Why Do Firms Adopt Green Design?: Organizational Opportunity, Organizational Resources, Costs, or Regulation[1]

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ABSTRACT

This paper evaluates four explanations for industrial facilities' incorporation of environmental considerations in their product designs (i.e., "green design"): organizational opportunity, organizational resources, cost reduction, and environmental regulatory pressure. Initial analyses of facility-level workplace practice and environmental data support all four explanations. Facilities vigorously practicing cost reduction, with greater opportunities and resource bases to engage in green design, and facing more intense environmental regulatory pressure are substantially more likely to adopt green design. The results of multivariate analyses, however, indicate that adoption of green design is primarily determined by organizational opportunities and resources.

AUTHORS

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1. INTRODUCTION

The issue of how industrial facilities decide to use new manufacturing processes, product designs, or raw materials which offer the potential for both productivity improvements and environmental benefits has attracted the attention of researchers from a wide variety of fields. Recent studies suggest that innovative manufacturing and management practices that improve facilities' overall efficiency (e.g., total quality management, continuous improvement, worker empowerment, and just-in-time inventory) can be applied to environmental management to reduce the toxicity and/or amount of wastes generated, thereby lowering the environmental risks resulting from production operations. According to this perspective, facilities' efforts to adopt innovative manufacturing practices can reduce the costs of waste management and disposal, and the potential liabilities associated with waste generation, while reducing pollutant emissions to the environment [2,5,17,18,21,22,24,25,26,28,30].

A 1994 U.S. Office of Technology Assessment report noted the growing adoption of such environmentally-conscious manufacturing practices in the U.S. [22]. Porter and van der Linde concluded that firms are responding to new competitive conditions by developing strategies to maximize resource productivity through efforts that jointly enhance industrial and environmental performance [25]. A study of the automotive industry found some relationship between the use of advanced production techniques and of innovative environmental practices [20]. The basic implication of these studies is that neither business competitiveness nor the environment need suffer if innovative management practices are incorporated into environmental management practices.

While this emerging literature has made an important contribution to the manner in which we conceptualize the relationship between environmental and industrial practices, few of its claims have been subjected to rigorous empirical tests.

This paper provides an empirical examination of the factors associated with the adoption of environmentally-conscious manufacturing practices by a large sample of industrial facilities. It focuses specifically on one such practice -- "green design." This term has evolved to take on a variety of meanings depending upon the industrial practices that it intends to describe in a particular situation [23]. In general, however, it always refers to attempts by manufacturers to take into account environmental concerns in their product designs and/or manufacturing processes. In this paper, it specifically means that environmental considerations had a significant impact on the design of the products manufactured by a facility.

This paper empirically evaluates four specific hypotheses why facilities might engage in green design. Our belief is that the adoption of green design is associated with organizational factors, particularly the resources and capabilities of facilities to engage in green design and the opportunities for them to do so. There is much literature on the question of organizational opportunities, capabilities, and processes, which basically suggests that organizations vary in their internal resource bases and procedures, which affect their opportunities and abilities to respond to and effectively address internal and external challenges [3,4,31,35]. Some literature focusing on the adoption of environmental practices already has explicitly noted the relevance of organizational factors [1,8,9,10,11,15,16,27,29,33,34]. None, however, has specifically and empirically addressed these issues.

Thus, building from this literature, our first hypothesis, which we refer to as the *organizational opportunity hypothesis*, focuses on the opportunities that organizations have to engage in green design. We hypothesize that facilities that engage in regular or continuous evaluation or change of their products' designs will have greater opportunities to integrate environmental considerations into their product design processes. This hypothesis assumes that when facilities continuously engage in product innovation, they have an everpresent opportunity to integrate green design concerns with existing product design considerations, along with the accumulated experience and expertise to do so. This ongoing process makes it easier for them to absorb the immediate costs of adopting green design, because a process already exists for considering such changes. Our second hypothesis, which we refer to as the *organizational resources hypothesis*, asserts that organizations with greater resources will be better able to engage in green design. This is because such organizations will more readily have the finances and personnel necessary to shoulder the initial costs of such efforts. It is our view that these two organizational hypotheses are the key to understanding the adoption of green design.

The remaining two hypotheses examined in this paper have been noted in the existing literature. One is a *cost reduction hypothesis*, which argues that facilities engage in innovative environmental practices to realize longer-run cost savings. Thus, the motivating force is simply the desire, as in many business decisions, to reduce overall costs, at least in the longer-run. The last hypothesis is a *regulatory pressure hypothesis*, which argues that facilities engage in green design as a response to pressure from environmental regulations. This assumes that facilities react creatively, sometimes reevaluating their entire operations, to respond to these laws in a cost-effective manner, leading to use of pollution prevention techniques such as green design, rather than end-of-pipe pollution control equipment.

We evaluate these four hypotheses by using data from an establishment-level survey of manufacturing facilities and from government environmental records for those same facilities. The survey collected data on a wide range of establishment-level characteristics (e.g., sales, employment, and research and development expenditures) and management practices (e.g., production and work force organization, and customer and supplier relations). The government records indicate under which environmental programs the facilities are regulated. We use both bivariate analyses and logit regression to test the explanatory power of the four hypotheses.

