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Environmental Issues in Operations Management

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Suresh Muthulingam

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The dissertation of Suresh Muthulingam is approved.

Shlomo Benartzi

Magali Delmas

Kumar Rajaram

Christopher S. Tang

Charles J. Corbett, Committee Chair

University of California, Los Angeles

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DEDICATION

For my wife, Rina Kumar

and

my son, Jayant Raghuram

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VITA

December 19, 1969	Born, Chennai, India
1991	B. Tech. in Mechanical Engineering Indian Institute of Technology, Chennai Tamil Nadu, India
1993	Post Graduate Diploma in Management Indian Institute of Management, Ahmedabad Gujarat, India
1993-1995	Executive Assistant to the CMD, Sr. Executive ITW Signode, Hyderabad, India
1995-2005	Consultant, Sr. Consultant, Principal Consultant, General Manager Coopers & Lybrand, PricewaterhouseCoopers, IBM Business Consulting Services Mumbai/ Chennai, India
2005-2009	Graduate Student Researcher, UCLA Anderson School of Management Los Angeles, California

PUBLICATIONS

Jones, B., Leung, Y.T., Muthulingam, S., Noronha, S. and Sanz, J. Performance Modeling of Service Businesses, *Int. J. Services Operations and Informatics*, forthcoming.

Karthik, P.R., and Muthulingam Suresh. 2002. Why are Chinese products cheaper? *Management Review*. June 7-15.

Sankar, R., and Muthulingam Suresh. 2000. – Applications of OR in the Indian Context. *Management Review*. December 55-59.

ABSTRACT OF THE DISSERTATION

Environmental Issues in Operations Management

by

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Adoption of sustainable operating practices is becoming an increasingly important issue for many organizations in the world today. In this dissertation, I use empirical methods to investigate factors that influence the adoption of sustainable practices and also identify issues that may hinder the adoption of such practices. I explore these issues in two diverse settings.

In Chapter1, I investigate the adoption and non-adoption of energy efficiency initiatives using a database of over 100,000 recommendations provided to more than 13,000 small and medium sized manufacturing firms. Even though the average payback across all recommendations is just over one year, many of these profitable opportunities

are not implemented. Using a probit instrumental variable model, I identify four biases in the adoption of these recommendations. First, managers are myopic as they miss out on many profitable opportunities. Second, managers are more influenced by upfront costs than by net benefits when evaluating such initiatives. Third, adoption of a recommendation depends not only on its characteristics but also on the sequence in which the recommendations are presented. Adoption rates are higher for initiatives appearing early in a list of recommendations. Finally, adoption is not influenced by the number of options provided to decision makers. This contributes to the debate about whether or not choice overload occurs. We highlight decision biases previously unobserved in the Operations Management literature using field data rather than experimental data. We draw implications for enhancing adoption of energy efficiency initiatives and for other decision contexts where a collection of process improvement recommendations are made to firms.

In Chapter 2, I examine the depth of adoption of the voluntary LEED (Leadership in Energy and Environmental Design) standards for green buildings. Depth of adoption refers to the extent to which the buildings adopt practices related to the standard. The LEED standard is based on a point system where buildings are awarded different certification levels based on the number of points they achieve. We use a database of 721 buildings certified to the LEED standard to investigate four issues related to the depth of adoption. First, I find that depth of adoption is influenced by the various certification levels (certified, silver, gold, platinum) incorporated into the LEED standards. In the distribution of points achieved by buildings, this results in large

"spikes" at the cutoffs for the various certification levels. Second, we find that the depth of adoption of the LEED standard increases over time as the standard becomes more widely accepted. Third, we find that among organizations that adopt the LEED standard, nonprofit organizations adopt it more deeply than other types of organizations. Finally, we find that deeper adoption is associated with longer project completion times, consistent with the greater complexity involved. Our study contributes to the literature by highlighting that the structure of a standard can influence depth of adoption, that depth of adoption can evolve over time, and that depth of adoption is influenced by organization type. We draw implications for the design and future development of similar voluntary standards.

CHAPTER 1

Managerial Biases and Energy Savings: An Empirical Analysis of the Adoption of Process Improvement Recommendations

1.1 Introduction

This paper investigates the adoption and non-adoption of energy-saving opportunities resulting from recommendations made to small and medium sized manufacturing firms. Most of these energy-saving opportunities pertain to process improvements in operations, such as improved management of existing systems, modification or replacement of equipment, minimization of waste or resource usage, enhanced quality management, adoption of preventive maintenance and improvement of productivity and management practices.

Adoption of process improvements contributing to energy efficiency can have a significant impact. For instance, the Intergovernmental Panel on Climate Change (IPCC) estimates that over 2.5 gigatonnes of CO_2 equivalents per year can be saved in 2030 using energy efficiency measures. This is nearly 4% of overall anthropogenic CO_2 emissions forecast for 2030 (Bernstein et al. 2007) and equivalent to the emissions of nearly 54% of the passenger vehicles in the world in 2004 (Bush et al. 2006, Emission Facts 2005). The United States has been aware of the immense potential and has been striving to improve energy efficiency since the early seventies. Industry accounts for a third of the energy usage in the United States, which is why the US Department of

Energy (DOE) has been working to improve energy intensity in industry through the Industrial Technologies Program (ITP).

The Industrial Assessment Centers (IAC) program is part of the ITP and provides free energy efficiency assessments to small and medium sized firms. The IAC program has been in existence since 1976 and is estimated to have provided cumulative energy savings of 1280 trillion BTU by 2005 (Impacts 2005). The energy efficiency assessments are done by faculty and students from accredited engineering schools (Muller et al. 2004). Specific improvement recommendations covering the entire gamut of operational improvements including equipment modification, operating procedures and management practices are provided in a report to the firm. Subsequently, the implementation status of the recommendations is tracked by the respective IAC.

The recommendations usually have very attractive rates of return and their average payback period is just over a year. A former IAC director (one of the authors) illustrates how easy it can be to achieve substantial savings: "A quarter-inch diameter hole in a compressed air system implies $5,000 per year in wasted energy costs." However, even with attractive rates of return, many energy efficient process improvement recommendations are not implemented, as demonstrated in Figure 1.1. This is in line with what has been documented in the energy efficiency literature. Many studies indicate that a significant proportion of energy efficiency opportunities are not exploited (Expert Group on Energy Efficiency 2007). Various studies have postulated theories and explanations for this apparent anomaly; however, the literature struggles to explain the high rates of non-adoption of profitable energy efficiency initiatives. The literature has drawn extensively from fields ranging from economics to organizational learning in its attempt to explain the gap in adoption. Behavioral explanations using concepts ranging from bounded rationality to inertia have also been proposed in the literature (Rohdin and Thollander 2006). However, as Kempton et al. (1992) point out, much of the psychological research has focused on residential energy users at home. Behavioral aspects related to the adoption of energy efficiency initiatives in an industrial context are largely unexplored.

In this paper, we study the role of biases in the adoption of energy efficiency initiatives in an operational context. We find that managers are myopic as they miss out on many profitable energy efficiency initiatives. They are more influenced by upfront costs than by net benefits when evaluating these initiatives. Further, we find that the adoption of a recommendation is influenced by the sequence in which it is presented. We also find that decision makers are not influenced by the number of recommendations made to them.

This paper aims to make four key contributions. First, it studies the adoption of energy efficiency initiatives to enable a better understanding of the reasons why a significant proportion of the energy efficiency potential remains untapped. This understanding may help improve adoption rates. Second, since the recommendations cover a wide range of operations, this understanding may facilitate adoption of process improvement initiatives more generally. Third, the paper demonstrates decision biases previously undocumented in the OM literature. Fourth, it highlights behavioral issues using actual field data as opposed to the majority of the behavioral operations literature which uses experiments.

The rest of the paper is organized as follows. In Section 1.2, we review relevant literature. In Section 1.3, we present the hypotheses. In Section 1.4, we describe the data. In Section 1.5, we present our methodology and results. In Section 1.6, we discuss the results, implications of our findings and limitations of our analysis. In Section 1.7, we provide a summary, discuss policy implications and indicate areas for further research.

1.2 Literature Review

Our work draws on and contributes to several streams of literature: the adoption of innovations in general, the adoption of energy efficiency innovations in particular, and the behavioral literature pertaining to choice decisions between multiple (non-exclusive) alternatives. We provide a broad overview of the relevant literature in these areas, but defer a more detailed discussion of literature pertaining to our specific hypotheses to the next section.

Rogers (2003) suggests that the relative advantage of an innovation – the ratio of the expected benefits and the costs of adopting an innovation – is one of the strongest predictors of an innovation's rate of adoption. One of the sub-dimensions of relative advantage is economic profitability. Evidence supporting the influence of economic profitability on the rate of adoption has been observed across many innovations, ranging from hybrid corn in agriculture (Griliches 1957) to continuous mining machines in bituminous coal (Mansfield 1961). In the context of environmental innovations, Porter and Van der Linde (1995) and many others provide numerous examples of innovations which provide net benefits to firms. King and Lenox (2002) find that firms adopting waste prevention practices gain unexpected innovation offsets. Corbett and Klassen (2006) synthesize the growing stream of literature which indicates that investments in environmental improvements often provide unexpected but significant profit improvements. In line with the environmental literature, several studies in the energy efficiency literature indicate the presence of many profitable improvement opportunities. Shama (1983), Lovins and Lovins (1993) and many others provide examples of such opportunities which may be realized at negligible costs or provide rates of returns often over 30%. However, DeCanio (1993) points out "Many investments in energy efficiency fail to be made despite their apparent profitability." Jaffe and Stavins (1994a) identify the gap between actual energy use on the one hand and the optimal energy use on the other hand as the "energy-efficiency gap."

The energy efficiency literature has drawn on many fields in a bid to explain the paradox of low adoption rates of profitable energy efficiency improvements. The reasons used in the literature include market-failure and non-market-failure explanations (Jaffe and Stavins 1994b), organizational and institutional factors (DeCanio 1998), technology adoption and learning by using (Mulder et al. 2003), real options framework (Dierderen et al. 2003), and complexity of regulation (Mueller 2006). Anderson and Newell (2004), the only scholarly study to our knowledge that has used the IAC data, link economic incentives to energy efficiency initiatives and find that adoption depends more on initial cost than on annual savings. However, the literature struggles to explain the "energy-efficiency gap."

An underlying assumption in most studies which address the "energy-efficiency gap" is that agents are rational, but as Kahneman (1994) points out people may not be entirely rational in their choices. Managers may cope with uncertainty and complexity of decision making by adopting simplifying heuristics which may lead to systematic bias (Gilovich et al. 2002). A growing body of literature suggests behavioral issues influence a variety of operational settings, ranging from a simple newsvendor setting (Schweitzer and Cachon 2000) to complex supply chain settings (Croson and Donohue 2006). As energy efficiency initiatives typically involve the entire spectrum of operations (Oppenheim 2007), it may be relevant to examine behavioral issues that influence their adoption. In this paper, we investigate behavioral biases in the adoption of energy efficiency opportunities.

We examine managerial myopia and cost focus by drawing on various streams of literature which highlight this behavior. Laverty (1996) synthesizes five broad explanations in the literature that drive economic short-termism. These explanations include flawed management practices, managerial opportunism, stock market myopia, fluid and impatient capital, and information asymmetry. The short-termism may influence managers to adopt low cost projects. We investigate the influence of the sequence in which choices are presented by relating to the literature on order effects. Bruine de Bruin and Keren (2003) observe that people make judgments by comparing options as they are presented in a sequence. Impressions of each new option are formed by comparing its unique features to those of the option that preceded it. They find that order or presentation dictates the order of comparison, which leads to order effects. We study the effect of the number of choices provided by relating to the literature which examines choices when decision makers are provided a set of options. Sethi-Iyengar et al. (2004) find that 401(k) plan participation levels drop with an increased number of investment options. While, Koelemeijer and Oppewal (1999) find that an increase in assortment attracts additional purchases in the context of cut flowers. We extrapolate observations from these literatures to our context on the adoption of energy efficiency initiatives and develop relevant hypotheses.

1.3 Hypotheses

Our hypotheses are grounded in the literature on adoption of innovations and energy efficiency initiatives while drawing upon the behavioral literature related to heuristics, biases and order effects. We develop four hypotheses related to the adoption of energy efficiency initiatives.

Our first hypothesis relates to managerial myopia in the adoption of energy efficiency opportunities. Several studies in the energy efficiency literature show the existence of many profitable energy-saving opportunities. Koomey and Sanstad (1994) highlight through four examples the presence of profitable energy conservation opportunities for both consumers and producers. The IPCC highlights a range of energy-efficiency opportunities in the industrial sector such as improved housekeeping and maintenance measures for older, less-efficient plants which may yield energy savings of 10-20% to higher capital expenditure measures which can result in energy savings of 40-50% (Bernstein et al. 2007). However, a significant proportion of these opportunities are not realized (Expert Group on Energy Efficiency 2007).

The mere presence of unrealized opportunities need not indicate that managers are myopic. However, if managers have access to funds which cost less than the returns provided by the unrealized profitable opportunities then one may argue that managers missed options to utilize the funds and realize possible gains. This behavior may result from looking at the opportunity at too close a cognitive distance, similar to the myopic behavior highlighted by Benartzi and Thaler (1999) in the context of investment in retirement savings. Or it may result from using an investment horizon of a year to evaluate opportunities, similar to the "myopic loss aversion" behavior highlighted by Benartzi and Thaler (1995) in the context of investments in stocks and fixed income securities.

One of the most expensive sources of funds mentioned in the literature is trade credit. The Federal Reserve Board's 2003 Survey of Small Business Finances indicates that trade credit was used by 60 percent of small businesses. Petersen and Rajan (1995) highlight that funds obtained through trade credit have an annualized rate of 44.6%. They argue a firm may utilize this expensive source of funds as long as the returns from investments exceed the cost of funds.

In our context, if we find that the rates of return for unrealized initiatives is higher than the cost of trade credit then we may conclude managers missed out on profitable opportunities. This is especially true given that most recommendations are quite trivial to implement (for instance, they may require coordinating with a vendor, and hence "the cost of managerial effort" is not a major obstacle). Note that we are not concerned with why an individual firm may not adopt these opportunities, but with a collection of firms. For the collection of firms in our study, if we find a significant proportion of unrealized opportunities have rates of return higher than the cost of accessible funds then we may conclude that managers are exhibiting myopia with regard to the adoption of energy efficiency initiatives.

Hypothesis 1: *Managers display myopia in the adoption of energy saving initiatives. They fail to adopt profitable energy efficiency initiatives even though the rates of return of such initiatives are higher than the cost of funds for small businesses.*

Our second hypothesis relates to the focus on upfront costs rather than on net benefits. Numerous studies in the literature point out a range of reasons why managers focus on costs while evaluating improvement opportunities. In the context of energy saving initiatives, Stern and Aronson (1984) argue that expenditures which fit in the present budget cycle may require fewer approvals and prompt managers to focus on low cost projects. Hirshleifer (1993) points out managers may be concerned about their reputation and consequently not undertake investments with large costs as such projects may affect their cash flows and reflect poorly on their performance. Thakor (1993) highlights that managerial incentives to build reputation may lead to myopic investment decisions. Antle and Eppen (1995) highlight that organizations may adopt capital rationing in the presence of asymmetric information and moral hazard. Zhang (1997) uses a principal agent model to highlight that capital rationing may be advantageous for some organizations which face asymmetric information between managers and owners. In such instances, managers may undertake lower cost projects to meet the capital rationing constraint. Marginson and McAulay (2008) indicate that accounting information measures may influence managers to adopt a short-term outlook and take actions solely to maximize short-term results. When purchasing energy efficient refrigerators, Meier and Whittier (1983) find that nearly 60% of buyers used a discount rate over 35% to evaluate the benefits of the more efficient appliance. Extrapolating to our context, we predict managers will be influenced to a greater degree by initial costs than by net benefits in the adoption of energy efficiency initiatives.

