

# **Absorptive Capacity, Organization Structure, and Information Provision**

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## **Abstract**

Central to a firm's absorptive capacity is not only its stock of prior-related knowledge but the distribution of this knowledge across multiple units of the organization and the flows of information between them. In this paper, we explore the conditions under which a firm is likely to use information provision – the transfer of practice-specific data from a central knowledge repository to agents within the firm that make technology adoption decisions – to increase the firm's ability to identify, select, and implement valuable practices and technologies. We propose that the organization structure – the size, diversity, and distribution of expertise across organizational units – influences the efficacy and hence use of information provision. Drawing upon a panel of manufacturing firms in the information and communication technology sector in the United States, we find empirical support for this underlying proposition.

Keywords: absorptive capacity, information provision, dynamic capability

## **Absorptive Capacity, Organization Structure, and Information Provision**

The absorptive capacity of a firm – the “ability to recognize the value of new information, assimilate it, and apply it to commercial ends (Cohen & Levinthal, 1990: p128)” – is largely determined by the distribution of prior-related knowledge within the firm (Cohen & Levinthal, 1990). Scholars have long recognized that managers may build absorptive capacity by investing in internal research and by promoting linkages to external knowledge sources such as universities (Cohen & Levinthal, 1990; Cockburn & Henderson, 1998; Lane, Salk, & Lyles, 2001). Less appreciated, however, is the degree to which managers may influence firm absorptive capacity through the management of incentives and information across organizational units (Van den Bosch, Volberda, and de Boer, 1999; Lenox & King, 2004).

Central to a firm’s absorptive capacity is not only the stock of prior-related knowledge but the distribution of this knowledge across multiple units of the organization and the flows of information between them (Cohen & Levinthal, 1990; Van den Bosch, Volberda, and de Boer, 1999). Countless cautionary tales exist of firms where individual units were successful at recognizing or discovering the value of some new technology or practice but failed to communicate that to other parts of the organization (Szulanski, 1996). This creates opportunities for managers to intervene to increase the likelihood that organizational subunits will adopt valuable new technologies and practices as they arise.<sup>1</sup> Managers have a number of tools at their disposal from providing incentives to adopt specific technologies and practices to subsidizing the implementation costs of adoption.

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<sup>1</sup> Throughout the paper, we will refer to the adoption of practices and technologies. We use this phrase broadly so as to encompass the development of capabilities and the acquisition of resources as well.

In this paper, we explore the value of an information strategy versus an incentive strategy to increase absorptive capacity within the organization. In particular, we focus on “information provision” by managers -- the transfer of practice-specific data from a central knowledge repository (e.g., a corporate R&D lab) to agents within the firm that make technology adoption decisions (Lenox & King, 2004). Information provision may occur through a number of mechanisms such as internal seminars, demonstrations, knowledge management systems, and promotional brochures. Previous work has shown that managers may actively shape firm absorptive capacity through information provision within the organization (Lenox & King, 2004).

In the section that follows, we develop a series of hypotheses that propose when information provision may be favored over incentive strategies such as managerial fiat for promoting the adoption of valuable practices within the organization. We argue that information provision may provide efficiencies over other management strategies depending on the organization structure. In particular, we argue that information provision is favored the less concentrated and more diverse the organizational units of the firm. Furthermore, we propose the distribution of expertise across organizational units influences the efficacy and hence the use of information provision. To test our hypotheses, we explore when firms are likely to use an information provision strategy to promote the adoption of Pollution Prevention practices in manufacturing facilities in the information and communication technology sector in the United States. We find support for each of our hypotheses.

## **Theory & Hypotheses**

In their seminal paper, Cohen & Levinthal (1990) emphasize that absorptive capacity "depends on the transfer of knowledge across and within subunits that might be quite removed from the original point of entry (Cohen & Levinthal, 1990: p131)." Critical is whether relevant decision makers within the organization have the necessary knowledge to make an informed adoption decision when confronted with an opportunity. Ultimately, a firm's absorptive capacity is strongly tied to the coordination of knowledge within the organization.

Over the past decade, firms have invested heavily to increase the odds that the right piece of information ends up in the right hands. Knowledge management systems have proliferated as information technology has facilitated the storage and transfer of vast amounts of data. Chief information officers have been appointed to manage the flow of information among organizational units. In response to managerial trends such as total quality management, firms have invested heavily in internal marketing campaigns. Is such internal information provision worthwhile? More to the point, under what conditions is information provision useful?