To our knowledge, this is the first U.S. study to use establishment-level survey data to examine the factors associated with the adoption of green design. Previous research in the area of environmentally-conscious manufacturing has largely been case studies. Thus, research in this area is overwhelmingly anecdotal. Case studies abound in which various facilities -- or sometimes just their parent organizations -- are cited for their environmentally-conscious manufacturing practices. Unfortunately, it is only the success stories that seem to be described, for the apparent purpose of demonstrating that such practices can be implemented and are beneficial. Consequently, not only are the facilities cited not a representative sample of all facilities, they were selected according to a deliberate -- though understandable -- bias. As a result, the existing research indicates only that some environmentally-conscious manufacturing practices are possible, not what factors affect facilities' adoption of them. Our research overcomes these limitations and biases by using survey data on manufacturing facilities to examine factors associated with the adoption of green design.

2. CONCEPTS AND HYPOTHESES

As noted above, this paper focuses on four possible factors associated with the adoption of green design: longer-run cost reduction concerns; regulatory pressures; organizational opportunity, defined as a drive for continuous innovation which triggers product design improvements; and organizational resources.

<u>Cost Reduction</u>: One reason facilities may adopt green design is to reduce their longer-run manufacturing costs. We refer to this first hypothesis as the *cost reduction hypothesis*. This cost reduction hypothesis is one of two hypotheses most often cited in the existing literature. Many studies have emphasized the importance of longer-run cost savings in facilities' decisions to adopt innovative environmental practices [1,6,10,25,32]. The use of green design is assumed to be influenced strongly by the desire to reduce manufacturing inputs and wastes, and thus costs. These cost savings are due to less wasted raw materials, lower energy use, reduced waste management and disposal fees, increased production efficiencies, and exemptions from some environmental laws due to reduced pollutant emissions.

The literature is rife with case studies of facilities that implemented green design and the cost savings that they ultimately achieved [5,18,25]. Therefore, this hypothesis follows classical economic theory by assuming that facilities act to reduce their costs, potentially leading to competitive advantages and higher profits. In the overwhelming proportion of cases cited, cost savings more than offsetting the expenses of implementing green design are achieved relatively quickly [25]. Thus, this is why we refer to *longer-*, rather than long-, run costs -- the payback period for recovering implementation costs may be so short that thinking of the truly long-term is unnecessary. This cost saving objective, and the potential for improved resource productivity and competitiveness of facilities that should result, should lead to increased adoption of green design and other environmentally-conscious manufacturing practices.

Regulatory Pressure: It has also been hypothesized that facilities engage in environmental innovation, including green design, due to pressure from environmental regulation [10,13,25,32]. We refer to this second hypothesis as the *regulatory pressure hypothesis*. Porter and van der Linde in particular have argued that facilities develop innovative environmental management strategies as a way of responding to increasingly stringent and comprehensive environmental regulation [25]. According to this perspective, facilities react creatively, and at times reevaluate their entire approaches to their operations, to respond to these laws in a cost-effective manner. This effort can lead to incorporating green design in facilities' production planning and processes in order to reduce wastes, rather than simply installing end-of-pipe pollution control equipment to treat those wastes.

This view suggests that the more that facilities are regulated under and feel pressured by environmental laws, the more likely they are to adopt green design. Such regulatory pressure might overcome organizational inertia to accepting new ideas, stimulate creative thinking, and alert facilities to possible resource inefficiencies and technological improvements [25].

<u>**Organizational Opportunity**</u>: In contrast to the preceding approaches, we advance the basic hypothesis that adoption of green design is related to facilities' organizational resources and processes, in particular those resources and processes which enable an organization to absorb the *immediate* costs of engaging in green design. We divide this basic hypothesis into two components, an *organizational opportunity hypothesis* and an *organizational resources hypothesis*, though the general theoretical justifications for both are similar.

Recent work by Teece and Pisano has argued for a theory of dynamic organizational capabilities [31]. According to this theory, organizational factors are critical to the innovativeness and overall business performance of facilities. These factors include both organizational resources and assets, and organizational capabilities -- the experiences, competencies, and capacities which condition how different organizations respond in various situations. In essence, this theory asserts that classical economics erroneously views organizations as "black boxes" that respond similarly to outside stimuli. Rather, organizations differ because they have different resource endowments, assets, and capacities to learn and respond, with some organizations constrained in their responses due to their own past practices. It is these factors that determine whether facilities have, recognize, and can seize opportunities to improve their procedures and products.

In any business decision there are unavoidable costs in even evaluating possible options, regardless of which option may be chosen. These costs include the time expended by a facility to research an issue, to consult with internal and external sources of expertise, to develop options for addressing the issue, and to gain the approval of management. These costs also include any out-of-pocket expenses associated with these efforts. Because of the complex technical and legal ramifications of many environmental issues, these time and financial expenditures can be considerable.

