***
Climate zone 3	-1.26	***
Climate zone 4	-1.25	***
Climate zone 5	-0.72	**
Climate zone 6	-1.09	***
Climate zone 7	-0.94	
Employment growth 2001-08	4.2	**
% public sector 2008	5.03	***
% financial sector 2008	-2.42	
% of population with degree	0.08	***
Average electricity price	-0.12	**
Tax incentives	-2.07	***
Log likelihood -366.1		
Wald chi2 127		
Prob >chi2 0.000		
N 174		
LR test of indep eqns	31.16	*** (0.000)

*** significant at 1% level

** significant at 5% level

* significant at 10% level

Table A3 Treatment Effect Model Results for Green Building

ML Treatment Effects Model		
Green Building		
Stage 1		
Constant	0.79	**
CO_2 per capita	0.05	
Population 2005	-0.01	*
Democratic mayor	-0.36	*
Republican mayor	0.56	
Average electricity price	0.46	*
% of population with degree	2.31	
Stage 2		
Constant	0.88	
Market size	0.01	***
Vacancy rate	2.58	
GDP per capita	0.01	***
CO_2 emissions psf	1.29	
Climate zone 1	Omitted	
Climate zone 2	-1.20	***
Climate zone 3	-1.31	***
Climate zone 4	-1.07	***
Climate zone 5	-0.65	*
Climate zone 6	-.97	**
Climate zone 7	-.86	
Employment growth 2001-08	2.4	*
% public sector 2008	1.91	***
% financial sector 2008	6.42	
Average electricity price	-0.12	**
Green Building	1.28	

Wald chi2 **81.05**
Prob >chi2 **0.000**
N **174**
LR test of indep eqns **0.01 (0.95)**

Table A4 Treatment Effect Model Results for Green Plan

ML Treatment Effects Model		
Green Plan		
Stage 1		
Constant	0.16	**
CO_2 per capita	0.11	*
Population 2005	0.01	
Democratic mayor	0.44	**
Republican mayor	0.53	**
Average electricity price	0.03	
% of population with degree	-4.31	***
Stage 2		
Constant	0.52	
Market size	0.01	***
Vacancy rate	3.37	
GDP per capita	0.04	***
CO_2 emissions psf	-0.69	
Climate zone 1	Omitted	
Climate zone 2	-0.93	**
Climate zone 3	-1.16	***
Climate zone 4	-1.08	***
Climate zone 5	-0.48	
Climate zone 6	-0.84	**
Climate zone 7	-0.28	
Employment growth 2001-08	3.81	*
% public sector 2008	6.55	***
% financial sector 2008	-7.81	
Average electricity price	0.03	
Green Plan	-2.13	***
Wald chi2 90.21		
Prob >chi2 0.000		
N 174		
LR test of indep eqns	**6.18***	**(0.01)**

Table A5 Treatment Effect Model Results for Incentive

ML Treatment Effects Model		
Incentive		
Stage 1		
Constant	-1.05	*
CO_2 per capita	-0.01	
Population 2005	0.01	
Democratic mayor	0.03	
Republican mayor	0.04	
Average electricity price	0.02	
% of population with degree	-4.14	***
Stage 2		
Constant	0.42	
Market size	0.01	*
Vacancy rate	3.29	
GDP per capita	0.19	
CO_2 emissions psf	-0.21	
Climate zone 1	Omitted	
Climate zone 2	-1.13	***
Climate zone 3	-1.37	***
Climate zone 4	-1.23	***
Climate zone 5	-.82	***
Climate zone 6	1.17	***
Climate zone 7	-.67	
Employment growth 2001-08	3.51	
% public sector 2008	4.14	**
% financial sector 2008	-4.81	
Average electricity price	-0.05	
Incentive	1.81	***
Wald chi2 108.62		
Prob >chi2 0.000		
N 174		
LR test of indep eqns	**16.05*** **	**(0.00)**

Table A6 Treatment Effect Model Results for Required

ML Treatment Effects Model		
Required		
Stage 1		
Constant	0.90	*
CO_2 per capita	-0.10	
Population 2005	0.01	
Democratic mayor	0.03	
Republican mayor	0.04	
Average electricity price	0.06	
% of population with degree	-5.25	
Stage 2		
Constant	0.42	
Market size	0.01	***
Vacancy rate	2.44	
GDP per capita	0.03	***
CO_2 emissions psf	-0.74	
Climate zone 1	Omitted	
Climate zone 2	-1.11	***
Climate zone 3	-1.21	***
Climate zone 4	-1.0	***
Climate zone 5	-0.52	
Climate zone 6	-0.85	*
Climate zone 7	-0.75	
Employment growth 2001-08	4.24	*
% public sector 2008	7.23	***
% financial sector 2008	-8.91	
Average electricity price	-0.09	***
Required	0.64	
Wald chi2 **63.31**		
Prob >chi2 **0.000**		
N **174**		
LR test of indep eqns	1.16	(0.28)