Hypothesis 2: *Managers focus more on upfront costs than on net benefits when evaluating energy efficiency initiatives.*

Our third hypothesis relates to the order in which recommendations are presented to managers. Anderson (1971) defines primacy effect as occurring when information presented early in a sequence has a higher effect on judgment and recency effect as occurring when the converse happens. Many studies in the literature highlight the presence of these effects. Symonds (1936), in an experiment with school children, varied the order of presentation of a list of items and studied the effect of ranking these items. He found items had a lower rank when they were placed earlier in the list. Ashton and Ashton (1988) investigated the role of information order in an audit context and found support for the recency effect while Anderson and Maletta (1999) found evidence that auditors are susceptible to primacy effects. Kardes and Kalyanaram (1992) performed experiments where consumers were given sequential exposure to information on various brands and found evidence of a primacy effect. Perrin et al. (2001) use a simulation exercise to find US Naval officers arrived at conclusions which were influenced by information that was presented later in a sequence. Terry (2005) investigated the impact of the serial position of a commercial in a batch of commercials and finds evidence for both primacy and recency effects. Bruine de Bruin (2006) observes serial position effects when options are judged in a sequence, as in the case of figure skating competitions, and finds evidence that later performers obtain higher scores. Meredith and Salant (2007) find evidence that the order in which candidates are presented in a ballot influences election outcomes with candidates being listed first gaining a significant advantage. Rubinstein and Salant (2006) formulate a model of choice from lists and explore a particular form of choice functions which leads to a preference relation. Salant (2008) studies the problem of choosing from a list and indicates that any choice rule which is simpler than rational choice leads to order effects. He derives conditions under which making one choice from a list leads to a primacy effect, recency effect, choice overload or status quo bias.

Overall, the literature finds evidence of both primacy and recency effects but has not been able to clearly delineate the contexts in which either effect will dominate. In our context, decision makers are provided a written report with the recommendations in a particular sequence. Based on the literature discussed above we can predict that the serial position of a recommendation in the report will influence the decision makers response to a recommendation. However, the direction of the influence cannot be unambiguously predicted.

Hypothesis 3: *The serial position of a recommendation in the report will influence adoption rates. As the direction of influence cannot be unambiguously predicted, it will be determined empirically.*

Our fourth hypothesis relates to the number of recommendations provided to the managers. The literature on choice overload is relevant to our context. On the one hand, a body of literature argues that decision makers are overwhelmed when they are provided too much choice. Benartzi and Thaler (2007) highlight many instances of this problem and discuss issues specifically related to retirement savings. They find that many decision makers adopt a naïve strategy of allocating their assets equally over "n" choices, which they call the "1/n rule." Huberman and Jiang (2006) analyze similar problems when the number of choices is large. They find that decision makers first restrict their choices to a smaller subset of "n" choices and then they allocate the assets equally over the subset of choices. They call this the "conditional 1/n rule." Iyengar and Lepper (2000) study the cases when consumers are provided a wide array of choice (24 flavors of jam) and limited choice (6 flavors of jam). They find that consumers were more likely to make a purchase when they have limited choice.

On the other hand, a body of literature argues that decision makers are drawn toward increased choice options. Bown et al. (2003), in a set of three studies, demonstrate that decision makers prefer options that allow them to take more choices over those that do not, even when the additional choices cannot improve the final outcome. Oppewal and Koelemeijer (2005) use a choice experiment with a large consumer panel to show that adding any item to an assortment improves the assortment evaluation, irrespective of the size or attributes of the assortment. Scheibehenne et al. (2009) replicate earlier studies that demonstrated choice overload and do not find the "too-much-choice" effect. They also perform a meta-analysis of studies in the literature and find the choice overload effect to be much less robust than previously thought.

Overall the literature finds evidence of both choice overload and preference for increased choice options but has not been able to clearly delineate the contexts in which either effect will dominate. Based on the literature discussed above, we can predict the number of recommendations provided will influence adoption rate. However, we cannot unambiguously predict the direction of this effect.

Hypothesis 4: *The number of recommendations in an assessment will influence adoption rates. As the direction of influence cannot be unambiguously predicted, it will be determined empirically.*

1.4 Data

The US Department of Energy's IAC program funds a network of universities to conduct free energy assessments for small and medium sized manufacturing firms. Assessments are done by engineering faculty and students from participating universities across the US. Over 50 universities have participated in the program at various times since it started in 1976. In fiscal year 2007, the budget for the IAC program was just over $4 million and around 350 assessments were expected to be performed (DOE 2009).

Firms eligible for the assessments are chosen based on multiple criteria. These include whether the plant's products are within standard industrial classification codes 20 through 39, whether the plant is within 150 miles of the host campus, has gross annual sales below $100 million, has employee count less than 500, has annual energy bills between $100,000 and $2 million and has no professional in-house staff to perform the assessment (Muller et al. 2004). A small number of larger firms exceeding these criteria are included in the database. These firms were assessed by IACs under different DOE programs, and on special request of DOE.

Firms may either contact the IAC expressing an interest in the assessment or the IAC may directly contact potential firms. The IAC team collects information to understand current energy usage in the firm. The next step is a site visit by the IAC team led by a faculty member. Typically the visit entails interviews with the plant management, plant tours and collection of operational data. Some energy saving opportunities are identified by observing the plant operations. The fourth author, a former IAC director, indicated that in some instances it was surprisingly easy to identify opportunities: "In some plants we hear a constant hiss which indicates compressed air is leaking out." Other recommendations are identified by analyzing the operational data and linking it with observations in the plant visit. As the former IAC director says; "In one plant we saw excess flash (extra material) on parts made using an injection molding process and later using the specific heat values for the molding material we identified they were using around forty times the energy required for the process." Subsequent to the visit, the team provides a written report with details of specific recommendations to improve efficiency across energy streams, waste streams and productivity. After six to nine months, the plants are contacted by the IAC to ascertain which of the recommendations have been implemented or will be implemented in the next year. The information on the recommendations and their implementation status is provided to the IAC database managers using standard templates.

Information on the recommendations and the assessments is maintained in a database at a public website hosted by the Center for Advanced Energy Systems at Rutgers University. The database has details of each assessment performed since 1981. Currently there are over 13,000 assessments with over 100,000 recommendations. The information maintained for each assessment includes plant demographics such as annual sales, employees, plant area, production hours, energy consumed, manufacturing sector, date of assessment, etc. For each recommendation the information maintained includes expected savings, quantity of energy conserved, implementation costs, payback calculations, whether the recommendation was implemented or not, etc. Details on the information maintained in the IAC database and on the IAC assessment process are available in "The DOE Industrial Assessment Database Manual" (Muller et al. 2004). The DOE has developed a coding system for the recommendations called Assessment Recommendation Code (ARC). This classifies recommendations into 25 major categories and over 600 sub-categories. The ARC number for each recommendation and the order in which the recommendations appeared in the report are also stored in the database.

We use the data from the IAC database for the years 1981-2006. We do not use the data for the years 2007-08 as the data pertaining to the implementation process is not yet complete. In our analysis, we adjust all monetary figures for inflation, scaling to year 2006 US dollars using the producer price index WPUSOP3000 series for finished goods from the Bureau of Labor Statistics (BLS 2008). We exclude 778 recommendations which have payback values greater than nine years, 44 recommendations that involve additional costs and do not provide any positive savings, and eight recommendations which have negative costs for implementation. These are all outliers and possibly errors; including them would not change our conclusions. Overall, the data pertaining to 92,723 recommendations are used in the analysis. However, some observations are not included in specific analyses; these are indicated where we present our results. Table 1.1 provides descriptive statistics for our data.

The average estimated implementation cost across all recommendations is $20,767 while the average estimated annual savings is $19,297. The average estimated simple payback period across all the recommendation is just over a year; however, even with the short payback periods, firms only adopted 50.01% of all recommendations. The actual adoption rates are probably lower still as implementation rates are based on projected implementation data provided by the firms and in some instances partial implementation may be recorded as complete implementation. Additionally, in some instances it is possible that firms might report higher implementation to avoid the embarrassment of reporting low implementation rates.

1.5 Methodology and Results

We test our hypothesis related to managerial myopia separately from the other hypotheses. We use a nonparametric sign test to test the hypothesis related to managerial myopia. To test the other hypotheses, we employ two econometric models that relate adoption to the economic drivers and specific characteristics of recommendations. First, we estimate a conditional logit model, building on Anderson and Newell (2004), and find that costs, savings, and the serial position of a recommendation influence the implementation rate. However, this model does not correct for the fact that the serial position may be endogenous as the IAC were asked to present more attractive recommendations first. Second, to account for the endogenous explanatory variable, we estimate a probit instrumental variables model. All the analyses were done using STATA version 10.0.

To test our hypothesis related to managerial myopia, we compute the Internal Rate of Return (IRR) for the recommendations which were not implemented. In our IRR calculation we assume that the annual savings accrue for three years. We compare the median IRR of unrealized opportunities against trade credit which is one of most expensive source of funds for small businesses mentioned in the literature (Petersen and Rajan 1995). The results of this comparison are provided in Table 1.2.

1.5.1 Conditional Logit Model

We build on Anderson and Newell's (2004) econometric model by incorporating variables to capture the uncertainty of the returns of a recommendation and the sequence in which the recommendations are presented.

We estimate a set of conditional logit models for the adoption decision, with an indicator variable Y_i that equals 1 if recommendation i is adopted and equals 0 otherwise. The choice problem is defined by the latent variable model:

$$Y_i^* = \alpha + \mathbf{M}_i * \beta + V_i * \gamma + \mathbf{T}_i * \delta + S_i * \varphi + \mathbf{C}_i * \lambda + \varepsilon_i \qquad (1.1)$$

where Y_i^* is the net benefit of adopting recommendation i; $\mathbf{M}_i$ is the vector of financial variables for recommendation i; V_i is the variance of the payback associated with recommendation i; $\mathbf{T}_i$ is a vector which indicates the type of recommendation i; S_i represents the serial position of the recommendation i in the report; $\mathbf{C}_i$ indicates the firm-level fixed effects; and ε_i represents the error term. We include the variance of the payback of a recommendation to capture the uncertainty related to its returns. We compute the variance of payback of a specific type of recommendation i as $\sum_j [(\text{Payback})_{ij} - (\text{Average Payback})_i]^2$, where j represents all firms in our dataset that were given recommendation i. Note this variable is not a perfect measure of the uncertainty related to the returns as it also captures the underlying heterogeneity of the firms in the dataset, but as long as there is a recommendation-specific element to the overall variance, this measure will be correlated with the uncertainty associated with a recommendation. We include the variables for the type of recommendations to capture the effects due to the heterogeneity among the recommendations. These variables identify each recommendation as belonging to one of the twenty-five different mutually exclusive major categories based on the first two digits of the ARC number. In this model, we do not include the number of recommendations as that effect will be embedded in the firm-level fixed effects $\mathbf{C}_i$.

Decision makers will adopt a recommendation only if the benefits from adopting it are positive, and thus the probability that a recommendation is adopted is

$$\begin{aligned} \text{Prob}\,[\, Y_i = 1 \,] &= \text{Prob}\,[\alpha + \mathbf{M}_i{*}\beta + V_i{*}\gamma + \mathbf{T}_i{*}\,\delta\, + S_i{*}\,\varphi + \mathbf{C}_i{*}\,\lambda + \varepsilon_i > 0\,] \\ &= F\,(\alpha + \mathbf{M}_i{*}\beta + V_i{*}\gamma + \mathbf{T}_i{*}\,\delta\, + S_i{*}\,\varphi + \mathbf{C}_i{*}\,\lambda + \varepsilon_i) \qquad (1.2) \end{aligned}$$

where F is the cumulative probability distribution function for ε. If we assume the cumulative distribution of ε follows a logistic distribution we have the logit model and if the cumulative distribution follows a standard normal distribution we have the probit model (Maddala 2003).

Following Anderson and Newell (2004), we estimate a "Payback" model and a "Cost-Benefit" model. In the "Payback" model, we use the logarithmic form of simple payback of the recommendation to construct the variables $\ln(\text{Payback})_i$ and $[\ln(\text{Payback})_i]^2$ for the vector $\mathbf{M}_i$. Similarly for the "Cost-Benefit" model, we construct the variables $\ln(\text{Cost})_i$, $[\ln(\text{Cost})_i]^2$, $\ln(\text{Savings})_i$ and $[\ln(\text{Savings})_i]^2$ using the logarithmic form of expected costs and savings for the vector $\mathbf{M}_i$. Further, Payback, Cost and Savings have been normalized to equal one at their respective means to ease interpretation of the coefficients. In line with Anderson and Newell (2004), we use the logarithmic form of the financial variables as it improves the model's fit with the data; using the linear form provides similar results. Table 1.3 presents the estimation results for the "Payback" and "Cost-Benefit" models. We recognize that significance may be driven by the large number of observations, consequently we report results using a stringent significance level evaluation with $p<0.001$.

1.5.2 Instrumental Variables Probit Model

The above econometric model treats the serial position of the recommendation as exogenous, but this may not be the case. For instance, the IACs were guided to put more attractive recommendations earlier in the report. If the IAC assessment of the attractiveness of each recommendation is observable then it can be included in the econometric model to obtain consistent estimates of model parameters. As this is not the case, the effect of these assessments of attractiveness will be captured in the error terms. This implies that the serial position is correlated with the error term and is therefore endogenous in the model. We can address the problem of the endogenous explanatory variable by identifying an instrumental variable that is related to the serial position of the recommendation, but is otherwise unrelated to the error terms (Wooldridge 2002).

We explore two instruments for the serial position of the recommendation. The first instrument is based on the order in which the recommendations appear in the IAC Assessment Recommendation Code (ARC) manual. The ARC manual groups recommendations so that they focus on the same energy system (for example, combustion systems) or they follow a similar strategy for enhancement (for example, maintenance). The recommendations are ordered by a unique ARC code. We use the ARC code to sequence the recommendations made to a firm so that the recommendation with the lowest ARC code is given the first rank and so forth. The assessors use the ARC codes to report their recommendations to the IAC Database managers. Consequently their reporting of recommendations in the report may partly follow the sequence in the ARC manual. As the ARC manual is maintained centrally, the ARC will not be related to the preferences of a specific firm, hence the instrument should not be correlated with the error terms.

The second instrument is related to the propensity with which each IAC makes a recommendation. We compile the frequency with which each IAC makes a particular recommendation across all assessments. We use this to sequence the recommendations made to a specific firm so that the recommendation with the highest frequency gets the first serial position and so forth. The resulting sequence is a reflection of the specific IACs familiarity with specific recommendations and this may be related to the way in which they present the recommendations to a specific firm. This sequence is based on the IACs interaction with all firms it has assessed and as such it will not be related to the preferences of a specific firm; hence the instrument should not be correlated with the error term.

We estimate a probit model as it allows us to incorporate the instrumental variable estimation and also enables us to incorporate the effects of the number of recommendations which was not possible in our earlier model (1.1). The specification of the probit instrumental variables model is

$$Y_i^* = \alpha + \mathbf{M}_i{*}\beta + V_i{*}\gamma + \mathbf{T}_i{*}\,\delta + S_i{*}\,\varphi + N_i{*}\omega + NP_i{*}\,\psi + \mathbf{R}_i{*}\,\lambda + \varepsilon_i \qquad (1.3)$$

$$S_i = \mathbf{M}_i{*}\,\Pi_\beta + V_i{*}\,\Pi_\gamma + \mathbf{T}_i{*}\,\Pi_\delta + N_i{*}\,\Pi_\omega + NP_i{*}\,\Pi_\psi + \mathbf{R}_i{*}\,\Pi_\lambda + v_i \qquad (1.4)$$

In this model the variable S_i is endogenous as opposed to model (1.1) where S_i is exogenous. The linear projection in equation (1.4) represents the reduced form equation for the endogenous explanatory variable S_i. The variable N_i represents the number of recommendations made to a firm. NP_i represents the interaction term for the number of recommendations in the assessment with the payback. The vector $\mathbf{R}_i$ includes controls for the year, specific IAC, two digit SIC codes, sales, employees and plant area. The variables $\mathbf{M}_i$, V_i and $\mathbf{T}_i$ are as discussed for the conditional logit model. As in the conditional logit model, decision makers will adopt a recommendation only if the benefits from adopting a recommendation are positive (1.2).

The model (1.3) seeks to capture two distinct effects, one due to the serial position of the recommendations and the other due to the total number of recommendations in an assessment. However these variables are not orthogonal as the correlation between them is 0.51. Consequently, to get a better understanding of these individual effects, we evaluate two versions of model (1.3). In the first version, the serial position of a recommendation is used as is; in the second version, the serial position of a recommendation is normalized within an assessment so that it equals one at its mean. For instance, in an assessment with five recommendations the serial positions will be recorded as 1, 2, 3, 4, and 5 in the first version, while it will be recorded as 1/3, 2/3,1,4/3, and 5/3 in the second version. Both specifications have advantages and disadvantages.

To validate the instruments for each version of model (1.3), we run a simple OLS regression of the variables for serial position of the recommendation on the instruments related to the ARC code and the IACs propensity to make a type of recommendation. The R^2 we obtain for this regression is 0.23 for the first version and 0.04 for the second version. For the first version this is comparable to similar values reported in the literature (e.g., Evans and Schwab (1995) report R^2 of 0.16 when they regress their endogenous variable -- catholic school -- on their instrument -- catholic religion). We also ran an ordered probit model for the first version. The z-stat for the instrument related to ARC code and the IAC's propensity to make a type of recommendation is 91.90 and 70.64 respectively and both are statistically significant at $p<0.001$. Therefore, the chosen instruments are valid determinants of the serial position of the recommendations for the first version of model (1.3). The validity of the instruments for the second version of model (1.3) is not clearly established and we proceed under the assumption that we have weak instruments for the second version.