Thus, we hypothesize that overcoming the initial hurdle of absorbing these immediate costs of simply considering green design is important in determining whether a facility ultimately adopts these practices [10,15]. Furthermore, these immediate costs may be a more important obstacle to using green design than considerations of longer-run costs. Naturally, any facility that is unwilling to accept the immediate costs of simply considering green design will never even reach the question of the longer-run costs versus benefits. Consequently, for facilities fitting this description, the adoption of green design is exclusively determined by immediate, as opposed to longer-run, costs.

In addition, for facilities that do accept the immediate costs of considering green design, longer-run costs may not typically distinguish between facilities that ultimately adopt or reject green design. As noted earlier, in virtually all reported case studies, the longer-run cost savings from engaging in environmentally-conscious manufacturing efforts have far -- and quickly -- exceeded any initial costs of implementing green design. Thus, once past the barrier of considering such initiatives, almost every facility may discover that the longer-run costs and benefits always favor adopting these practices. Therefore, sensitivity to longer-run costs again would not differentiate between green design and non-green design facilities.

Consequently, green design facilities might be those that -- simply due to their normal production management processes -- more frequently have the opportunity, at little or no cost, to consider and adopt green design. Such facilities would be those that are particularly, and continually, concerned and innovative about the design of their products. Facilities that are always researching, evaluating, and changing their products' designs should find it relatively easy to include environmental considerations as one of the factors in their evaluations. In contrast, a facility that did not frequently review its products' designs may find it difficult to accept the immediate costs of conducting a review simply to consider green design issues. Therefore, the *organizational opportunity hypothesis* is that the more that facilities practice continuous product innovation, the more opportunity they have, and thus the more likely they are, to adopt green design.

Organizational Resources: A facility's ability to absorb the immediate costs of considering green design is not just a function of the absolute incremental costs involved, but also of the relative costs to that facility [15,19]. For example, if the incremental immediate costs of considering green design were 200 hours of personnel time and $10,000 in expenses, this may be inconsequential to a facility with large resources, but unacceptable to smaller facilities. Thus, in assessing the impact of immediate costs upon facilities' green design decisions, their relative available resources also should be taken into account. These resources could include the size of their labor forces and sales, their spending on research and development, and the size of the companies of which they are a part [32]. Facilities with more of these resources could be regarded as having a larger organizational resource base against which to absorb the immediate costs of considering green design, thus making them more likely to consider and subsequently adopt green design. Therefore, this represents the *organizational resources hypothesis*.

3. DATA

This study examines these hypotheses using extensive establishment-level data from a survey of manufacturing facilities in various industries. The data are from a 1994 survey of Japanese-affiliated manufacturing facilities in the U.S. and U.S.-owned manufacturing facilities that serve as suppliers to Japanese-affiliated automobile assembly complexes in the U.S. [7,14]. The survey typically was completed by plant managers from these facilities. They answered nearly 300 separate questions eliciting detailed information about their facilities' products, labor force, management of production work, and relations with outside customer and supplier organizations.

Among this information was their facilities' adoption of green design. Specifically, they were asked the following: "Have environmental considerations had a significant impact on the design of the products produced by this plant?" For the purposes of this study, facilities that responded "yes" to this question are referred to as "green design facilities," while those that responded "no" are "non-green design facilities." Of the 316 facilities that responded to this question, 36 percent were green design facilities and 64 percent were not.

We also used data from the U.S. Environmental Protection Agency ("EPA") in combination with the survey data. Each survey facility was matched to certain EPA lists of environmentally regulated facilities. Through this process, it was determined whether a facility was a permitted direct discharger of wastewater into some surface water body, a permitted emitter of air pollutants, a facility required to report on its handling of large amounts of toxic chemicals,[2] and/or a large, small, or conditionally-exempt generator of hazardous waste.[3]

4. FACTORS ASSOCIATED WITH ADOPTION OF GREEN DESIGN

We begin by using the survey data to examine the adoption of green design in light of each of the hypotheses described above: cost reduction, regulatory pressure, organizational opportunity, and organizational resources. For each of these hypotheses, relevant data from the survey and EPA databases were used to operationalize variables that enabled the testing of these hypotheses individually.

Cost Reduction

As noted earlier, literature suggests that adoption of green design depends largely on facilities' interest in cost reduction. Thus, facilities especially motivated by cost and waste reduction objectives should be more likely to use green design. To initially test this hypothesis, we used facilities' responses to the four survey questions listed in Table I to examine the relationship between cost reduction and adoption of green design. As Table I shows, green design facilities exhibit the greater attention to cost reduction that was hypothesized, with more of them agreeing with the cost reduction questions than did

TABLE I

GREEN DESIGN AND NON-GREEN DESIGN FACILITIES' RESPONSES TO COST REDUCTION QUESTIONS

Cost Reduction Question	Green Design Facilities	Non-Green Design Facilities
Facility changed design of largest selling product in last 12 months for cost reduction reasons (% "YES")	64%	44%**
Facility changed manufacturing process for largest selling product in last 12 months for inventory or waste reduction reasons (% "YES")	59	41**
Facility provided cost reduction technical assistance or training to suppliers in past 3 years (% "YES")	47	34*
Facility obtained cost reduction technical assistance or training from its most important customer in past 3 years (% "YES")	30	32

Statistical significance of differences between percentages:
*: $p<.05$
**: $p<.01$

non-green design facilities.[4] For three of the four cost reduction questions, the differences in agreement between the two groups of facilities were statistically significant, with facilities 40 percent to 50 percent more likely to employ certain cost reduction techniques if they also used green design.