Arguably, the structure of the firm – its size, the number and diversity of business units, the distribution of prior knowledge across these units – influence the efficacy and thus the use of information provision. To explore how organization structure impacts the efficacy of information provision, it is useful to consider the fundamental coordination problem firms face. On one hand, managers must coordinate incentives among multiple actors so as to encourage joint productive effort (Holmstrom & Milgrom, 1994; Holmstrom, 1982). On the other hand, managers must coordinate information and tasks among these actors (Marschak & Radner, 1972). The challenge to building absorptive capacity is in large part managing internal

incentives and information flows such that organizational actors are likely to make good resource and capability decisions as new opportunities present themselves.

### **Incentives & Information**

Given the time and effort required to search for and adopt new practices or technologies, employees will likely be hesitant to act without some personal benefit to action. Scholars have long recognized that individuals may act in ways unfavorable to the firm when individual incentives are not aligned with organizational incentives (Holmstrom & Milgrom, 1994; Holmstrom, 1982). In many cases, employment contracts provide the necessary incentives to employees to search for and adopt valuable, new practices. These contracts may include clauses or options that reward an employee when either the firm or the employee's work-unit performs well. Through bonuses, stock options, and performance reviews, employees often have incentives to do what is in the firm's best interest. These incentives may be sufficient to motivate employees to search for and adopt new practices even in the absence of direct orders from management.

However, employees may fail to adopt valuable new practices even in the presence of high-powered incentives when they do not have good information about the value of a practice or technology to the firm (Lenox, 1999). When confronted with an opportunity to adopt a new practice or technology, organizational actors make an assessment of the benefits of engaging in such behavior. Absent conclusive information on a practice's value, employees within the firm rely heavily on their prior experience to assess the costs and benefits of adopting a practice (Arrow, 1974; Jensen, 1982; von Hippel, 1994). As Tversky & Kahneman (1974) demonstrate, people use that information which is most "available" in their memory. If employees can more

easily perceive the cost of the practice versus the benefits, they may form a negative opinion of the practice's overall value. This is likely when the benefits to adoption are delayed and uncertain relative to the costs. This is often the case with the adoption of new technologies and practices. Employees may be well aware of the costs to implementing the practice but less sure of the benefits that may not be realized until well into the future. As a result, an employee uncertain of the value of a practice may fail to adopt a practice that is in fact beneficial.

In the end, the likelihood that the firm will make good adoption decisions, i.e. its absorptive capacity, is influenced by the distribution of both incentives and information within the organization.

### **Managerial Responses**

Managers may evoke a number of strategies to increase the likelihood that individuals in their organizations will correctly value and adopt valuable practices and technologies. For one, managers might simply demand adoption (managerial fiat) of specific valuable practices. Performance reviews and potential promotions induce adoption regardless of employees' expectations of the value of the practice to the firm. In some instances, managers may create bonuses or other forms of compensation specific to the adoption of the desired practice to provide additional incentives. This approach relies on two necessary conditions: 1) that managers are able to effectively monitor that employees adopt practices demanded of them, and 2) that managers are privy to some preferential information that allows them to form a more accurate estimate of the value of engaging in the practice.

The first condition is necessary to ensure compliance with managerial edicts. The second condition is necessary to motivate managers to intervene. If information sets were homogenous

throughout the organization, all would be in agreement about the value of the practice and managerial intervention would be unnecessary. Such a situation will likely be infrequent, however. There are a number of reasons to believe that top managers may be privy to preferential information about the value of specific technologies and practices. For one, given managers positions in firm hierarchies they have better access to local information across the organization. For example, top managers may have a better understanding of what is taking place in each of its divisions than divisions have of each other. In addition, most corporations have centralized functions that may generate important information on opportunities as they arise. Foremost among these functions is corporate R&D labs who may generate opportunities (i.e., innovations) themselves and who are likely most aware of developments outside the firm.

A fiat and monitoring strategy does not rely on decision makers to change their expectations about the value of a practice or technology. They adopt because they are required to do so. Information provision, on the other hand, relies on the transfer of practice-relevant information so as to increase the likelihood that an agent will correctly value a practice (Lenox & King, 2004). Recall that an agent may expect to gain little value from adopting a practice because of the salience of implementation costs and the uncertainty surrounding benefits. Assuming that at some level employees are motivated to help improve overall firm performance, information provision may reduce the uncertainty of adoption and consequently lower the risk to the decision maker. For example, a firm may establish a technical support unit that provides value-revealing information. By providing know-why managers may change the expectations of employees and consequently increase the likelihood of adoption. Stated another way, the manager reduces the search cost of the employee and thus lowers the overall cost of adoption.