For both versions, we evaluate two probit models for the Payback model discussed in (1.1): one where the variable S_i is treated as exogenous and the other where it is treated as endogenous. The models are labeled Exog_PB and Endog_PB respectively. Similarly for both versions, we evaluate two probit models for the Cost-Benefit model discussed in (1.1) and label the models Exog_CB and Endog_CB. Tables 1.4 and 1.5 present the results for the four models with the first and second specification for the sequence variable respectively.

1.6 Results, Implications and Limitations

In this section, we present our main results related to our four hypotheses, draw implications from our results and then discuss limitations and alternative explanations for our study. With respect to our hypothesis on managerial myopia, we appeal to the summary statistics in Table 1.1, where we observe that nearly half the recommendations are not implemented despite the fact that average payback for the recommendations is just over a year. From the results of the nonparametric sign test in Table 1.2, we see that the median rates of return for the unrealized recommendations are significantly higher than the cost of trade credit, one of most expensive sources of funds available to small business managers. Further, the median rate of return for recommendations not implemented is 84% which is a very attractive proposition considering any rational investment hurdle rate. These observations provide support for hypothesis 1 that managers are myopic and indeed miss out on many profitable energy saving opportunities. This is in line with existing literature – our contribution is that we build on this by identifying that returns for the unrealized opportunities are higher than one of the most expensive sources of funds available to managers. This is relevant for the IAC program which aims to improve energy-efficiency of small and medium sized firms. The objectives of the program may not be met by just providing information on profitable energy-efficiency opportunities. Additional factors, as highlighted in the discussions of our subsequent hypotheses, need to be considered to improve adoption of energy-efficiency initiatives.

With respect to our other hypotheses, we draw inferences from the results for the conditional logit model provided in Table 1.3 and the results for the probit models provided in Tables 1.4 and 1.5. We observe that the coefficients for the cost variables are significant and larger than those for the savings variables in the Exog_CB and Endog_CB models in Tables 1.4 and 1.5 and the Cost-Benefit model in Table 1.3. In addition, the coefficients for the savings variables are not significant in the instrumental variables probit model. These observations provide support for hypothesis 2 that managers are influenced more by initial costs than by net benefits when evaluating energy efficiency opportunities. This has significant implications for the IAC program as well as other initiatives where managers are provided costs and savings for investment opportunities.

The results related to hypothesis 2 are similar to Anderson and Newell (2004), but we build on their models by incorporating variables related to the uncertainty of the returns and to the underlying behavioral factors that influence the adoption decision. The coefficient for the variance of payback for all the models in Tables 1.3, 1.4 and 1.5 are significant and have a negative sign as expected.

With regards to hypothesis 3 on the order effects, we observe that the average adoption rate falls for recommendations that occur later in the report (as demonstrated in Figure 1.2), from over 50% for the earliest recommendations to around 40% for the last ones. Further, we observe that the coefficients of the serial position of the recommendation are significant across all models in Tables 1.3, 1.4, and 1.5. This supports hypothesis 3 that the serial position of a recommendation has an influence on the adoption rate. In addition, the coefficients of the serial position are negative across all models in Tables 1.3, 1.4 and 1.5. These indicate that the probability of implementation falls as the recommendation occurs later in the report. Additionally, in Table 1.4 for the Endog_CB model, if we consider an average assessment where the recommendation is moved from the fourth position to the fifth position in the report then its probability of adoption will fall by 0.052. This is the same effect as will be achieved by increasing the cost of implementation by $34,446 from the average level of $20,767. In Tables 1.4 and 5, the coefficient of the serial position is over four times larger for the endogenous model than for the exogenous models. This indicates that the impact of the serial position in the exogenous model tends to be understated due to the correlation with the error terms. Overall this provides empirical support for the primacy effect in our context (i.e., recommendations that appear later in the report have lower rates of adoption than those that occur earlier in the report).

As the recommendation order variable is also related to the total number of recommendations, a possible concern may be that the effect we identified is in fact due to the total number of recommendations. To address this we formed groups of all recommendations with the same total number of recommendations and then we redid the probit instrumental variables analysis within each group. The results of this analysis are provided in Table 1.6. The coefficients for the serial position variable are significant across all models and have a negative sign. This supports the inference that the sequence of recommendations is significant in explaining the adoption rates and indicates the presence of primacy effects. This result has significant implications for the IAC program and for other contexts where a collection of process improvement opportunities are presented to decision makers. As the serial position of the recommendation has a significant effect on the adoption rate, the IAC teams must take particular care in how they present the recommendations to the firms. This implication may also carry over to other business contexts, such as consultants providing reports to clients, or firms providing retirement saving options to their employees, or internet firms providing choices to prospective customers, etc. In all these situations, decision makers are exposed to a set of choices and are possibly influenced by the sequence in which those choices are presented to them.

In the context of hypothesis 4 on the total number of recommendations provided to managers we see that the coefficient of the number of recommendations is positive and significant at $p<0.001$ in three models in Table 1.4 while the coefficients are negative but not significant at that level in any of the models in Table 1.5. This does not support hypothesis 4 that the number of recommendations in an assessment will have an influence on adoption rates. However, as the coefficients are not significant in any model with a negative sign it provides empirical support for the absence of choice overload in our context (i.e., adoption rates do not fall with the increase in the number of recommendations in an assessment).

A possible concern with this result may be that the serial position of the recommendation is masking the effect of the number of recommendations. To address this concern we formed groups of all recommendations with the same serial position value and then we estimated a probit model of the adoption rates within each group separately. The results of this analysis are provided in Table 1.7. The coefficients of the number of recommendations have a positive sign in all the five models and are not significant in four of the five models in Table 1.7. This supports our inference that the total number of recommendations is not significant in explaining the adoption rates and since the coefficients do not have negative signs it provides support for the absence of choice overload. Further we appeal to the chart presented in Figure 1.3 where we observe that nearly 50% of the recommendations are implemented irrespective of the number of recommendations made to a firm. This might indicate that decision makers are not adopting a choice heuristic as suggested by Iyengar and Lepper (2000) but are adopting some other simplifying heuristic (Gilovich et al. 2002) which prompts them to adopt on average half of all recommendations they receive. Note though that there is a substantial variance around the average adoption rate of 50%; further research could take a firm-based perspective to explain variation in adoption patterns across firms, rather than the recommendation-level analysis we do here. This result also may have implications for situations in which a list of recommendations is provided to operations managers. In many instances consultants tend to focus on providing a few critical recommendations in the belief that adoption may increase if the set of choices is limited. However, as demonstrated here, operations managers do not seem to be overwhelmed by choices, consequently it may be advisable to present all opportunities.

A possible alternative explanation for our results is that firms might plan to adopt all the recommendations but decide to do so in the sequence in which the recommendations are presented. Hence when the IACs contact them to check on the implementation status they would have implemented recommendations which were presented early in the report. This would be consistent with our findings as this would imply that firms are using the sequencing of recommendations to guide their adoption sequence decision making as opposed to deciding that based on the merits of a recommendation.

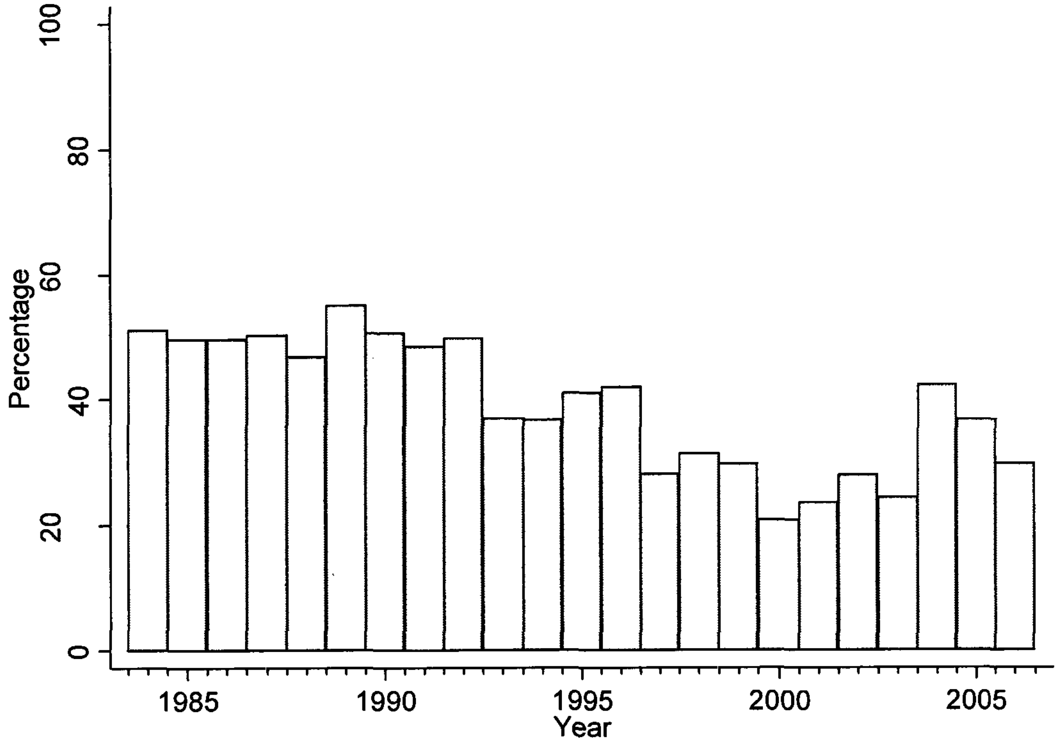
A possible cause for concern may be that some unobserved costs of implementation which are not included in the analysis are driving the results. The only way this is addressed in this study is by controlling for the recommendation types, but this is not a comprehensive and robust approach and remains as a possible limitation of this study. However given the heterogeneity of firm types based on their standard industrial classifications and the wide variety of recommendations, we do not believe such unobserved costs, if any, would be present across all recommendations in such a way as to systematically bias our results.

1.7 Summary and Discussion

In this paper we analyze the adoption of energy efficiency related process improvement recommendations made to small and medium sized firms and find evidence related to four biases. First, managers are myopic as they miss out on many profitable energy efficiency initiatives. Our contribution is to highlight that these profitable opportunities have rates of return which are significantly higher than the most expensive source of funds mentioned in the literature. Second, managers are more influenced by initial costs than by net benefits when evaluating such initiatives. Given the focus on costs it may be prudent to present the lifetime savings of a recommendation rather than the annual savings along with the implementation costs, or provide options to spread the implementation costs over the lifetime of the initiative. This may prompt managers to focus on net benefits and improve the adoption of such initiatives. Third, the sequence in which the recommendations are presented influences adoption rates: recommendations which appear early in a list of recommendations have higher rates of adoption compared to those which appear later in the list. A possible strategy in light of this result could be to include recommendations that have larger societal impact, such as energy saving or pollution reduction, earlier in the report. This will increase the adoption rates of these recommendations and provide higher benefits to society. Fourth, we do not find evidence of choice overload. Adoption does not decrease with the number of recommendations provided to operations managers. This points to the possibility of providing more recommendations to the managers, which may result in increased overall adoption. Our study thus highlights biases which have been previously unobserved in the operations management context. Moreover, since most of the energy saving recommendations relate to some form of operational process improvements, our findings have broader implications for the adoption of process improvements in operations. Better understanding of these biases and underlying managerial behavior may facilitate the adoption of process improvement initiatives across general operational settings. Finally we contribute to the behavioral operations literature by studying behavioral issues using actual field data as opposed to the majority of the studies which use experimental data.

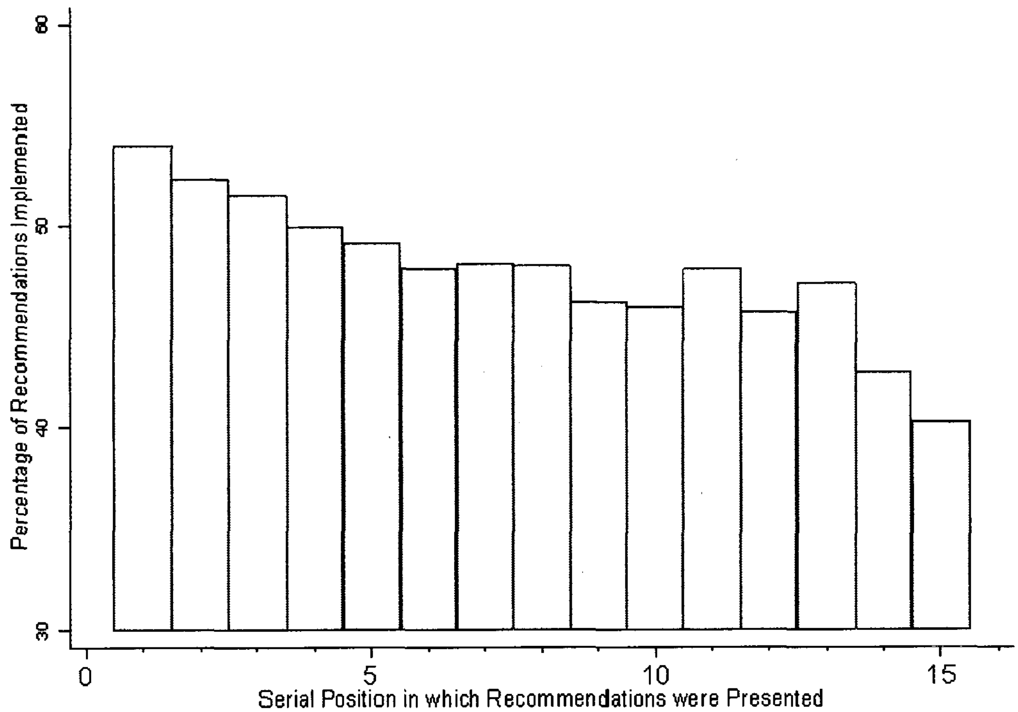
An intriguing area for further research would be to identify similar groups of firms who may have comparable efficiency improvement requirements and then see if the adoption varies with the order of the recommendations and the number of the recommendations. This would require a controlled field experiment and would provide greater support and insights leading to the decision of adoption.

Figure 1.1: Energy Savings Implemented as a Percentage of Total Savings Recommended



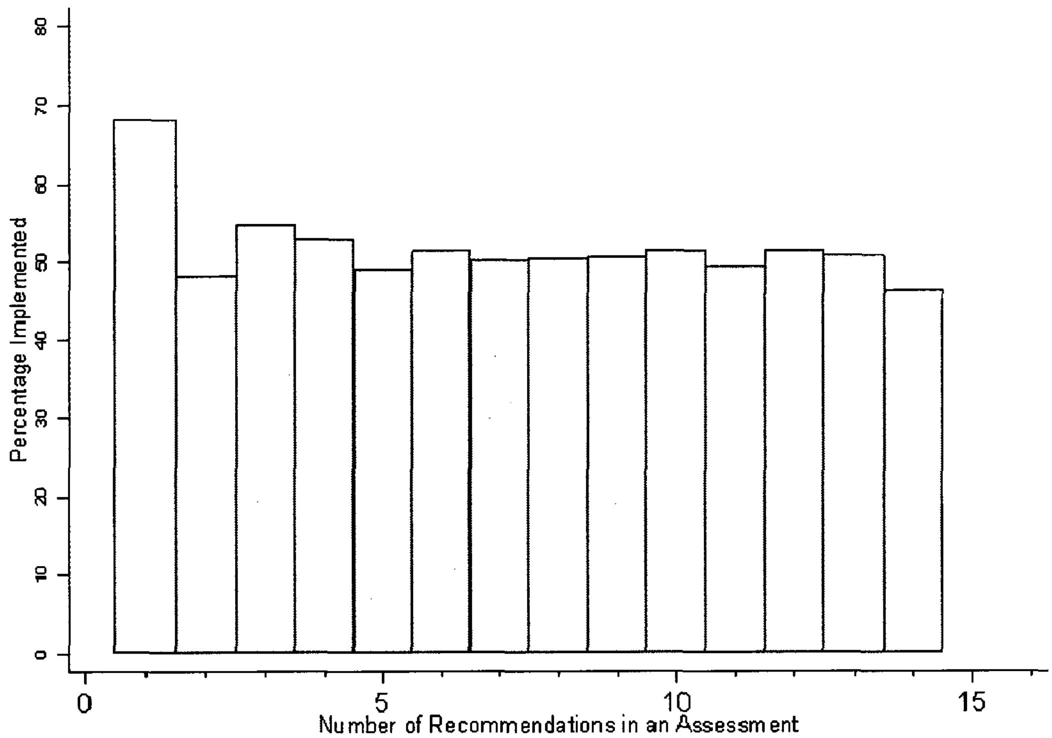
Over 50% of energy savings recommended are not implemented. Moreover, the percentage of energy savings implemented is decreasing over time.