The four cost reduction questions were then combined into a Cost Reduction Index, with each facility's score on this index computed as the total number of "yes" responses to those questions, which always indicated interest in cost reduction. This index allowed the separation of these facilities into five groups, each of which reflected a different level of broad concern about cost reduction, as measured over multiple dimensions. Thus, this index provides an indication of the breadth of a facility's commitment to cost reduction, with a higher index score indicating a higher degree of commitment.

Table II displays the percent of the facilities with a particular Cost Reduction Index score that had adopted green design. As the table shows, the likelihood of a facility using green design rose substantially and significantly ($p<.01$) only after its score on this index exceeded three. Thus, rather than revealing a smoothly increasing relationship between these two variables, these data indicate a step-function-like trend, with green design adoption levels about doubling after that threshold is reached. Only when facilities' attention to cost reduction achieves a certain critical intensity does it appear to be associated with increased adoption of green design. Above and below that critical intensity there appears to be no difference in the use of green design. This signifies that the pervasiveness, rather than mere existence, of a facility's commitment to

TABLE II

PERCENT OF FACILITIES THAT USE GREEN DESIGN BY COST REDUCTION INDEX SCORE

Cost Reduction Index Score	Percent of Facilities Using Green Design	N
0	25.8%	66
1	34.5	87
2	26.3	76
3	53.8	65
4	59.1	22

cost reduction may be the better indicator of its likelihood of adopting green design.

<u>Regulatory Pressure</u>

Literature also suggests that use of green design will be associated with increased environmental regulatory pressure on facilities. We used EPA data in combination with the survey data to explore this hypothesis. As noted earlier, each survey facility was matched to certain EPA lists of environmentally regulated facilities to determine whether it was a permitted wastewater discharger, a permitted emitter of air pollutants, a large toxic chemical user, and/or a large, small, or conditionally-exempt generator of hazardous waste.

Because falling into any of these categories subjected a facility to a particular set of environmental requirements, each such designation, and their cumulative number, was regarded as an indicator of the environmental regulatory pressure on a facility. Table III shows that, with just one exception, facilities that were regulated under these regulatory programs were more likely to use green design than unregulated facilities. For four of the five regulatory programs, the differences were statistically significant, with facilities 50 percent to over 100 percent more likely to use green design if they were regulated under an environmental program. The only exception to this pattern was that holders of water discharge permits adopted green design at essentially the same rate as facilities without such permits.[5] Overall, however, these results are consistent with the hypothesis that facilities are more likely to adopt green design if they are under environmental regulatory pressure.

TABLE III

PERCENT OF FACILITIES REGULATED OR UNREGULATED UNDER ENVIRONMENTAL PROGRAMS THAT USE GREEN DESIGN

Environmental Regulatory Program	Percent of Facilities Using Green Design	N [a]
Large quantity hazardous waste generator	46.6%*	103
Small quantity hazardous waste generator	32.2	118
Conditionally-exempt small quantity hazardous waste generator	48.0*	25
No hazardous waste generated	22.4	67
Air pollution permit holder	47.2*	106
No air pollution permit	30.4	207
Water pollution permit holder	34.8	46
No water pollution permit	36.3	267
Large toxic chemical user	47.4*	116
Not a large toxic chemical user	29.4	197

* $p<.01$ for differences between facilities regulated under a program and those that are not

[a] EPA information on 3 of the 316 facilities surveyed was not found

The environmental programs were then combined into an Environmental Program Index, with each facility's score on the index computed as the total number of programs under which it was regulated.[6] Similar to the Cost Reduction Index, this index allowed the separation of these facilities into six groups, each of which reflected a different level of regulatory pressure as measured over multiple dimensions. Thus, this index provides an indication of the intensity of the regulatory pressure on a facility, with a higher index score indicating a higher degree of pressure. Table IV displays the percent of the facilities with a particular Environmental Program Index score that had adopted green design. As the table shows, the likelihood of a facility using green design consistently rose as its score on this index increased ($p<.01$ for a chi-square test of the association between the index score and the percent of green design adoption).[7] The rate of adoption of green design for the most regulated facilities was about triple that of unregulated facilities. Thus, these data indicate that the greater the regulatory pressure on a facility, the more likely that it was to use green design.