Which particular strategy are managers most likely to pursue? One would expect that rational managers would adopt the strategy that is most efficient given the structure of the organization. Previous work has proposed that the efficiency of information provision is determined by the relative costs of monitoring agent's behavior and of providing practice-relevant information (Lenox, 1999). The more difficult it is to observe whether an agent has adopted a practice, the less effective is a monitoring strategy. The more difficult it is to acquire and transfer information to potential adopters, the less effective is information provision. In the following section, we explore how the distribution of size, markets, and expertise across organization units affects the choice of strategy.

## **Hypotheses**

We would expect information provision to be most effective in larger firms with multiple potential adopters. Providing information does not depend on the ability to observe behavior. By changing expectations, managers may encourage adoption without needing to monitor. Furthermore, the overall cost of management collecting and disseminating information may be less than the sum of the cost to each agent individually collecting the same data. In other words, managers may be able to acquire value-revealing information at lower cost than dispersed organizational units.

Interestingly, it is in these same less concentrated firms that we would expect monitoring to be more difficult. It has long been observed that larger, decentralized organizations are harder to manage (Lawrence & Lorsch, 1967). In such firms, managers will have greater difficulty observing activities in lower levels of the organization. In order to be effective, a strategy of

rewarding (or punishing) those who adopt (or fail to adopt) will require significant effort by managers to verify that agents have, in fact, adopted a practice.

We would therefore expect an information strategy to be more efficient, the more potential adopters with whom to share information. In essence, we propose that there are economies of scale to information provision that are not realized with monitoring. Stated another way, the less the firm is concentrated, i.e. reliant on a few large adopters, the more attractive an information provision strategy and less attractive a fiat and monitoring strategy.

*Hypothesis 1:* The less concentrated the firm, the more top management will rely on information provision.

Fiat and monitoring is also problematic when potential adopters vary greatly in their activities (Holmstrom & Milgrom, 1991). Often the returns to adoption will vary across decision making units of the organization. Individual units likely hold some private information about the applicability of the practice or technology to its situation. Managers lacking this idiosyncratic information are forced to decide on a management strategy based on the average value of adoption across all agents. While the manager would like to encourage adoption only among those agents from whom it is truly valuable, fiat and monitoring will provide incentives to those who should not be adopting as well.

The problems associated with this unobserved heterogeneity are more salient the more diversified the potentially adopting units, i.e., adopting units produce different products for different markets. For example, total quality management practices may be a valuable innovation for the hardware units of a computer manufacturing, but of limited value to the software unit. Diversification confounds attempts by management to construct general compensation systems. Diversification increases the risk that incentives will be incorrectly provided resulting in adoption in some instances and over adoption in others.

Interestingly, such concerns do not exist in the case of information provision. Private information held by the agent may be used in his or her assessment of whether engaging in the practice is worthwhile. Any additional information provided by managers will only improve those estimates. If the agent believes that engaging in a practice is not the best course of action, he or she will not engage in the practice.

*Hypothesis 2:* The more diverse potential adopting units within the firm, the more top management will rely on information provision.

Organizational actors may vary in their degree of familiarity or expertise with respect to a practice under consideration. Greater expertise<sup>2</sup> will arguably allow an individual or group to make a more accurate assessment of the value of adopting the practice. This is in essence the absorptive capacity hypothesis – prior related knowledge increases the likelihood that someone or some group will make better resource and capability decisions. To the extent that a decision making unit possesses prior related knowledge, the less management will need to advocate adoption (regardless of the advocacy strategy adopted). Thus, all else being equal, we would expect managers to use information provision less, the greater the expertise of individual decision making units.

On the flip side, if a decision making unit lacks prior related knowledge, the firm benefits greatly from managerial advocacy to promote adoption. However, information provision may be a less effective mechanism vis-à-vis fiat and monitoring in these situations. This is because a lack of prior related knowledge affects not only the ability to assess the value of engaging in some new practice but also affects the desire and ability of the organization actor to receive value-revealing information provided by managers. Without a requisite knowledge base,

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<sup>2</sup> For our purposes, “expertise” is simply shorthand for “prior-related knowledge”.

information provision efforts may fall on deaf ears. After attending a corporate “dog and pony” show, an employee with limited expertise in the given area may leave confused and unconvinced of the practice’s value. In these same instances, a managerial dictate to adopt the practice followed up with monitoring would remain effective regardless of the agent’s prior related knowledge.