Figure 1.2: Adoption Rate vs. Serial Position of Recommendation in the Report



A drop in adoption rates, of over 13% is observed between recommendations which occur in the 1st vs. 15th position in a report.

Figure 1.3: Adoption Rate vs. Number of Recommendations in an Assessment



On average, approximately half of the recommendations are implemented irrespective of the number of recommendations made to a firm.

Table 1.1: Descriptive Statistics

Variable	Mean	S.D	Minimum	Maximum
Adopted**	0.5001	0.50	0	1
Payback (years)	1.0579	1.29	0	9
Implementation Cost (US$)	20,766.82	301,632.42	0	55,429,808
Annual Savings (US$)	19,296.85	130,001.21	1.12	8,519,905
Annual Sales (US $)	41,729,814.57	247,954,127.97	0	25,000,000,000
Employees	175.02	177.78	0*	5,800
Floor Area (square feet)	201,027.04	2,592,045.59	0*	150,000,000
Annual Energy Cost (US$)	727,867.34	2,643,844.22	0*	189,742,848

Statistics are based on data for the 92,723 recommendations, representing 12,703 assessments.
Monetary figures are in 2006 US Dollars
** Adopted =1 if the recommendation is implemented and 0 otherwise

* **Note:** Data is missing and coded as 0 for : 1) Annual Sales (755 records), 2) Employees (101 records) 3) Floor Area (26,596 records). All the analysis has also been done by removing the missing data and the results of the study are still valid.

Table 1.2: Sign Test for Paired Comparisons: Median Rates of Return for Unrealized Recommendations vs. Cost of Trade Credit

Sign	Observed Returns for Recommendations as Compared to Cost of Trade Credit	Expected Returns for Recommendations as Compared to Cost of Trade Credit
Positive *(Returns are More Than Cost of Trade Credit)*	**23907**	**18746**
Negative *(Returns are Less Than Cost of Trade Credit)*	**13585**	**18746**
Total	**37492**	**37492**

One-sided tests:

Ho: Median Rate of Return of Unrealized Opportunities is Equal to Cost of Trade Credit

Ha: Median Rate of Return of Unrealized Opportunities is More Than Cost of Trade Credit

p Value =0.000

Two-sided test:

Ho: Median Rate of Return of Unrealized Opportunities is Equal to Cost of Trade Credit

Ha: Median Rate of Return of Unrealized Opportunities is Not Equal to Cost of Trade Credit

p Value =0.000

Data pertains to recommendations made by IAC centers from 1981-2006. 37,492 recommendations that were not implemented are used in the analysis. 2,790 unrealized recommendations were excluded in this analysis as their internal rates of return were over 100 and 17 unrealized recommendations were excluded as their payback were negative and 6,068 unrealized recommendations were excluded as their cost figures were recorded as zero. Including these recommendations in this analysis does not alter the inferences.

Table 1.3: Conditional Fixed Effects Logit Estimates of Adoption of Recommendations

Dependent Variable : Adopted (equals 1 if implemented 0 otherwise)

	Conditional Logit Models	
	Payback	**Cost-Benefit**
ln(Payback)	-0.3124***	
	(0.023)	
ln(Payback)^2	-0.0348***	
	(0.005)	
ln(Cost)		-0.2868***
		(0.018)
ln(Cost)^2		-0.0170***
		(0.002)
ln(Saving)		0.1246***
		(0.017)
ln(Saving)^2		-0.0032
		(0.003)
Serial	-0.0424***	-0.0550***
	(0.004)	(0.004)
Number*Payback	0.0124	-0.0470***
	(0.017)	(0.013)
Variance	-0.1566***	-0.1252***
	(0.014)	(0.014)
Controls:		
Recommendation Type (Number significant at p<0.001 out of 25 recommendation types)	0	0
Firm Fixed Effects	Yes	Yes
Observations	61955	61955
Log-Likelihood	-25437.613***	-25348.141***
Likelihood-Ratio	3304.1	3326.8

standard errors are in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Data pertains to recommendations made by IAC centers from 1981-2006. Dependent variable is the implementation status of a recommendation - Adopted equals 1 if recommendation is implemented and equals 0 otherwise. Estimation method is maximum likelihood conditional fixed effects. Standard errors reported are using robust clustered variance covariance matrix. Each model is estimated for an effective sample of 9310 plants representing 61,955 recommendations. 3,362 plants (17,090 recommendations) were dropped from the full sample due to their having no variation in whether the recommendations were adopted or not. 13,678 recommendations were dropped as they have payback less than or equal to zero and the logarithmic form for payback is not defined. Including these recommendations in a model without logarithmic transformation does not change the inferences we derive from this model.

Tablel. 4: Instrumental Variables Probit Estimates of Adoption of Recommendations (Version : Absolute Serial Position)

Dependent Variable : Adopted (equals 1 if implemented, 0 otherwise)

	Probit Exog_PB	IV Probit Endog_PB	Probit Exog_CB	IV Probit Endog_CB
ln(Payback)	-0.1468 ***	-0.1097 ***		
	(0.0107)	(0.0161)		
ln(Payback)^2	-0.0164 ***	-0.0152 ***		
	(0.0022)	(0.0022)		
ln(Cost)			-0.1392 ***	-0.1276 ***
			(0.0085)	(0.0091)
ln(Cost)^2			-0.0084 ***	-0.0075 ***
			(0.0011)	(0.0011)
ln(Saving)			0.0609 ***	0.0128
			(0.0084)	(0.0135)
ln(Saving)^2			-0.0013	0.0018
			(0.0014)	(0.0016)
Serial Position	-0.0203 ***	-0.1643 ***	-0.0259 ***	-0.1322 ***
	(0.0018)	(0.0377)	(0.0019)	(0.0227)
Number	0.0384	0.6182 ***	0.0911 ***	0.5162 ***
	(0.0267)	(0.1526)	(0.0261)	(0.0928)
Number*Payback	-0.0006	0.0037	-0.0276 ***	-0.0218 ***
	(0.0079)	(0.0083)	(0.0060)	(0.0063)
Variance of Payback	-0.079 ***	-0.1185 ***	-0.0629 ***	-0.0721 ***
	(0.0073)	(0.0117)	(0.0072)	(0.0073)
Sales	-0.0007	-0.0005	-0.0007	-0.0006
	(0.0005)	(0.0005)	(0.0004)	(0.0004)
Employees	-0.0078	-0.0032	0.0034	0.0194
	(0.0073)	(0.0070)	(0.0072)	(0.0081)
Plant Area	0.0003	0.0003	0.0004	0.0006
	(0.0007)	(0.0007)	(0.0007)	(0.0006)
Controls				
Recommendation Type (No. significant at p<0.001 out of 25 recommendation types)	0	0	1	1
IAC Centers (No. significant at p<0.001 out of 45 IAC centers)	31	28	31	28
Years (No. significant at p<0.001 out of 26 Years)	0	0	0	0
Observations	78811	78811	78811	78811
Firms (Assessments)	12628	12628	12628	12628
Log-PseudoLikelihood	-51526.82 ***	-233295.9 ***	-51432.89 ***	-229748.36 ***
Exogeneity_Wald_Stat		12.03		19.91

standard errors are in parantheses
* p<0.05, ** p<0.01, *** p<0.001

Data pertains to recommendations made by IAC centers from 1981-2006. Dependent variable is the implementation status of a recommendation - Adopted equals 1 if recommendation is implemented and equals 0 otherwise. Estimation method is Maximum Likelihood. Standard errors reported are using robust clustered variance covariance matrix. 1 IAC center and its 12 related recommendations were dropped from the full sample due to their having no variation in whether the recommendations were adopted or not. 13,644 recommendations were dropped as they has payback less than or equal to zero and the logarithmic form for payback is not defined. Including these recommendations in a model without logarithmic transformation does not change the inferences we derive from this model. Also 256 recommendations with sic two digit codes less than 20 and more than 39 were not included in the analysis reported here. Including them does not change the inferences obtained from the models.

Table 1.5: Instrumental Variables Probit Estimates of Adoption of Recommendations (Version: Normalized Serial Position)

Dependent Variable : Adopted (equals 1 if implemented, 0 otherwise)

	Probit Exog_PB	IV Probit Endog_PB	Probit Exog_CB	IV Probit Endog_CB
ln(Payback)	-0.1457 ***	-0.0261		
	(0.0107)	(0.0166)		
ln(Payback)^2	-0.0162 ***	-0.0081 ***		
	(0.0022)	(0.0022)		
ln(Cost)			-0.1388 ***	-0.1040 ***
			(0.0085)	(0.0098)
ln(Cost)^2			-0.0084 ***	-0.0057 ***
			(0.0011)	(0.0011)
ln(Saving)			0.0600 ***	-0.0387 **
			(0.0084)	(0.0133)
ln(Saving)^2			-0.0012	0.0053 ***
			(0.0014)	(0.0015)
Serial Position (Normalized)	-0.1101 ***	-1.6060 ***	-0.1403 ***	-1.1690 ***
	(0.0091)	(0.1043)	(0.0096)	(0.0997)
Number	-0.044	-0.0447 *	-0.0148	-0.0296
	(0.0255)	(0.0187)	(0.0248)	(0.0223)
Number*Payback	-0.0011	-0.0018	-0.0277 ***	-0.0174 **
	(0.0079)	(0.0072)	(0.0060)	(0.0059)
Variance of Payback	-0.0797 ***	-0.1499 ***	-0.0633 ***	-0.0784 ***
	(0.0074)	(0.0081)	(0.0072)	(0.0071)
Sales	-0.0007	-0.0005	-0.0007	-0.0007
	(0.0006)	(0.0003)	(0.0004)	(0.0003)
Employees	-0.0079	0.0005	0.0034	0.0326 ***
	(0.0072)	(0.0052)	(0.0072)	(0.0080)
Plant Area	0.0003	0.0002	0.0004	0.0006
	(0.0007)	(0.0005)	(0.0007)	(0.0006)
Controls				
Recommendation Type (No. significant at p<0.001 out of 25 recommendation types)	0	0	1	4
IAC Centers (No. significant at p<0.001 out of 45 IAC centers)	31	16	30	18
Years (No. significant at p<0.001 out of 26 Years)	0	0	0	0
Observations	78811	78811	78811	78811
Firms (Assessments)	12628	12628	12628	12628
Log-PseudoLikelihood	-51519.05 ***	-105020.28 ***	-51422.18 ***	-101430.56 ***
Exogeneity_Wald_Stat		65.56		72.02

standard errors are in parantheses
* p<0.05, ** p<0.01, *** p<0.001

Data pertains to recommendations made by IAC centers from 1981-2006. Dependent variable is the implementation status of a recommendation - Adopted equals 1 if recommendation is implemented and equals 0 otherwise. Estimation method is Maximum Likelihood. Standard errors reported are using robust clustered variance covariance matrix. 1 IAC center and its 12 related recommendations were dropped from the full sample due to their having no variation in whether the recommendations were adopted or not. 13,644 recommendations were dropped as they has payback less than or equal to zero and the logarithmic form for payback is not defined. Including these recommendations in a model without logarithmic transformation does not change the inferences we derive from this model. Also 256 recommendations with sic two digit codes less than 20 and more than 39 were not included in the analysis reported here. Including them does not change the inferences obtained from the models.

Table 1.6: Instrumental Variables Probit Estimates of Adoption of Recommendations – Grouped by Total Number of Recommendations (Version: Absolute Serial Position)

Dependent Variable : Adopted (equals 1 if implemented, 0 otherwise)				
	IVProbit (for groups by total number of recommendations)			
	5	7	9	11
ln(Cost)	-0.076 **	-0.062 **	-0.093 **	-0.113 ***
	(0.029)	(0.023)	(0.030)	(0.033)
ln(Cost)^2	-0.003	-0.006 *	-0.006	-0.005
	(0.004)	(0.003)	(0.003)	(0.004)
ln(Saving)	-0.039	-0.087 ***	-0.077 *	-0.064
	(0.030)	(0.026)	(0.034)	(0.038)
ln(Saving)^2	0.007	0.008 *	0.009	0.014
	(0.005)	(0.004)	(0.004)	(0.007)
	-0.45	-0.374	-0.293	-0.236
Serial	-0.043 ***	-0.038 ***	-0.035 ***	-0.041 ***
	(0.016)	(0.038)	(0.004)	(0.026)
	-0.033	-0.019	-0.017	-0.019
Number*Payback	-0.116	-0.093	-0.074	-0.046
	(0.021)	(0.017)	(0.017)	(0.026)
	0.006	-0.001	0.011	0.028
Variance in Payback	-0.01 ***	0 ***	-0.02 ***	-0.025
	0.013	0.058	0.058	0.027
	-0.021	-0.017	-0.024	-0.034
Sales	0	0.001 **	0.004	0.001
	(0.001)	0.000	(0.002)	(0.001)
Employees	0.013	0.058 ***	0.057 *	0.026
	(0.021)	(0.017)	(0.024)	(0.034)
Plant Area	0	0.001 *	0.004	0.001
	(0.001)	0.000	(0.002)	(0.001)
Controls				
Recommendation Type	Yes	Yes	Yes	Yes
IAC Centers	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
SIC	Yes	Yes	Yes	Yes
Observations	7358	12166	9446	5183
Log-PseudoLikelihood	-17307	-32708 ***	-27400	-15831

standard errors are in parentheses (* p<0.05, ** p<0.01, *** p<0.001)

Data pertains to recommendations made by IAC centers from 1981-2006. Dependent variable is the implementation status of a recommendation - Adopted equals 1 if recommendation is implemented and equals 0 otherwise. Estimation method is Maximum Likelihood. Standard errors reported are using robust clustered variance covariance matrix.

Table 1.7: Probit Estimates of Adoption of Recommendations – Grouped by Serial Position of Recommendations

Dependent Variable : Adopted (equals 1 if implemented, 0 otherwise)					
	Probit (for groups by same serial position values)				
	1	**3**	**5**	**7**	**9**
ln(Cost)	-0.166 ***	-0.172 ***	-0.155 ***	-0.141 ***	-0.142 ***
	(0.020)	(0.026)	(0.029)	(0.031)	(0.042)
ln(Cost)^2	-0.012 ***	-0.011 ***	-0.012 ***	-0.012 **	-0.002
	(0.003)	(0.003)	(0.004)	(0.004)	(0.006)
ln(Saving)	0.082 ***	0.106 ***	0.086 **	0.048	0.042
	(0.020)	(0.026)	(0.029)	(0.031)	(0.038)
ln(Saving)^2	0	0.003	0.005	0.001	-0.008
	(0.004)	(0.005)	(0.005)	(0.005)	(0.006)
Number of Recommendations	0.041	0.076	0.125 *	0.08	0.038
	(0.050)	(0.049)	(0.055)	(0.071)	(0.106)
Number*Payback	-0.014	-0.017	-0.042 *	-0.051 *	0.008
	(0.018)	(0.019)	(0.020)	(0.021)	(0.025)
Variance in Payback	-0.09 ***	-0.071 ***	-0.069 **	-0.036	-0.116 **
	(0.019)	(0.020)	(0.022)	(0.024)	(0.038)
Sales	0.001	0.001	-0.008	-0.005	-0.006
	(0.001)	(0.002)	(0.005)	(0.004)	(0.006)
Employees	0.013	-0.009	0.003	0.003	0.002
	(0.015)	(0.015)	(0.015)	(0.018)	(0.029)
Plant Area	0	0	0	-0.001	-0.003
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Controls					
Recommendation Type	Yes	Yes	Yes	Yes	Yes
IAC Centers	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
SIC	Yes	Yes	Yes	Yes	Yes
Observations	10769	10745	9331	6162	2994
Log-PseudoLikelihood	-6678 ***	-6959.5 ***	-6089.7 ***	-4012.7 ***	-1901.7

standard errors are in parentheses (* p<0.05, ** p<0.01, *** p<0.001)

Data pertains to recommendations made by IAC centers from 1981-2006. Dependent variable is the implementation status of a recommendation - Adopted equals 1 if recommendation is implemented and equals 0 otherwise. Estimation method is Maximum Likelihood. Standard errors reported are using robust clustered variance covariance matrix.