Organizational Opportunity

As described earlier, one of our new hypotheses was that the adoption of green design is associated with organizational opportunity. Specifically, we hypothesized that facilities that engage in continuous product innovation will have more opportunity, and thus be more likely, to adopt green design. We define continuous product innovation as a facility paying substantial and frequent attention to the development, design, and performance of its products. We have hypothesized that organizations engaging in

TABLE IV

PERCENT OF FACILITIES THAT USE GREEN DESIGN BY ENVIRONMENTAL PROGRAM INDEX SCORE

Environmental Program Index Score	Percent of Facilities Using Green Design	N
0	18.2%	55
1	29.9	87
2	37.5	56
3	50.0	54
4	55.1	49
5	16.7	12

continuous product innovation have both greater opportunity and capacity to engage in green design and lower immediate costs of doing so. To initially test this hypothesis, we used responses to several survey questions to examine the relationship between continuous product innovation and adoption of green design.

As Table V shows, green design facilities exhibit the greater attention to continuous product innovation that was hypothesized. The analysis indicates that, to a far greater extent than other facilities, green design facilities change the designs of their existing products and create new products. These changes in product designs often are motivated by customer demands. Presumably as a result and cause of these frequent modifications and additions to their products, green design facilities engage in more research and development relating to their products, and are more likely to share product-related information with their workers.

The eight continuous product innovation questions in Table V that were dichotomous were then combined into a Continuous Product Innovation Index, with each facility's score on this index computed as the total number of "yes" responses to those questions, which always indicated an orientation towards continuous product innovation. Similar to the Cost Reduction Index, this index allowed the separation of these facilities into eight groups, each of which reflected a different level of commitment to continuous product innovation, as measured over multiple dimensions. Thus, this index provides an indication of the intensity of a facility's commitment to continuous product innovation, with a higher index score indicating a higher degree of commitment.

Table VI displays the percent of the facilities with a particular Continuous

TABLE V

GREEN DESIGN AND NON-GREEN DESIGN FACILITIES' RESPONSES TO CONTINUOUS PRODUCT INNOVATION QUESTIONS

Continuous Product Innovation Question	Green Design Facilities	Non-Green Design Facilities
R&D currently conducted at facility:		
Product design (% "YES")	45%	31%*
Product development (% "YES")	50	32**
Product testing (% "YES")	53	34**
Facility's management regularly shares information with production workers about:		
Performance of competing products (% "YES")	68%	56%*
Plans for new product development (% "YES")	88	75**
Performance of the facility's products in the field (% "YES")	94	89
Number of times in last 12 months facility changed design of largest selling product	14.9	8.3**
Facility changed design of largest selling product in last 12 months due to change in product specifications by customer (% "YES")	58%	39%**
Facility changed manufacturing process of largest selling product in last 12 months due to changes in product design or specifications (% "YES")	58%	37%**
New products or new product generations facility produced in last 12 months	9.4	4.0**

Statistical significance of differences between percentages/means:
*: $p<.05$
**: $p<.01$

TABLE VI

PERCENT OF FACILITIES THAT USE GREEN DESIGN BY CONTINUOUS PRODUCT INNOVATION INDEX SCORE

Continuous Product Innovation Index Score	Percent of Facilities Using Green Design	N
0	23.1%	13
1	16.7	24
2	31.9	47
3	22.7	66
4	36.8	76
5	58.2	55
6	50.0	28
7	57.1	7

Product Innovation Index score that had adopted green design. Comparable to the cost reduction analysis results, the table shows that the likelihood of a facility using green design rose substantially and significantly ($p<.01$) only after its score on this index exceeded four. Thus, rather than revealing a smoothly increasing relationship between these two variables, these data indicate a step-function-like trend, with green design adoption levels about doubling after that threshold is reached. Only when facilities' attention to continuous product innovation achieves a certain critical intensity does it appear to be associated with increased adoption of green design. Above and below that critical intensity there appears to be no difference in the use of green design. This signifies that the pervasiveness, rather than mere existence, of a facility's commitment to continuous product innovation may be the better indicator of its likelihood of adopting green design.

The organizational opportunity to consider green design also could be affected by the type of manufacturing in which a facility is engaged. Some industries manufacture products whose designs may be inherently easier to change and/or which are changed frequently due to detailed and varied customer specifications. Thus, as a result, such industries may intrinsically have greater opportunities to consider product design changes, including for environmental reasons. To determine whether the adoption of green design differed by industry, the two-digit Standard Industrial Classification ("SIC") codes of the facilities were used to separate them into industries. The percentages of green design adoption among these industry groups were then compared. With the exception of the chemical industry, which had a higher than expected use of green design, no statistically significant differences were found by industry group. Thus, it appears that the characteristics of individual facilities, as opposed to broad industries, are most important in explaining use of green design.

Organizational Resources

The other of our new hypotheses was that organizations with greater resources at their disposal are expected to possess a greater capacity to engage in, and thus a higher probability of ultimately adopting, green design. These greater resources could be in the form of more funds, personnel, or corporate sibling facilities from which to draw necessary financing and expertise. The survey data confirm that this is indeed the case. The adoption of green design was consistently associated with facilities that had substantially larger resource bases.

As Table VII shows, green design facilities were part of larger companies and had higher levels of sales, employment, capital, and research and development expenditures than did non-green design facilities. In particular, green design facilities had about double the mean amount of sales, employees, and sibling facilities, and over ten times the mean research and development expenditures. Thus, green design facilities clearly had far greater resources to draw upon. These results are consistent with the hypothesis that facilities are more likely to adopt green design if they are better positioned to absorb the immediate costs of doing so.

TABLE VII

MEAN ORGANIZATIONAL RESOURCES OF GREEN DESIGN VS. NON-GREEN DESIGN FACILITIES[a]

Organizational Resource	Green Design Facilities	Non-Green Design Facilities
Sales	$145277	$62213**
Employment	472	243**
Value of installed capital	$55958	$46789**
R&D expenditures	$4232	$389**
New plant and equipment expenditures	$6565	$5828**
North American facilities owned by parent company	14.9	6.4**

**: $p<.01$ for differences between means

[a] All dollar figures are in thousands of dollars and all figures are for 1994, except for 1993 new plant and equipment expenditures.

5. GREEN DESIGN ADOPTION MODELS

To move beyond the bivariate hypothesis tests described above, we developed a multiple regression model to examine the overall and relative importance of the factors associated with the use of green design. These models were designed to test the relative explanatory power of each of the four hypotheses regarding adoption of green design. As we have already shown, the survey and EPA data provide some support for each of the four competing explanations. Multiple regression allows us to isolate the independent effects of variables underlying each of the four hypotheses. We used logit regression to examine these variables because the dependent variable is dichotomous (from the yes/no response to the green design survey question).

The following independent variables were included in the model to evaluate the four alternative hypotheses for adoption of green design:

Cost Reduction Variables: As this hypothesis asserts, facilities engage in green design primarily to reduce their longer-run costs. To reflect this hypothesis, we use the Cost Reduction Index score for each facility created from combining the cost reduction-related survey questions described earlier.[8] In addition, we include a dummy variable reflecting a threshold effect for this index, because the earlier analyses indicated that the relationship between the adoption of green design and the Cost Reduction Index appeared to take the form of a step-function.

Regulatory Pressure Variables: This hypothesis proposes that facilities adopt green design primarily in response to pressure from environmental regulations. To represent this hypothesis, we include a dummy variable for each of the previously described environmental programs under which a facility could be regulated (i.e., whether a facility was a water or air pollution permit holder, a large user of toxic chemicals, or a large, small, or conditionally exempt small quantity hazardous waste generator, respectively).

Organizational Opportunity Variables: Four variables are included in the regression model to represent the hypothesis that organizational opportunity affects a facility's use of green design. These variables include the number of times in the last 12 months that a facility either changed the design of its largest selling product or began manufacturing new products, respectively. We also use the Continuous Product Innovation Index score for each facility created from combining the continuous product innovation-related survey questions described earlier.[9] In addition, we include a dummy variable reflecting a threshold effect for this index, because the earlier analyses indicated that the relationship between the adoption of green design and the Continuous Product Innovation Index appeared to take the form of a step-function.

Organizational Resources Variables: Three variables are included in the regression model to represent the hypothesis that the resources available to a facility affect its adoption of green design. These variables are a facility's 1994 sales and research and development expenditures, respectively, and the number of North American facilities owned by its corporate parent. The first two variables are intended to reflect the internal financial resources available to a facility,[10] while the latter reflects the external resources potentially available to a facility, both in terms of funds and of useful experiences (e.g., in implementing green design) accumulated by sibling facilities.

<u>Industry Controls</u>: To control for possible differences in green design adoption by industry sectors, the model also includes dummy variables for the ten major industries (based upon their two-digit SIC codes) in which the survey facilities were categorized.

6. MODEL RESULTS

The findings for the model are summarized in Table VIII. The variables in the table are grouped according to the hypotheses to which they are relevant, and listed in descending order of their statistical significance. As the table shows, the logit model was highly statistically significant (p = .000) and explained a moderate amount of variance in facilities' adoption of green design (Pseudo-R^2 = .220 and adjusted Pseudo-R^2 = .318).[11] Another way of measuring the model's performance is how well it predicted whether a facility fell into the green design or non-green design groups. By simply randomly assigning facilities into the two groups, one would expect to correctly classify 54.5 percent of the facilities. Based upon the probability of being a green design facility calculated for each facility by the logit model, however, 75 percent of the facilities were correctly classified.

This explanatory power, however, was largely provided by just the four independent variables which had statistically significant effects. These variables were the