CHAPTER 2

An Empirical Investigation of the Depth of Adoption of the LEED Green Building Standards

2.1 Introduction

This paper investigates questions related to the depth of adoption of the voluntary LEED standards for green buildings. In the LEED standards, buildings are awarded points based on whether they incorporate various green building practices. Depth of adoption refers to the extent to which firms incorporate the practices defined by the LEED standards.

Voluntary standards related to organizational practices are appearing in many areas including trade, environment, and social governance (Kirton and Trebilock 2004). Voluntary standards play a significant role in addressing environmental issues. This is reflected not only in the increased number of voluntary environmental standards such as ISO 14000, the Forest Stewardship Council (FSC) series, and Responsible Care, but also in the increased adoption of these standards. For instance, over 150,000 facilities were ISO 14000 certified by December 2007 (ISO 2007) and over 100 million hectares of forests were FSC certified by March 2008 (FSC 2008). The increased number of adopters highlights the potential environmental impact of these voluntary standards. However, as Westphal et al. (1997) point out, to assess the effectiveness of any innovation it is essential to measure not only the breadth of adoption (number of adopters) but also the depth of adoption (the extent to which the practices have been incorporated by adopting firms). Breadth of adoption is often relatively easy to measure; depth of adoption by contrast, is usually not easily observable.

The majority of voluntary standards have a binary variable which indicates whether the organization has adopted the standard or not, where adoption can be self-reported or certified by a third party. The binary nature of most adoption information makes it difficult to empirically investigate issues related to the depth of adoption. In the highly successful LEED standards for green buildings, adoption is not a binary variable, but has multiple levels of certification (certified, silver, gold, or platinum), which in turn depend on the number of LEED elements a building adopts (resulting in a score between 26 and 69 points). This structure, including both certification levels and individual elements, allows us to formulate and test hypotheses related to the depth of adoption of the standard.

This paper investigates four elements related to the depth of adoption of voluntary standards. First, we investigate whether defining discrete categories (in this case: certified, silver, gold, platinum) influences adoption behavior. Second, we investigate whether the depth of adoption increases over time as the standard becomes more accepted or as the cost of adoption decreases. Third, we assess whether depth of adoption is influenced by the type of organization adopting the standard. Fourth, we examine whether the greater complexity associated with deeper adoption leads to increased project completion time.

This paper aims to make several contributions. First, this is one of the first scholarly studies that examine the adoption of the LEED standards. The LEED standards are an interesting addition to the growing collection of voluntary standards, but they are particularly relevant due to the immense scale of the underlying industry: the real estate sector. In the US, the construction and contracting industries accounted for approximately $1.78 trillion in sales in 2007[1], which is over 12% of GDP in 2007. Additionally, with the LEED standards expanding from new construction and renovation to existing buildings, the economic scope of the standards has increased even further. Second, this is one of the first scholarly studies to empirically examine hypotheses specifically related to the depth of adoption. Thus, we contribute to the literature on diffusion of innovations in general and to that on diffusion of voluntary standards. Third, many for-profit, nonprofit and governmental organizations design standards: for example, purchasing managers often design and implement vendor rating systems, just as industry associations and policy makers design voluntary standards and eco-labels. Hence, our study on factors that influence depth of adoption of a standard has broader implications for other contexts which involve the design and implementation of performance standards.

The rest of the paper is organized as follows. In Section 2.2, we provide an overview of green buildings and the LEED standard. In Section 2.3, we review the relevant literature. In Section 2.4, we present our hypotheses. In Section 2.5, we describe the data. In Section 2.6, we present our methodology and results. In Section

[1] Data from US Census Bureau; the value of business done in 2007 in construction of buildings (NAICS code 236) was $701 billion, heavy and civil engineering construction was $287 billion and that by specialty trade contractors (NAICS code 238) was $792 billion. Information available at http://factfinder.census.gov/servlet/FindEconDatasetsServlet?ds_name=EC0700A1&_ts=256230258304, last accessed March 27, 2009.

2.7, we discuss the results, the implications of our findings, and the limitations of our analysis.

2.2 Green Buildings and LEED

Buildings have a significant impact on the environment. In the United States, buildings account for 37% of the primary energy use, 68% of all electricity use, 40% of non-industrial solid waste, 12% of potable water use, 35% of carbon dioxide emissions, and 49% of sulfur dioxide emissions.[2] "Green building" evolved as a means to reduce this negative environmental impact throughout the complete building life cycle. In 1990 the British real estate industry asked the UK government to introduce a rating scheme for green buildings, which became BREEAM, the Building Research Establishment's Environmental Assessment Method (Lockwood 2006). The United States Green Building Council (USGBC) was founded in 1993 as a nonprofit organization that seeks "to transform the way buildings and communities are designed, built and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life."[3] The US Department of Energy and the US Environmental Protection Agency funded the initial effort in 1996 to create a manual to provide information on the design and construction of green buildings. Public Technology Inc. and USGBC worked on this effort to create the Sustainable Building

[2] "The Federal Commitment to Green Building: Experiences and Expectations," p. 9, available at http://www.ofee.gov/sb/fgb_report.pdf, last accessed on March 30, 2009.
[3] See http://www.usgbc.org/DisplayPage.aspx?CategoryID=1, last accessed on March 30, 2009

Technical Manual[4]. The USGBC constituted a broad based committee including architects, realtors, owners, lawyers, environmentalists, and industry representatives to develop the LEED green building rating system, which was launched in 1998 and which facilitates design, construction, and operation of high performance green buildings. Today the LEED rating system is a largely voluntary, consensus based, and market driven rating system. It recognizes performance in six key areas: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process. Projects are awarded points for adopting specific elements in each of these six areas. There are 50 elements that are eligible for points; 41 elements earn one point each while multiple points are awarded based on the extent to which the other 9 points are adopted. For instance, one point is awarded by using certified wood in construction while a project can earn 1 to 3 points by adopting varying degrees of renewable energy. A project can obtain a maximum of 69 points. The LEED rating system for New Commercial Construction and Major Renovations (LEED-NC) was the first such standard in the US and is the most widely adopted amongst the various LEED standards to date. An example of the LEED-NC rating system, showing the full list of elements and the points that LaKretz Hall (the home of the Institute of Environment at UCLA) earned towards LEED-NC silver certification, is provided in figure 2.5. Other standards include LEED for Existing Buildings, LEED for Commercial Interiors, LEED for Core and Shell, LEED for Schools, LEED for Retail, LEED for Healthcare, LEED for Homes, and LEED for Neighborhood Development.

[4] "Sustainable Building Technical Manual," available at https://www.usgbc.org/Docs/SBTM/sbt.pdf, last accessed April 30, 2009.

Under LEED-NC, a project is eligible for certification if it earns at least 26 points and meets certain additional prerequisites. A project will be LEED Certified if it earns 26 to 32 points, LEED Silver if it earns 33 to 38 points, LEED Gold if it earns 39 to 51 points, and LEED Platinum if it earns 52 to 69 points. The authors are not aware of any reason behind these specific cutoffs.

Interest in green building and LEED has grown rapidly, as reflected in the increase in USGBC membership from 1,137 in 2001 to over 18,000 in 2009.[5] The attendance at the annual Greenbuild Expo conference has risen to over 28,000 attendees in 2008.[6] The number of buildings that have achieved LEED-NC certification increased from one in 2000 to 721 certified projects as of May 24, 2008. As of April 2009, there were 81,155 LEED Accredited Professionals and 19,524 buildings had registered their intent to seek LEED certification .[7]

Organizations interested in obtaining LEED certification must first register their projects online at the USGBC website (www.usgbc.org). This is typically done at the design stage of the construction project. The next step is to collect information and perform calculations to satisfy the prerequisites and submit the relevant documentation for review by USGBC. The submission of the documents is typically done after a substantial portion of the construction is completed. The documentation for each point

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[5] See "Building Design & Constructions - White Paper on Sustainability: A Report on the Green Building Movement," p. 7, available at http://www.usgbc.org/Docs/Resources/BDCWhitePaperR2.pdf, and http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1942, last accessed March 30, 2009.

[6] See http://www.greenbuildexpo.org/About/, last accessed March 30, 2009.

[7] See "Green Building Facts" p. 2, available at http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1718, last accessed on April 13,2009

is evaluated by an independent USGBC reviewer; the review is supplemented with discussions with the project team. Based on the evaluation and discussion the USGBC team awards or denies the point. The total number of points achieved serves as the basis for awarding the LEED certification and information on the certified projects is included on the USGBC website.

To understand the practical context of how organizations make decisions related to LEED certification, we hosted a workshop at UCLA on March 10, 2006, in which we invited 4 panelists and 25 participants from the real estate and green building industries, including architects, designers, consultants, developers, and real estate professionals, from the USGBC and several independent firms, such as Toyota, KB Home, The Olson Company, Swinerton, Turner Construction, Morgan Stanley Real Estate, and Wells Fargo. We also interviewed 12 professionals associated with LEED projects in April and May of 2008. An underlying theme that emerged, both in the workshop and the individual interviews, was that organizations were influenced by the various certification levels, though in widely varying degrees. Two quotes illustrate the influence of the certification levels. One participant stated:

> "Organizations tend to target the LEED certification level ... If you need bragging rights (among the people who value the environment) you need to target levels above silver,"

which indicates that some organizations may let the structure of the standard influence their building design, particularly if their primary aim is to publicly demonstrate their commitment to environmental stewardship. Another participant stated:

> "...(Organizations) are adopting good building practices. Using daylight, reducing water usage, etc., leads to better buildings – and by just adopting such practices they get LEED certification as the buildings meet the requirements for the LEED standards,"

which suggests that other organizations may primarily aim to build better buildings and may view the associated LEED certification level as a byproduct rather than an objective in itself. Most of the industry professionals we spoke to agreed that both of these approaches are common.

The workshop and the interviews enabled us to get a basic understanding of possible underlying drivers for the adoption of the LEED standards. With this background, we now review the literature and develop our hypotheses.

2.3 Literature Review

Our work draws primarily on the literature on adoption of innovations in general and on the adoption of voluntary standards in particular. We provide a broad overview of the relevant literature in this section, and defer a more detailed discussion of the literature pertaining to our specific hypotheses to the next section.

Various perspectives have been brought to bear on the factors that influence the diffusion of innovations. A body of literature highlights that adoption of innovations is influenced by economic, technological and organizational factors (Mansfield 1961). Another body of literature emphasizes the role of institutional pressures and network ties in the adoption of innovations (DiMaggio and Powell 1983, Guler et al. 2002, Westphal et al. 1997). Rogers (2003) provides an extensive overview of the literature on the adoption of innovations.

Gatignon and Robertson (1985) highlight that much of the literature focuses on examining breadth of adoption and that depth of adoption is relatively understudied. More recently, Åstebro (2004) points out (p. 382) that "depth of adoption is a relatively new construct [...]" in his study of the adoption of CAD and CNC technology. Some studies are now starting to explore depth of adoption. One stream focuses on identifying the impact of deeper adoption of practices. For instance, Yeung et al. (2006) find that firms obtain operational benefits from TQM even if their implementation is not deep. Similarly, Jin and Leslie (2003) study depth of adoption using the voluntary and mandatory restaurant hygiene grading cards in Los Angeles county; they find that the cards do improve hygiene, and that many restaurants earn precisely the minimum number of points needed to qualify for the letter grade received. Another stream focuses on identifying the factors that influence the depth of adoption. For instance, Åstebro (2004) finds that depth of adoption of CAD and CNC technology depends more on plant-level factors than does the overall decision whether to adopt. Jensen and Szulanski (2007) examine the transfer of best practices from one unit of an organization to recipient units in other countries, and find that using templates enhances the extent of adoption in the recipient units. We contribute to this literature by showing that depth of adoption can be influenced by the design of the standard, and by examining links between depth of adoption and the age of the standard, the type of organization adopting the standard, and the project completion time.

The literature on voluntary standards has examined factors that influence the adoption of these standards and identified many benefits of adopting these standards. King and Toffel (2007) provide a thoughtful overview of the various strands of management literature related to voluntary environmental standards. Anderson et al. (1999), Guler et al. (2002), Albuquerque et al. (2007) and many others examine the forces which explain the diffusion of ISO 9000 and ISO 14000 quality and environmental management systems standards. Videras and Alberini (2000) examine factors that influence participation in three voluntary environmental programs – 33/50, Green Lights and WasteWi$e. They find that publicity associated with joining the program, organization size, technology transfer potential, and poor environmental performance are factors that influence voluntary participation. Corbett et al. (2005) find that firms gain significant improvements in financial performance after obtaining ISO 9000 certification. Terlaak and King (2006) find that ISO 9000 certification may reduce information asymmetries in supply chains and generate competitive advantage for certified firms. Issues related to the depth of adoption of voluntary standards are relatively unexplored. One exception is Naveh and Marcus (2005), who investigate depth of implementation of ISO 9000 and find that firms that integrated it deeper into their daily practice obtained greater benefit from the standard. In this study we explore four issues related the depth of adoption of the voluntary LEED standard for green building practices.

Many studies in the trade literature have documented the benefits that can accrue by adopting green building practices. For instance, Fowler and Rauch (2008) investigate the post-occupancy performance of 14 U.S. General Services Administration buildings that were sustainably designed (8 buildings are LEED certified, 2 are registered for certification and one has an equivalent LEED score). They find that the sustainably designed buildings cost less to operate, have better energy performance and have more satisfied occupants compared to industry baselines for building performance. Miller et al. (2008) compare LEED certified and Energy Star rated buildings with those buildings which are neither LEED certified nor Energy Star rated. They find that LEED certified and Energy Star rated buildings command higher rental prices, sales prices, and occupancy levels and conclude that it pays to adopt green building practices. Kats (2003) finds that the direct (energy, emissions, and water-related) and indirect (productivity and health-related) benefits of LEED certification outweigh the additional costs of green building. Other studies also find that the additional costs are lower than is often thought: Turner Construction (2005) found average cost premiums of 0.8% for LEED certified, 3.1% for silver, 4.5% for gold, and 11.5% for platinum buildings, while Matthiessen and Morris (2004, 2007) found no significant cost differential between comparable-quality LEED and non-LEED buildings. The emerging consensus in the trade literature is that many green building practices are beneficial.

2.4 Hypotheses

Our hypotheses are grounded in the literature on adoption of innovations and on the adoption of voluntary standards, the literature which examines depth of adoption, the inputs from the workshop conducted at UCLA, and our interviews of professionals associated with LEED projects. We develop four hypotheses related to the depth of adoption of the LEED standards.

Our first hypothesis relates to the effect of the various LEED certification levels on adoption behavior. We first discuss several documented reasons why organizations might decide to seek LEED certification at all; then we argue that, for many of those reasons, the level of certification earned also matters to the organization beyond the mere fact of getting certified at all. First, organizations are able to convey some information about their practices to external stakeholders by adopting voluntary initiatives. Khanna (2001) points out that besides the quest for cost efficiency, the literature identifies three broad motivations that drive organizations to adopt voluntary initiatives to address environmental issues. The first motivation is that firms may adopt voluntary standards to preempt regulatory threats. For instance, the Responsible Care Program of the U.S. Chemical Manufacturer's Association was set up with the purpose to protect member firms from adverse government regulation (King and Lenox 2000). The second motivation is that firms may adopt voluntary standards as a means to gain financial rebates or technical assistance. For instance, firms participating in the Green Lights program of the U.S. Environmental Protection Agency were provided technical information, information on sources of financing, information provided by other participants, and publicity materials (Videras and Alberini 2000). The third motivation is that firms may adopt such initiatives as a response to pressures from various stakeholder groups, including investors, consumers, and the public. Investor pressure is implicit in the finding by Konar and Cohen (1997 and 2001) and Khanna et al. (1998)

that firms which suffered the largest abnormal returns when the Toxic Release Inventory (TRI) information was first made public subsequently improved their environmental performance as measured by TRI releases. Appealing to green consumers is cited as a reason for firms to join voluntary programs such as WasteWi$e, Green Lights, and 33/50 (Videras and Alberini 2000). Demonstrating environmental stewardship to the public is cited as a reason for firms to adopt standards by Delmas (2002). In the three motivations illustrated above, an underlying mechanism is that firms are able to provide information about their practices to various stakeholders by adopting voluntary initiatives.

Next, we argue that in the case of LEED, organizations are able to convey additional information about their practices beyond the fact that they just adopted the standard. In most voluntary standards the adoption variable is binary, consequently external entities are only able to see whether a firm has adopted a standard or not. However, as the LEED standard distinguishes multiple levels based on a point system, external entities can not only see the adoption of the standard but can also get information on the depth of adoption by the organization. In the context of the LEED standards, depth of adoption could be measured by the certification level achieved or by the actual number of points earned; most public communications refer to the level of certification achieved rather than the number of points earned. For instance, the list of LEED certified projects on the USGBC website[8] shows the level of certification earned; only upon viewing the details for a specific project does one see the total number of

[8] See http://www.usgbc.org/LEED/Project/CertifiedProjectList.aspx?CategoryID=19&CMSPageID=244, last accessed on March 30, 2009.