TABLE VIII

LOGIT REGRESSION MODEL RESULTS

Independent Variable	Coefficient	z	P> z [a]
Organizational Opportunity Variables			
Continuous Product Innovation Index threshold effect	1.651725	2.958	0.002
New products or new product generations produced in last 12 months	.029881	1.532	0.063
Number of times in last 12 months design of largest selling product was changed	.0037211	1.091	0.138
Continuous Product Innovation Index	-.3355709	-0.271	0.393
Organizational Resources Variables			
1994 sales	.00000344	2.434	0.008
North American plants owned by parent company	.0109493	1.341	0.090
1994 research and development expenditures	.00000300	0.084	0.467
Regulatory Pressure Variables			
Conditionally-exempt small quantity hazardous waste generator	2.347972	2.985	0.002
Large quantity hazardous waste generator	1.034157	1.837	0.033
Water pollution permit holder	-.6713379	-1.295	0.098
Small quantity hazardous waste generator	.5975539	1.188	0.118
Large toxic chemical user	-.061527	-0.157	0.438
Air pollution permit holder	.0300552	0.076	0.470
Cost Reduction Variables			
Cost Reduction Index threshold effect	.5578817	0.867	0.193
Cost Reduction Index	-.5295212	-0.506	0.307
Industry Control Variables			
Measuring, Analyzing and Controlling Instruments	-2.531516	-1.209	0.227
Transportation Equipment	-1.516499	-0.778	0.437
Primary Metal Industries	-1.505051	-0.757	0.449
Fabricated Metal Products	-.9768056	-0.516	0.606
Industrial and Commercial Machinery	-.8982197	-0.472	0.637
Electronic and Other Electrical Equipment	-.8281112	-0.438	0.661
Apparel	-.9272816	-0.424	0.671
Stone, Clay, Glass, and Concrete Products	-.7127787	-0.354	0.723
Chemicals and Allied Products	.6516987	0.342	0.732
Rubber and Miscellaneous Plastic Products	-.4980522	-0.262	0.793

Log-likelihood	-121.18
Number of observations	240
x^2 [25]	68.41, p = .000
Pseudo-R^2	.220
Adjusted Pseudo-R^2	.318
Percent correctly classified	75%

[a] One-tailed tests for all variables, except for Industry Control Variables

Continuous Product Innovation Index threshold effect, 1994 sales, and large quantity hazardous waste generators, and conditionally-exempt small quantity hazardous waste generators. Thus, at least one variable was significant which represented each of three of the four hypotheses examined in this study, the only exception being the cost reduction hypothesis. Only a few other variables attained even remotely near statistical significance. The specific model results with respect to each of the hypotheses can be summarized in terms of the following findings.

First, our interpretation of the results is that organizational opportunity, reflected here in facilities' commitment to continuous product innovation, is an important determinant of their adoption of green design. The Continuous Product Innovation Index threshold effect is highly positively statistically significant, demonstrating that not only is this indicator of organizational opportunity more important than longer-run costs, but also that its relationship with the adoption of green design is in the form of a threshold effect. Facilities with an especially high (i.e., above the threshold) commitment to continuous product innovation are over five times more likely to adopt green design than those with less commitment. Below and above that threshold, however, there is no clear trend within these two groups. Apparently, only after facilities are using a critical mass of product innovation practices, and thus have systematic opportunities to incorporate environmental considerations into their decision-making, are they led to dramatically increase their use of green design. Furthermore, it is the planning and evaluation process, rather than the actual frequency of product changes, that appears to be most important in stimulating green design. In addition, as reflected by the consistent insignificance of the industry control variables, it is the practices of specific facilities, rather than patterns of practices within general industries, that prompt use of green design.

Second, the model results also support the hypothesis that a broad measure of organizational resources is associated with facilities' adoption of green design. The regression coefficient for 1994 sales is positive and statistically significant. As a facility's sales, and thus presumably its available resources, increase, so does its likelihood of using green design. The coefficient, however, is so small that only enormous differences between facilities' sales would produce meaningfully substantial differences in their probabilities of using green design.

Third, among the regulatory pressure variables, two of the three hazardous waste generator groups (large quantity generators and conditionally-exempt small quantity generators) have substantially, and statistically significant, higher probabilities of using green design than other facilities. The small number of conditionally-exempt small quantity generators in the sample, and the fact that they are subject to less regulation than any of the other hazardous waste generator groups, however, makes their results less reliable. With respect to the regulatory pressure hypothesis in general, it is important to note that none of the other regulatory pressure variables were statistically significant. In addition, in a separate logit regression model that used the Environmental Program Index as an independent variable, instead of the individual regulatory pressure variables, that index, reflecting the cumulative regulatory pressure on a facility, was not a statistically significant predictor of the adoption of green design.[12] Thus, there is limited support for the hypothesis that increased regulatory pressure leads to use of green design.

Fourth, the model results provide no support for the cost reduction hypothesis. Neither the Cost Reduction Index nor its threshold effect achieve anything near statistical significance.

Taken together, these findings indicate that it is primarily the immediate costs of a facility's considering green design, reflected -- above a certain threshold -- in both its organizational resources and in its organizational opportunity to consider green design, that are significantly related to its likelihood of adopting green design. Longer-run costs do not appear to help explain the use of green design, and regulatory pressure appears to be only somewhat relevant. Consequently, the existing literature's reliance upon the latter factors as providing the best explanation for facilities' behavior may be misplaced.

7. CONCLUSIONS

This paper has examined four competing theories for the adoption of green design. Under the hypothesis cited most in the existing literature, use of green design should be related primarily to facilities' concerns about reduction of longer-run costs. Under another previously advanced hypothesis, the degree of environmental regulatory pressure on a facility should affect its adoption of green design. Under the theory developed in this paper, facilities' use of green design should be related primarily to their sensitivities to immediate costs, as reflected by their organizational opportunities and resources.