LEED points achieved and the specific elements adopted. Similarly, company press releases and the plaques that adorn certified buildings often only mention the level of LEED certification achieved; see for instance Toyota's company website[9] or the Goldman Sachs 2007 Environmental Report.[10] Thus organizations are able to communicate additional information about their practices through the certification level achieved, beyond the traditional binary adoption variable.

Therefore, the reasons cited earlier why firms might adopt LEED will also cause them to be concerned about which specific level of certification they achieve, so if they are close to the cut-off number of points required for certification at the next higher level, they may wish to adopt additional points to achieve that higher certification level. This is similar to McCardle et al. (2009) who observe, in the context of charitable donations, that individuals are nudged to increase their donations to move up to the next tier when they participate in a tiered donation scheme. Consequently, we predict there will be more organizations that adopt just enough points to reach each certification level than would be expected in the absence of the certification levels.

Hypothesis 1: *Firms perceive value in the levels of certification of the LEED standard. Consequently, we will observe more buildings adopting the minimum number of points required for each certification level than we would expect to observe in the absence of discrete certification levels.*

[9] See the Toyota North America Environmental Report 2006, http://www.toyota.com/about/our_commitment/environment/awards/ , last accessed on March 30, 2009.
[10] See the Goldman Sachs 2007 Evironmental Report, http://www2.goldmansachs.com/services/advising/environmental-markets/documents-links/Environmental-Report-2007.pdf , last accessed on March 30, 2009.

Our second hypothesis relates to how the depth of adoption of the LEED standard evolves over time. Three mechanisms are relevant to our context, each of which reduces the cost and/or increases the benefits associated with deeper adoption as more other organizations have already adopted the standard. First, the costs of adopting practices related to the standard may fall over time which would increase breadth and depth of adoption. For instance, as more individuals become LEED accredited, they can charge less of a premium for their services. Delmas (2002) indicates that the development of a market of consulting firms reduced the costs for a firm to adopt ISO 14001. Terlaak (2007) highlights that voluntary standards typically codify and compile best practices in their respective management areas. She argues that this reduces the search costs and uncertainty in identifying best practices and consequently facilitates deeper adoption of practices over time. Second, as professionalization related to the LEED standard increases over time, it may facilitate deeper adoption of the standard. For instance, DiMaggio and Powell (1983) point out that information exchange among professionals leads to a hierarchy of status for organizational practices, with some firms recognized as having practices with higher status. Such firms are often recognized and given substantive roles in professional and trade associations. This further increases the visibility of the practices of these firms and provides incentives for other firms to adopt them. In the context of the LEED standard, increased professionalization can be attributed to the increased education related to green building, the increased number of LEED APs (accredited professionals), the rising attendance at the annual Greenbuild

Expo, and the increased membership of USGBC over the years. Over time increased interactions among these professionals provides legitimacy to the LEED standard. The legitimacy coupled with the structure of the standard endow higher status to higher certification levels. This is also reinforced by the case studies highlighted by the USGBC, the majority of which have Gold or Platinum certification. Consequently in line with the arguments above, organizations adopting LEED standard in later years will strive to achieve higher certification levels and hence undertake a deeper adoption of the standard. Third, the value of adopting a standard for an organization may increase with the number of other organizations that have already adopted the standard. There are many sources of positive externalities for organizations in a network (Katz and Shapiro 1985). Organizations may benefit from the improved information availability on the practices pertaining to the standard, the network of vendors and contractors who could help them to adopt the standard, or the purely psychological and bandwagon effects associated with conforming to the standard. Additionally, organizations may infer the quality or benefits of the practices related to a standard from the number of other organizations that have already adopted these practices. These positive network externalities may facilitate deeper adoption of the standard. For instance, Westphal et al. (1997) examine adoption of TQM practices in hospitals, and find that in a network where a large number of members have adopted TQM the late adopters display a greater level of conformity (i.e., deeper adoption) to the normative pattern as defined by the regulatory body (the Joint Commission on Accreditation of Health Care Organizations) which reviews the quality of care provided by the hospitals.

In the context of the LEED standard, all three mechanisms mentioned above appear relevant. For instance, over time there is an increased body of architects and consultants who are LEED APs and who can assist organizations to obtain LEED certification, a greater degree of professionalization related to the standard as reflected in the increased membership of the USGBC, and a growing network of organizations that have adopted the standard as reflected in the increasing number of buildings registered for LEED certification. Even though we cannot distinguish among the three mechanisms, all three would lead to deeper adoption over time of practices related to the LEED standard.

Hypothesis 2: *Over time, as the LEED standard becomes more established, newly adopting organizations will achieve a deeper adoption of the standard.*

Our third hypothesis relates to the adoption behavior of different types of organizations. Nonprofit organizations are often thought of as being strapped for cash, but of the 721 LEED certified buildings in our database no less than 140 belong to nonprofit organizations, such as "The Hewlett Foundation Headquarters", "The Russell Family Foundation", and "William J. Clinton Presidential Center and Park". In fact, within the subset of organizations that are sufficiently well informed and well endowed to be able to consider LEED certification at all, there are several reasons why nonprofit organizations, on average, will achieve deeper adoption. First, many nonprofit organizations are financed by donors who may not be able to easily observe effectiveness of the services they finance, so there are significant asymmetries of information between the philanthropist and the nonprofit organization (Hansmann 1980). Under extreme circumstances the nonprofit organizations may take funds from donors but neglect to provide promised services to the intended recipients. Donors will consequently seek organizations which they believe are trustworthy (Schlesinger 1998). Thus, nonprofit organizations have particularly strong incentives to adopt practices that enhance their reputation and build their trustworthiness, which may motivate them to adopt more LEED elements than other types of organizations. For example, as one of our interviewees stated:

> "...is a nonprofit organization associated with the health industry. They saw LEED as a natural outgrowth of their image and they adopted the LEED standard in line with their efforts to maintain their image and reputation."

Second, nonprofit organizations are prohibited from distributing profits (Hansmann 1980). This implies that employees of nonprofit organizations cannot be compensated by profit sharing. As nonprofit organizations are restricted in the extent to which they can offer pecuniary benefits to their employees, they may place greater emphasis on non-pecuniary rewards as compared to other organizations (Weisbord 1988). Plausible non-pecuniary rewards could include a better physical working environment and higher prestige associated with the organization, both of which can potentially be achieved by adopting more LEED points. Third, nonprofit organizations enjoy many regulatory advantages, such as tax exemptions, capacity to issue tax-exempt bonds, or favored treatment under the unemployment insurance laws (West 1989, Schlesinger et al. 1996).

In return for these advantages and to pre-empt questions about the nonprofit status of an organization, regulators may encourage or require deeper adoption of practices not motivated by profit (Potter and Longest 1994). This may also prompt nonprofit organizations to adopt more LEED points beyond those which actually save money in response to the expectations of regulators. Finally, the social mission of nonprofit organizations may cause them to attach greater value to the social and environmental benefits of sustainable practices, which could lead them to adopt more LEED points than a for-profit organization would. These four broad reasons lead to our third hypothesis:

Hypothesis 3: *Among all the organizations that adopt the LEED standard, nonprofit organizations will achieve more points than other types of organizations (e.g. government and for-profit firms).*

Our fourth hypothesis relates to the impact of depth of adoption on the lead time for project completion, in which we include not only the actual construction time but also the time spent on planning, design, obtaining permits, etc. The project management literature suggests that increases in project scope or complexity may increase project lead time. Clark (1989) finds that increase in project scope results in increased lead time in product development in the automotive industry. Baccarini (1996) in a review of literature on the construction industry highlights that increased project complexity is associated with greater time and costs. In our context, deeper adoption of the standard implies adoption of more elements. This usually increases the cost of the project as well as its complexity due to the increased need for co-ordination. For instance, Matthiessen and Morris (2004) point out that increased coordination with contractors and vendors is required to achieve LEED points such as those related to construction waste management, usage of local materials, and indoor air quality. Several studies in the LEED trade literature confirm that higher levels of certification entail higher costs. This leads to our fourth hypothesis.

Hypothesis 4: *Projects that achieve a deeper adoption of the LEED standard will take more time to complete.*

2.5 Data

The data for this study involves two components which we extracted from the USGBC website. The first includes data on the adoption of all 69 specific elements for all 721 buildings that, by May 24, 2008, had been certified to the LEED-NC 2.0, 2.1 or 2.2 standards and for which information is available in the certified projects section of the USGBC website. These standards for new construction are the most widely used of the LEED standards. Of these 721 projects, 681 were located in the USA, 22 in Canada, 4 in China, 7 in India, 2 in the UAE, and 1 each in Mexico, Spain, Bulgaria and Puerto Rico. 276 projects had attained the LEED Certified level, 226 projects had attained Silver, 181 had attained Gold and 38 had attained Platinum. The second includes data on specific project characteristics such as square footage, registration date, certification date, address, project owner, and ownership type. This information is available in the registered projects section of the USGBC website. Data on the second component was available for 687 of the 721 buildings. Ownership types and the level of certification of the buildings are shown in Table 2.1. Of these buildings the USGBC classified 225 as for-profit corporations, 140 as nonprofit corporations, 43 as federal government, 79 as state government, 132 as local government, 11 as individual owners, and 54 as others. Data on ownership type was missing for 37 buildings.

Descriptive statistics for our data are shown in Table 2.2. The mean number of points earned was 34.61 with a standard deviation of 7.27. Of the 721 projects in our study, 86 projects earned precisely 26 points, the lowest possible number, while 1 project earned 61 points, the highest number of LEED points earned by any project. The average square footage for the buildings is 105,912 square feet with a standard deviation of 168,792. The largest project has a gross square footage of over 1.7 million square feet. The average time from when a project is registered with the USGBC to the time when it receives LEED certification is 968 days with a standard deviation of 424 days. The longest time taken by a project from registration to certification is over 6 years while the shortest time from registration to certification is 51 days. Table 2.3 provides all 23 pairs, out of a total of 2346 pairs, of LEED points with correlation greater than 0.4. (Our methods are anyway not sensitive to correlation between elements.) Table 2.4 shows the average number of points earned by year.

2.6 Methodology and Results

In this section we discuss the methodology used to test our hypotheses and the results we obtained. All the analyses were done using STATA version 10.1.

We test our first hypothesis related to adoption behavior at the certification levels by examining overall adoption patterns, by testing for spikes at the various certification levels, and by analyzing adoption behavior of select LEED elements. First, we visually examine the overall adoption pattern by plotting the histogram of LEED points earned, shown in Figure 2.1. We define "spikes" more formally below but visual inspection strongly suggests spikes in adoption rates precisely at 26, 33, 39, and 52 points, which are the cutoff number of points required for certified, silver, gold, and platinum certification respectively. In fact, 235 of the 721 projects in our study have adopted the exact number of LEED points required for one of the certification levels. The probability of these visual spikes occurring precisely at these four cutoff points if the location of spikes were random and uniformly distributed is 0.000007 (from $1/\binom{44}{4}$).

Although we find the graph compelling in itself, we provide an additional perspective on Hypothesis 1. We are not aware of statistical tests designed specifically for our purpose, so the method below should be seen as a heuristic, despite its statistical nature. We examine whether there are any spikes in the histogram and whether any spikes found correspond to the cutoff number of points required for the various certification levels using an approach similar to Karlöf et al. (2000), who seek to test whether spikes in electrical and radioactive measurements in ice core data correspond to known historical volcanic events. Following their approach, we first de-trend the data by removing the best fitting straight line, reflecting that one might expect the number of buildings earning precisely n points to be decreasing in n. (Of course, our data have no time trend unlike Karlöf et al. (2000); repeating our analysis without de-trending the data gives the same result. One could imagine many other approaches to de-trending, each largely arbitrary.) Then we define spikes as points at which the amplitude of the de-trended data exceeds a threshold value of two standard deviations as in Karlöf et al. (2000). The plot corresponding to this analysis is shown in Figure 2.2. The results indicate the presence of three spikes at 26, 33, and 39 points, which are precisely the cutoffs for certified, silver, and gold certification respectively. The probability of precisely identifying any three of the four cutoff levels if the location of the spikes were random is 0.0003 (from $1/(4*\binom{44}{3})$).

For a different perspective consider an organization that, at the end of the project, falls just one or two points short of the next level of LEED certification. For example, when the "Chicago Marine Safety Station" building was assessed it earned 32 points, 1 point below the 33 needed for silver certification. If such organizations care about the certification levels, they will in these circumstances seek to add a point or two at the last minute to move to the higher certification level. The easiest LEED elements to adopt at the end of a project are those related to "Alternative Transportation" (which can be earned by, among other, installing bicycle racks) and "Landscape & Exterior Design to Reduce Heat Islands, Non-roof" (which can be earned by changing the color of concrete pavements). Thus, among the organizations that fall just short of the certification levels, those which have not adopted these points could still adopt them and move to the next level of certification (e.g., the "Arrowhead Bottling Plant" adopted both these points and achieved exactly the 33 points required for silver certification), while those that had already adopted these points may not be able to move easily to the next certification level (e.g., the "Chicago Marine Safety Station" building adopted both these elements but earned only 32 points). Consequently, if organizations care about certification levels, we would expect more buildings that are one point short of a cutoff level to have adopted the "Alternative Transportation" and the "Landscape & Exterior Design to Reduce Heat Islands, Non-roof" points. Note that this effect should be most visible just below the cutoffs, not necessarily at the cutoffs themselves: a building that plans for and earns precisely 33 points need not have a higher proportion of these easy last-minute elements. We plot the percentage of projects that adopt these LEED elements against the total points earned, as shown in Figure 2.3 and Figure 2.4. In Figure 2.3, we observe that 100% of the organizations that just failed to achieve silver or gold did earn the "Alternative Transportation" point, while only 70 – 90 % of buildings that earned a different number of points did so. Similarly in Figure 2.4, we observe that over 80% of the buildings that just failed to achieve silver or gold did adopt the "Landscape & Exterior Design to Reduce Heat Islands, Non-roof" point, while substantially less buildings that earned a different number of points did so. Altogether, even though none of these three perspectives (the visual inspection of the histogram, the statistical analysis of the de-trended histogram, and the more anecdotal analysis of adoption of easy "last minute" elements) is an unambiguous test by itself, we believe that taken together they provide strong support for our hypothesis that cutoff levels do influence the depth of adoption.

To test our second hypothesis, which predicts increased adoption of LEED points over time, and our third hypothesis, which predicts that nonprofit organizations will engage in deeper adoption as compared to other organization types, we estimate the following model:

$$P_i = \alpha + \mathbf{O}_i * \beta + G_i * \gamma + R_i * \delta + \varepsilon_i \quad (2.1)$$

where P_i is the number of points adopted by project i, O_i is the vector representing the type of organization implementing project i, G_i is the gross square footage for project i, R_i is the year in which project i was certified, and ε_i represents the error term.

As the dependent variable is a discrete count variable we estimate two count regression models, the Poisson regression model and the negative binomial regression model. In the former, the dependent variable has a Poisson distribution which is parameterized in terms of a single scalar parameter, the intensity or rate parameter which makes it restrictive (Cameron and Trivedi 2007). There are two ways in which this restriction manifests itself. First, in many applications the model predicts considerably less zeroes than observed in the data, this is known as the excess zeroes problem. Second, in many applications the variance in the count data exceeds the mean, this is called overdispersion. The issue related to overdispersion is addressed in the negative binomial regression model which is generated by assuming that the Poisson intensity or rate parameter itself is gamma distributed (Cameron et al. 1988). The estimation results of these analyses are provided in Table 5. We use the Bayesian information criterion (BIC) to ascertain which model has a better fit with our data. The BIC for the Poisson regression was 6460.08 while that for the negative binomial model was 4528.71. As the BIC for the negative binomial model is lower we consider this model to have a better fit with our data (Cameron and Trivedi 2007).

With respect to Hypothesis 2 that the number of points earned will increase over time, Table 2.4 already shows that the mean increased from 33 points in 2000 to over 36 points in 2008, not controlling for building size and other factors. Including these factors in the count regression models in Table 2.5, we observe that the coefficients of the "Year of Certification" variable are positive and significant at the $p<0.01$ level across both models. For the negative binomial model, an otherwise comparable project completed just one year later achieves on average 0.60 more points. These results indicate that depth of adoption increases over time providing support for Hypothesis 2. Turning to Hypothesis 3, the coefficients of the "Nonprofit Organization" dummy variable are positive and significant at the $p<0.01$ level across both models. Further, for the negative binomial model, a nonprofit organization building the same project will, on average, earn 2.21 more LEED points than a for-profit organization would. This provides support for Hypothesis 3.

Our fourth hypothesis relates to project completion time. We do not observe the exact project duration, however we observe when the projects are registered with the USGBC, which serves as our proxy for the start time, and we observe when the projects are awarded the LEED certification which serves as our proxy for the project finish time. Date of certification is a good proxy for completion time, as a building must be complete and ready for use before the LEED audit takes place; organizations have no incentive to delay the certification audit once the building is complete. The connection between the date of registration and the project start date is looser though still reasonable as "project completion time" does include planning, design, permitting etc. Moreover, the proxies are adequate for our purposes as long as the measurement error is not correlated with the number of points earned. Our proxy is invalid only if projects that earn more points systematically register earlier (or later) in the process than other projects. We have no evidence to suggest that this is the case. The USGBC states that the time required for review for certification does not depend on the level of certification, and our interviews with industry professionals confirm this. Moreover, we confirmed in our interviews with industry experts that the time from registration to certification is a reasonable proxy for project completion time.

This hypothesis links project completion time and the depth of adoption. There is a possibility that these variables are jointly determined. For instance, on the one hand project completion time can depend on the number of points adopted, but on the other hand bigger projects may adopt more points and also take longer to complete. Consequently, the natural way to test this hypothesis would be to estimate a simultaneous equation model where one equation has project completion time as the dependent variable and depth of adoption as one of the independent variables, while the other equation has depth of adoption as the dependent variable and project completion time as one of the independent variables. We estimated various versions of simultaneous equation models, however in all cases the overall fit was poor. Further, we observed that project completion time was not significant in explaining the depth of adoption in any of the models we estimated, though depth of adoption was significant in explaining project completion times in all the models. We also used an instrumental variables estimation of the econometric model (2.2), shown below, where we instrumented the number of points adopted with the level of certification. The Wooldridge's (1995) robust score test for the endogeneity of the number of points adopted clearly indicated that this variable is not endogenous (robust score chi-square(1) = 0.87, p=0.35). Thus, we infer that the endogeneity of the number of points adopted is not a concern in our econometric model (2.2). Consequently we concluded that project completion times and the depth of adoption are not jointly determined and hence we test this hypothesis by estimating the following econometric model:

$$T_i = \alpha + P_i{*}\ \varphi + \mathbf{O}_i{*}\beta + G_i{*}\gamma + \mathbf{R}_i{*}\ \delta + \varepsilon_i \qquad (2.2)$$

where T_i is the time from registration to completion in days for project i, P_i is the number of points adopted by project i, O_i is the vector of organization type implementing project i, G_i is gross square footage for project i, $\mathbf{R}_i$ is the vector of the year in which project i was certified, and ε_i represents the error terms. Since time is a continuous variable, we use ordinary least squares (OLS) estimation. We estimate four versions of this model, by using the natural and logarithmic transformations of the variables T_i and P_i. The results of these estimations are provided in Table 2.6. The overall fit for these OLS models is reasonable and significant at the $p<0.001$ level. In all these models we incorporate several controls for how the proxy for project completion time may vary over time. We control for the organization type, year effects, and the building size. After controlling for these effects we find that the coefficients for "Points Achieved" and "Ln (Points Achieved)" are positive and significant at the $p<0.05$ level when explaining "Points Achieved" and at the 0.01 level when explaining "ln(Points Achieved)". This indicates that an increase in the number of points adopted is associated with an increase in the time from registration of the project to certification, which supports Hypothesis 4. Further, across the models in Table 2.6, a project which achieves 34 points will take between 5.04 days to 5.62 days on average to achieve an additional point; similarly for an average project to move from certified (26 points) to platinum (59 points) would take between 163.1 days to 195.9 days extra. In all four specifications, the year dummies are significant, and generally increasing over time. If organizations are registering their buildings earlier over time, or if the certification process is taking longer over time (despite the USGBC's claims to the contrary), these year dummies would account for that, so we can be fairly confident that the observed effect of points achieved on project completion time is not distorted by a change over time in how our dependent variable is measured. Add to that the high face validity of the association between points achieved and project duration and we believe our findings provide support for Hypothesis 4.

2.7 Discussion, Limitations, and Conclusions

In this section, we discuss our main results, draw implications, and discuss limitations and alternative explanations. Our results support Hypothesis 1 that there is higher adoption at the cutoff number of points required for each certification level. This result builds on the literature which indicates that voluntary approaches could be adopted to address environmental issues – our contribution is to demonstrate that the structure of the standard can have an impact on depth of adoption. This result has the potential to influence adoption of practices related to many voluntary standards. In most voluntary standards, such as Responsible Care, ISO 9000, ISO 14000, Green Lights, etc., adoption is a binary variable. This may result in organizations just adopting enough practices to meet the requirements of the standard, as highlighted by King and Lenox (2000) in the context of the Responsible Care program. By incorporating certification levels it may be possible to encourage organizations to adopt additional practices related to these voluntary standards. This result may also carry over to general business contexts, such as purchasing managers designing vendor rating systems or service managers designing performance rating systems. Even though these standards are usually not voluntary, introducing multiple discrete levels may well have the same effect as we find here. These managers could design the structure of their rating systems to elicit desired behavior from their vendors or employees. In this context, one cannot help but wonder why gold requires 6 points over silver, while silver requires 7 points above certified.

Our results support Hypothesis 2 that depth of adoption of the LEED standard increases over time. The literature has mainly focused on how the breadth of adoption may increase over time. This is one of the earliest studies to our knowledge that demonstrates an increase in depth of adoption over time. This result provides some evidence that the USGBC is meeting its stated objective of facilitating the adoption of green building practices.

A possible limitation of our result is that after some time organizations may not derive significant value in the adoption of additional individual practices related to the standard but may derive benefits mainly from the legitimacy they attain by adopting the standard (DiMaggio and Powell 1983). It is possible that such legitimacy benefits may coalesce around a certification level and hinder deeper adoption of the standard beyond that certification level. For instance, over time the normative pattern of adoption may be to achieve silver certification and this may foil deeper adoption of practices. We may need to revisit our findings after sufficient time has elapsed, to verify how the depth of adoption evolved.

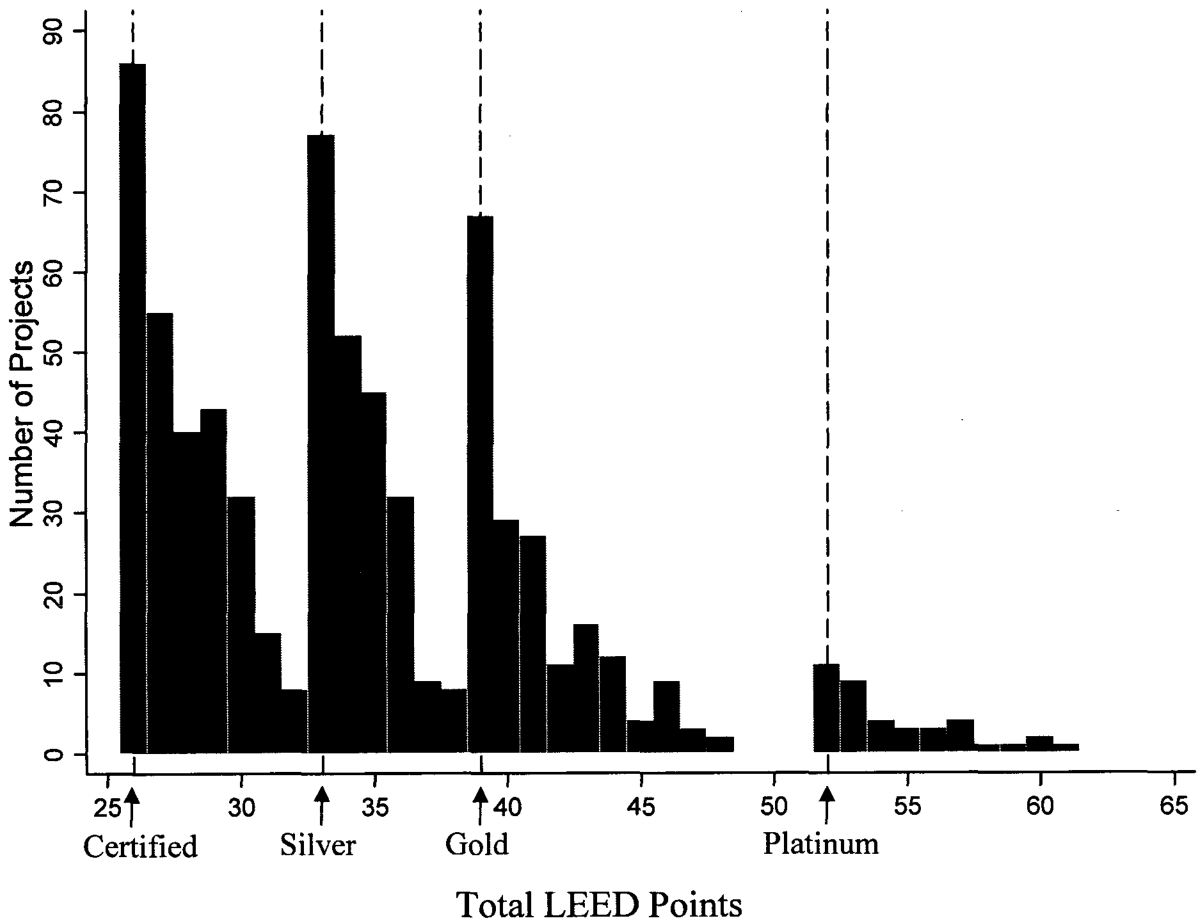
Our results support Hypothesis 3 that nonprofit organizations which seek LEED certification obtain more points than other organization types. It must be noted that this result is only for nonprofit organizations that seek LEED certification, and the result cannot be generalized to all nonprofit organizations. A separate study would be needed to determine how the nonprofits in our sample compare to random samples of nonprofit organizations (and, similarly, how the for-profit firms, government agencies and other organizations that adopted LEED compare to their non-LEED peers). These results have implications for organizations such as USGBC that seek to increase the adoption of a standard: they could target select types of leading-edge nonprofit organizations with an aim to increase overall adoption. This result also dispels the notion that nonprofit organizations are often strapped for cash and hence may not be able to adopt standards or practices that entail additional costs; in the context of standards such as LEED, some nonprofit organizations could be potential lead adopters as they have inherently different motivations that may induce them to adopt the standard.

Our results support Hypothesis 4 that project completion time increases with the increased depth of adoption, presumably due to the corresponding increase in project complexity. Anecdotal evidence often suggests that financial considerations make project completion time a critical factor in the construction industry. The LEED literature tends to find a small (but ambiguous) cost premium for more points, however our results confirm that adoption of more points involves a time premium, providing support to the argument that LEED is not free. Developers and contractors may hesitate to undertake green building practices if they expect a longer project completion time, so policies such as expedited processing of permits for construction may be effective in enabling the spread of green building practices.

An underlying assumption in our analysis is that the USGBC has maintained similar criteria for evaluating projects over the years. For instance, if the USGBC diluted the evaluation criteria over the years, then it is possible that organizations planned to adopt similar number of LEED points across the years but ended earning more points over time. However, since the LEED rating system and evaluation criteria has been developed through a consensus based system and is open to public scrutiny, it is quite unlikely that the evaluation criteria have been diluted over the years, and we have no evidence to suggest that is the case.

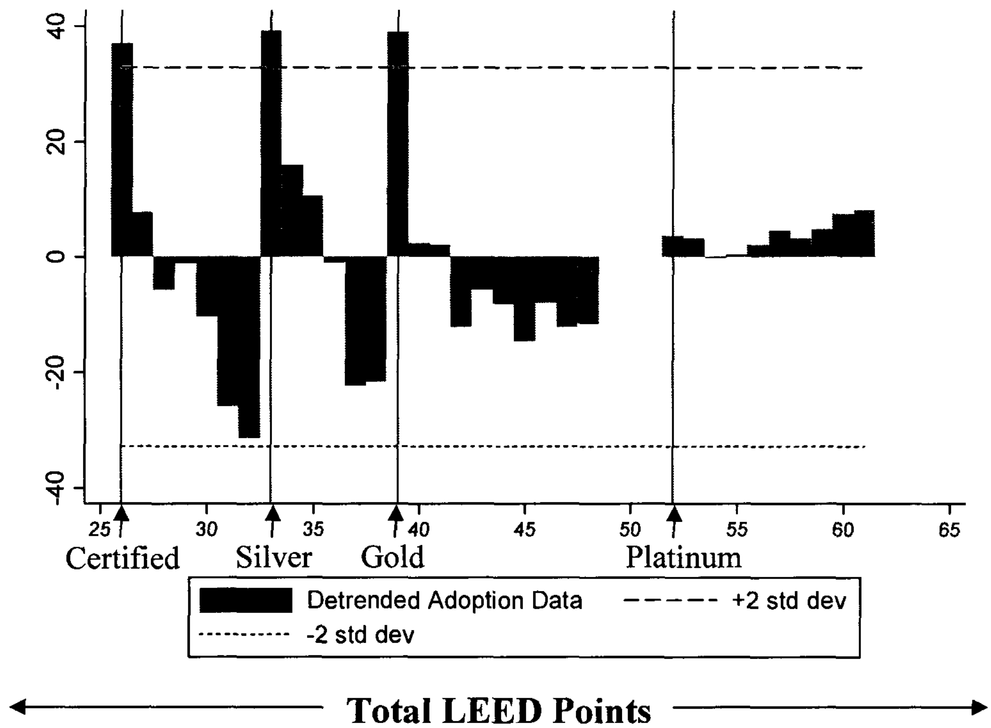
To recapitulate, in this paper we examined issues related to the depth of adoption of the LEED standards for green buildings. We find that depth of adoption is influenced by the structure of the standard, depth of adoption increases as the standard gets more established, and nonprofit organizations undertake a deeper adoption of practices related to the standards as compared to other organization types. We also find evidence that deeper adoption results in longer project completion times. Overall this study contributes by enhancing our understanding of factors that influence the extent to which practices related to a standard are adopted. We expect this understanding to contribute to the design and the development of future similar voluntary standards.

Figure 2.1: Histogram of number of points earned by LEED-NC 2.0, 2.1 or 2.2 certified projects as of May 24, 2008.



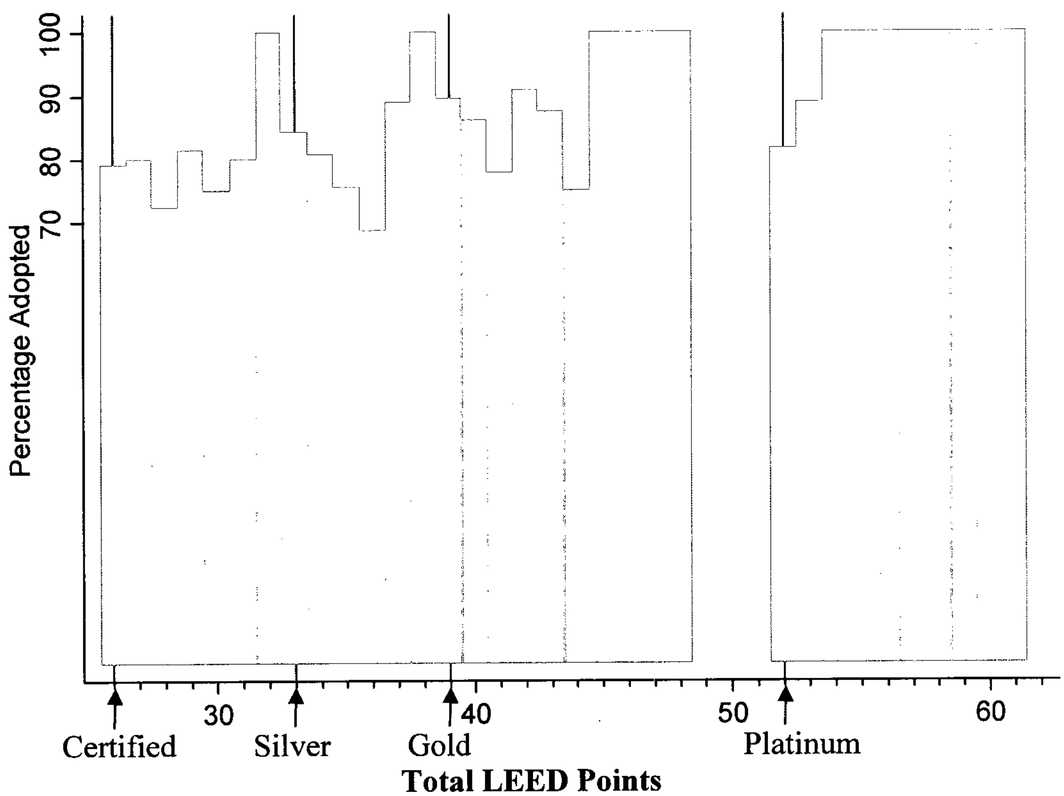
Data pertains to 721 construction projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008.