All four of these hypotheses are supported by bivariate analyses of the survey data used in this study. Facilities with more cost reduction practices, organizational opportunities, and resource bases, and under more intense regulatory pressure are substantially more likely to adopt green design. Thus, this is consistent with prior researchers who found evidence, albeit largely anecdotal, supporting their hypotheses. The results of the regression analysis, however, primarily confirm the research hypotheses. These results show that the variables representing organizational opportunities and resources were most important, while concerns about longer-run costs were irrelevant and regulatory pressures were only sporadically important. Furthermore, it was the existence of a critical mass of organizational opportunities, rather than just more or less of them, that best differentiated facilities' adoption of green design.

Thus, facilities' immediate opportunities and capacities to engage in green design, rather than the prospect of longer-run cost or regulatory benefits from doing so, appear most important. Naturally, such a finding substantially affects the existing ways of analyzing and developing policies to encourage the adoption of green design. Rather than simply focusing on factors exogenous to facilities -- cost and regulatory pressures -- the internal structures and external relationships of facilities must be considered. Facilities facing the same outside pressures may be quite differently organizationally equipped and motivated to respond to them. Clearly, this makes researching these issues more difficult, because organizational behaviors typically are more complex to determine and measure than the better defined and more obvious characteristics of costs and legal requirements. Consequently, this study makes a case for not only focusing attention on these new hypotheses, but also for researching these issues in a more comprehensive, sophisticated, and quantitative manner that better enables the identification of the factors affecting use of environmentally-conscious manufacturing practices.

This finding also supports the belief that innovative production management practices and green design efforts can reinforce one another. The more that a facility implements the former, the more opportunities that it should have and the better prepared it should be to adopt the latter. By encouraging a focus on continuous product improvement, efficiency, research and development, and worker participation, a facility better positions itself to perceive and act upon opportunities to incorporate environmental considerations into its production processes. By inculcating the values inherent in innovative production management practices, both the facility and the environment should be able to reap the benefits.

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ENDNOTES

1. Research funding was provided by the Alfred P. Sloan Foundation, National Science Foundation Environmentally-Conscious Manufacturing Program and Division of Geography and Regional Science, and the Great Lakes Protection Fund. Davis Jenkins collaborated in the collection of the survey data and Christopher Bell assisted in various aspects of this research.

2. These reports are for the Toxics Release Inventory, and are required under the federal Emergency Planning and Community Right-to-Know Act.

3. Hazardous wastes are wastes that EPA has designated as posing dangers to the environment or public health if they are not managed and disposed of with special precautions. Large quantity generators of hazardous waste (typically facilities that generate over 2,200 pounds of such waste in a month during a calendar year) are subject to more extensive waste management and reporting requirements than small quantity generators (typically facilities that generate 220 to 2,200 pounds of such waste in a month). Conditionally-exempt small quantity generators (typically facilities that generate under 220 pounds of such waste in a month) are subject to virtually no such requirements.

4. An explanation for the only question on which there was no statistically significant difference could be that if green design facilities already were quite sensitive to and successful at reducing their costs, they would not necessarily be motivated to seek assistance from their customers in this area.

5. The reason for this exception is uncertain. One possibly relevant difference between the water discharge permit program and the other regulatory programs is that the latter apply only to facilities that manage clearly hazardous substances, while the former applies to facilities that discharge any pollutants, even if relatively benign, to water bodies. Thus, the water discharge permit program may not differentiate as well between the degree of hazard associated with the operations engaged in by facilities. Consequently, if adoption of green design is motivated by regulatory pressure, the level of that pressure imposed upon water discharge permit holders may be low compared to other regulatory programs.

6. These programs were for air pollution, water pollution, toxic chemical use, and hazardous waste generation. Because of the additional regulatory requirements on large quantity generators of hazardous waste, being such a generator was counted as an additional program, thus bringing the number of regulatory programs comprising the index to five.

7. The only exception to this trend occurred when the index score was 5, but this may simply be due to the variability inherent in analyzing only 12 observations.

8. Because a few facilities did not respond to all of the questions comprising this index, for purposes of these regression analyses this index score is expressed as the percentage, rather than raw number, of questions responded to that were answered consistent with an interest in cost reduction.

9. Because a few facilities did not respond to all of the questions comprising this index, for purposes of these regression analyses this index score is expressed as the percentage, rather than raw number, of questions responded to that were answered consistent with a commitment to continuous product innovation.

10. Other indicators of facilities' resource bases (e.g., number of employees) were highly correlated with these variables, and thus they were not included in the model.

11. Adjusted for the number of variables estimated and the maximum possible value of the Pseudo-R^2 [12].

12. The results of this alternative model using the Environmental Program Index produced essentially similar results to the primary model, except that, in addition to 1994 sales and the Continuous Product Innovation Index threshold effect, the number of new products or new product generations variable also was statistically significant. The latter variable, however, had a very small positive effect on the adoption of green design compared to the Continuous Product Innovation Index threshold effect.