Figure 2.2: Identification of peaks in the de-trended adoption data based on number of points earned by LEED-NC 2.0, 2.1 or 2.2 certified projects as of May 24, 2008.



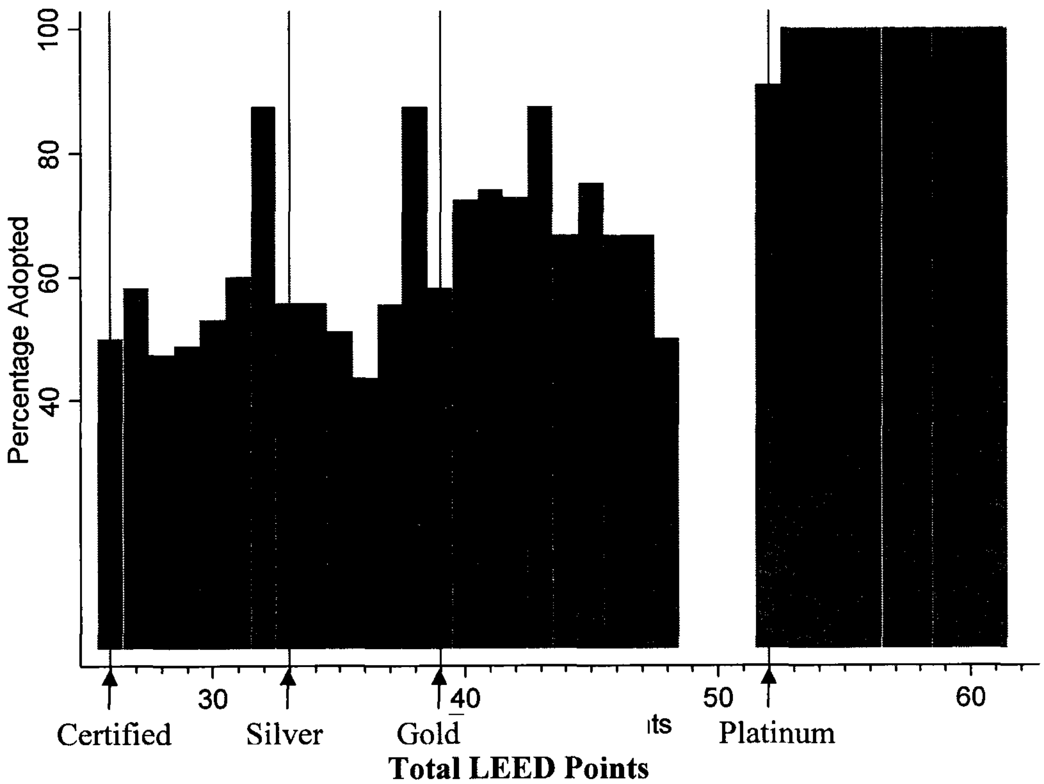
Data pertains to 721 construction projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008.

Figure 2.3: Percentage of Alternative Transportation (Bicycle Storage and Changing Room) Point Adopted Against Total Points Earned



Data pertains to 721 construction projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008.

Figure 2.4: Percentage of Landscape & Exterior Design to Reduce Heat Islands (Non-Roof) Point Adopted Against Total Points Earned



Data pertains to 721 construction projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008.

Figure 2.5: sample LEED-NC certification checklist

LEED-NC

UCLA La Kretz Hall
LEED® Project # 677
LEED Version 2 Certification Level: SILVER
4/27/2006

34 Points Achieved — Possible Points: 69

	6 [illegible]	
Y	Erosion & Sedimentation Control	
1	Site Selection	1
	Urban Redevelopment	1
	Brownfield Redevelopment	1
1	Alternative Transportation Public Transportation Access	1
1	Alternative Transportation, Bicycle Storage & Changing Rooms	1
	Alternative Transportation, Alternative Fuel Refueling Stations	1
1	Alternative Transportation, Parking Capacity	1
	Reduced Site Disturbance, Protect or Restore Open Space	1
	Reduced Site Disturbance, Development Footprint	1
	Stormwater Management, Rate and Quantity	1
	Stormwater Management, Treatment	1
1	Landscape & Exterior Design to Reduce Heat Islands, Non-Roof	1
1	Landscape & Exterior Design to Reduce Heat Islands, Roof	1
	Light Pollution Reduction	1

	2 [illegible]	
	Water Efficient Landscaping, Reduce by 50%	1
	Water Efficient Landscaping, No Potable Use or No Irrigation	1
	Innovative Wastewater Technologies	1
1	Water Use Reduction, 20% Reduction	1
1	Water Use Reduction, 30% Reduction	1

	8 Energy & Atmosphere	
Y	Fundamental Building Systems Commissioning	
Y	*Minimum Energy Performance*	
Y	CFC Reduction in HVAC&R Equipment	
2	Optimize Energy Performance, 20% New / 10% Existing	2
2	Optimize Energy Performance, 30% New / 20% Existing	2
2	Optimize Energy Performance, 40% New / 30% Existing	2
	Optimize Energy Performance, 50% New / 40% Existing	2
	Optimize Energy Performance, 60% New / 50% Existing	2
1	Renewable Energy, 5%	1
1	Renewable Energy, 10%	1
	Renewable Energy, 20%	1
	Additional Commissioning	1
	Ozone Depletion	1
	Measurement & Verification	1
	Green Power	1

	4 [illegible]	
Y	Storage & Collection of Recyclables	
	Building Reuse, Maintain 75% of Existing Shell	1
	Building Reuse, Maintain 100% of Existing Shell	1
	Building Reuse, Maintain 100% Shell & 50% Non-Shell	1
1	Construction Waste Management, Divert 50%	1
	Construction Waste Management, Divert 75%	1
	Resource Reuse, Specify 5%	1
	Resource Reuse, Specify 10%	1
1	Recycled Content	1
1	Recycled Content	1
1	Local/Regional Materials, 20% Manufactured Locally	1
	Local/Regional Materials, of 20% Above, 50% Harvested Locally	1
	Rapidly Renewable Materials	1
	Certified Wood	1

	10 [illegible]	
Y	Minimum IAQ Performance	
Y	Environmental Tobacco Smoke (ETS) Control	
1	Carbon Dioxide (CO_2) Monitoring	1
	Increase Ventilation Effectiveness	1
1	Construction IAQ Management Plan, During Construction	1
1	Construction IAQ Management Plan, Before Occupancy	1
1	Low-Emitting Materials, Adhesives & Sealants	1
1	Low-Emitting Materials, Paints	1
1	Low-Emitting Materials, Carpet	1
1	Low-Emitting Materials, Composite Wood	1
	Indoor Chemical & Pollutant Source Control	1
	Controllability of Systems, Perimeter	1
	Controllability of Systems, Non-Perimeter	1
1	Thermal Comfort, Comply with ASHRAE 55-1992	1
1	Thermal Comfort, Permanent Monitoring System	1
	Daylight & Views, Daylight 75% of Spaces	1
1	Daylight & Views, Views for 90% of Spaces	1

	4 Innovation & Design Process	
1	Innovation in Design	1
1	Innovation in Design	1
1	Innovation in Design	1
	Innovation in Design	1
1	LEED® Accredited Professional	1

The checklist above shows which elements of LEED-NC version 2 were incorporated in UCLA's LaKretz Hall, the home of the UCLA Institute of the Environment. This document was downloaded from the USGBC website's list of LEED certified projects: see http://www.usgbc.org/ShowFile.aspx?DocumentID=1576, last accessed April 11, 2009.

Table 2.1: Frequency of Number of Projects - Tabulation of Ownership Type vs Certification Levels

Ownership Type	Certified	Silver	Gold	Platinum	Total
Nonprofit Organizations	50	38	35	17	140
For-Profit Organizations	89	78	52	6	225
Federal Government	21	14	7	1	43
State Government	31	24	20	4	79
Local Government	43	50	37	2	132
Individual Owners	4	2	2	3	11
Other (Owners)	25	13	13	3	54
Not Available	13	7	15	2	37
Total	276	226	181	38	721

Data pertains to 721 construction projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008.

Table 2.2: Descriptive Statistics

Variable	N	Mean	Std Dev	Min	Max	Max Possible
Sustainable Sites (Points Earned)	721	6.889	2.343	0	13	14
Water Efficiency (Points Earned)	721	3.123	1.344	0	5	5
Energy & Atmoshpere (Points Earned)	721	6.555	3.710	0	17	17
Material and Resources (Points Earned)	721	5.412	1.632	0	11	13
Indoor Environmental Quality (Points Earned)	721	8.728	2.489	2	15	15
Innovation and Design Process (Points Earned)	721	3.904	1.210	1	5	5
Points Earned (Total)	721	34.612	7.273	26	61	69
Gross Square Footage (sq. ft.)	669*	105912	168792	555	1728702	
Time From Registration to Certification	657**	968	424	51	2350	

Data pertains to 721 construction projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008.

* Data on square footage is not available for 38 projects. For 12 projects it is recorded as 0 and for 2 projects it is recorded as 1.

** Data on time from registration to certification is not available for 64 projects. For 37 projects the date of registration is not available and for 27 projects the date of Certification is less than the date of registration.

Table 2.3: Correlation for pairs of LEED points for which the Correlation is greater than 0.4

Leed Point 1	Leed Point 2	Correlation
Ren Energy 2	Ren Energy 3	0.77
Ren Energy 1	Ren Energy 2	0.75
Opt Energy 3	Opt Energy 4	0.69
Resource Reuse 1	Resource Reuse 2	0.68
Opt Energy 4	Opt Energy 5	0.68
Water Use 1	Water Use 2	0.68
Bldg Reuse 1	Bldg Reuse 2	0.62
Bldg Reuse 2	Bldg Reuse 3	0.60
Opt Energy 5	Ren Energy 1	0.58
Recyc Content 1	Recyc Content 2	0.57
Ren Energy 1	Ren Energy 3	0.57
Therm Comfort 1	Therm Comfort 2	0.56
Waste Mgmt 1	Waste Mgmt 2	0.54
Opt Energy 5	Ren Energy 2	0.53
Opt Energy 5	Ren Energy 3	0.52
Opt Energy 4	Ren Energy 1	0.51
Opt Energy 4	Ren Energy 2	0.51
Opt Energy 4	Ren Energy 3	0.49
Landscape 1	Landscape 2	0.49
Opt Energy 3	Opt Energy 5	0.46
Indoor Air Quality 1	Indoor Air Quality 2	0.44
Control of Systems 1	Control of Systems 2	0.44
Bldg Reuse 1	Bldg Reuse 3	0.43

Data pertains to 721 construction projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008.

Table 2.4: Points Earned by Years

Year of Certification	Points Earned				N
	Mean	Std Dev	Min	Max	
2000	33.00	-	33	33	1
2001	33.00	10.44	26	45	3
2002	33.94	6.09	26	43	16
2003	34.00	7.58	26	56	44
2004	32.86	6.01	26	56	83
2005	33.99	7.09	26	60	158
2006	34.13	6.24	26	55	195
2007	36.39	8.68	26	61	187
2008	36.06	6.46	26	57	34
Total					721

Data pertains to 721 construction projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008.

Table 2.5: Poisson and Negative Binomial Estimates of Points Achieved Over the Minimum Required for LEED Certification

Dependent Variable : Total Points Achieved in Excess of Minimum Required for Certification to LEED Standard	Poisson	Negative Binomial
Constant	-143.000 **	-31.200 **
	(48.200)	(11.300)
Year of Certification	0.072 **	0.017 **
	(0.024)	(0.006)
Gross Square Footage (in millions	-0.042	-0.009
	(0.171)	(0.041)
Nonprofit Organizations	0.487 **	0.116 ***
	(0.163)	(0.035)
For-Profit Organizations	0.258	0.055
	(0.156)	(0.031)
State Government	0.225	0.048
	(0.177)	(0.037)
Local Government	0.291	0.064 *
	(0.157)	(0.032)
Individual Owners	0.588	0.147
	(0.305)	(0.089)
Other Organizations	0.187	0.039
	(0.194)	(0.040)
ln(alpha)		-4.410 ***
		(0.182)
Log-PseudoLikelihood	-3200.770 **	-2231.833 **
Chi Square	23.839	24.238
BIC	6460.08	4528.71
Observations	668	668

standard errors are in parantheses
* p<0.05, ** p<0.01, *** p<0.001

Data pertains to all 721 projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008. Of these, 37 projects did not have information on ownership, 38 did not have information of gross square footage, 12 had gross square footage recorded as zero and 2 had gross square footage recorded as 1. The information on 668 projects was used in the analysis. Dependent variable is the total number of LEED points achieved by each project in excess of the 26 points required for certification to the LEED standard. Estimation method is Maximum Likelihood. Standard errors are reported using robust variance covariance matrix. The default building owner is federal government.

Table 2.6: OLS estimates of Time from Registration to Completion

Dependent Variable	Time from Registration to Completion (a)	(b)	ln (Time from Registration to Completion) (c)	(d)
Constant	67.42	-417.25	4.95 ***	4.29 ***
	(120.10)	(294.82)	(0.13)	(0.33)
Points Achieved	5.04 *		0.01 **	
	(2.27)		(0.00)	
Ln (Points Achieved)		186.48 *		0.25 **
		(81.92)		(0.09)
Gross Square Footage (in millions)	378.44 **	377.45 **	0.39 **	0.39 **
	(121.05)	(121.18)	(0.12)	(0.12)
Nonprofit Organizations	-170.73 *	-170.16 *	-0.15	-0.15
	(71.91)	(71.88)	(0.08)	(0.08)
For-Profit Organizations	-316.53 ***	-317.00 ***	-0.32 ***	-0.33 ***
	(68.19)	(68.15)	(0.08)	(0.08)
State Government	-58.63	-59.27	-0.03	-0.03
	(79.55)	(79.46)	(0.09)	(0.09)
Local Government	-24.11	-25.81	0.03	0.02
	(71.91)	(71.88)	(0.08)	(0.08)
Individual Owner	-528.87 ***	-527.04 ***	-0.52 ***	-0.51 ***
	(117.04)	(116.12)	(0.15)	(0.15)
Other Organizations	-137.43	-137.20	-0.09	-0.09
	(78.86)	(78.85)	(0.09)	(0.09)
Year of Certification 2008	957.72 ***	958.65 ***	1.83 ***	1.83 ***
	(95.19)	(95.18)	(0.10)	(0.10)
Year of Certification 2007	988.23 ***	992.00 ***	1.83 ***	1.83 ***
	(81.01)	(80.81)	(0.08)	(0.08)
Year of Certification 2006	928.36 ***	930.16 ***	1.80 ***	1.80 ***
	(74.52)	(74.55)	(0.08)	(0.08)
Year of Certification 2005	827.26 ***	829.82 ***	1.70 ***	1.70 ***
	(71.52)	(71.54)	(0.08)	(0.08)
Year of Certification 2004	723.46 ***	725.78 ***	1.55 ***	1.55 ***
	(80.04)	(79.95)	(0.10)	(0.10)
Year of Certification 2003	575.32 ***	578.42 ***	1.42 ***	1.43 ***
	(72.50)	(72.40)	(0.09)	(0.09)
Year of Certification 2002	384.46 ***	386.53 ***	1.01 ***	1.01 ***
	(83.05)	(82.80)	(0.17)	(0.17)
Year of Certification 2001	278.51 **	283.79 **	0.69 **	0.70 **
	(93.22)	(92.81)	(0.24)	(0.24)
R-square	0.24	0.24	0.25	0.25
Adj R-square	0.22	0.22	0.23	0.23
Observations	641	641	641	641

standard errors are in parantheses (* p<0.05, ** p<0.01, *** p<0.001)

Data pertains to all 721 projects that were certified to LEEC NC standards version 2.0, 2.1 and 2.2 by May 24, 2008. Of these, 64 projects did not have information on either registration date or certification date, 2 did not have information on organization type, 12 had gross square footage recorded as zero and 2 had gross square footage recorded as 1. The information on 641 projects was used in the analysis. Estimates are based on ordinary least-squares. Standard errors are reported using robust variance covariance matrix. The default building owner is federal government.

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