Thus, we propose that the use of information provision will be curvilinear with the average expertise of potential adopting units within the firm. In particular, we expect that managers will be more inclined to use information provision as average expertise increases but that the desire to use information provision will eventually decline as expertise becomes great.

*Hypothesis 3:* The use of information provision by top management will be concave with respect to the average expertise of potential adopting units within the firm.

When deciding on an appropriate advocacy strategy, managers must consider not only the average distribution of expertise across decision making units, but the variance of expertise as well. We propose that the greater the variance in prior related knowledge across organizational decision-making units, the more desirable is an information provision strategy. Our reasoning centers on the risk of over-adoption with monitoring versus information provision (similar to Hypothesis 2). Greater variance in expertise across decision-making units increases the right tail of the distribution, increasing the percentage of those firms for whom advocacy is unnecessary. If we assume that not all organizational units create value by adopting the practice under consideration and that the expertise of those units is distributed uniformly across the population, increasing variance increases the percentage of those firms who adopt under a monitoring strategy who otherwise would (correctly) not adopt. While the marginal value added of an

information provision goes down as well, an information provision strategy should not cause units to go against their beliefs.

*Hypothesis 4:* The greater the variance in expertise across potential adopting units within the firm, the more top management will rely on information provision.

## **Data & Method**

To test our hypotheses, we collected data on the diffusion of Pollution Prevention practices across firms within the information and communications technology (ICT) industry. Pollution Prevention is the reduction of pollution through the design or redesign of products and/or manufacturing processes. Adoption of Pollution Prevention practices takes place at the manufacturing facility level. This setting was chosen because field studies revealed vast differences in the knowledge of Pollution Prevention practices between corporate managers and facility-level decision makers. When it first appeared, Pollution Prevention was a new practice of uncertain value. Consequently, diverse expectations arose among potential adopters and managers.

### **Setting**

The information and communications technology industry is a broad industry including makers of computers, servers, storage devices, telecommunications equipment, semiconductors, and printed circuit boards. While the ICT industry is generally perceived as a “clean” industry, it faces a number of environmental challenges spanning the entire product life cycle including the use of high levels of water, energy, and toxic chemicals in manufacturing, the phase-out of CFCs

in manufacturing cleaning processes, the use and reuse of lead solder, energy efficiency during product use, and the recycling of metals and plastics at the end of product life (Frankel, 1998).

Pollution Prevention arose among a set of leading firms and industry groups as a way to prevent pollution through the design or redesign of products and/or manufacturing processes. As early as 1990, the American Electronics Association, a professional organization for the ICT industry, began convening task groups to formalize and standardize Pollution Prevention practice. In general, Pollution Prevention is a set of management practices and tools that aided in the consideration of environmental issues during design. Pollution Prevention was related to and built upon other innovations in operations management such as total quality management, design for manufacturing, and design for serviceability.

By 1991, Pollution Prevention was beginning to diffuse across the ICT industry. Early research revealed a strong resistance by facility-level managers within firms (Shelton, 1994; Lenox & Ehrenfeld, 1997). Faced with the prospect of dedicating valuable time to the consideration of environmental issues, managers were reluctant to adopt Pollution Prevention practice without a clear indication of its value. The impacts on the natural environment from individual design choices were often difficult to assess. Assessing the return to the firm for a pro-environmental decision was even more difficult. As a result, diffusion of Pollution Prevention at the facility level was uneven and strongly influenced by the diverse expectations of individual managers.

In response, corporate environmental managers in a number of firms established company-wide programs to encourage the adoption of Pollution Prevention (Lenox & Ehrenfeld, 1997). At IBM, the CEO signed an executive order requesting all design teams to adopt Pollution Prevention (Lenox, King, & Ehrenfeld, 2000). A number of firms adopted policy

statements asserting their commitment to pollution prevention. A few firms established incentive programs making Pollution Prevention a criterion in performance reviews. Other firms established teams to promote Pollution Prevention in their firms (Lenox & Ehrenfeld, 1997). These groups typically developed pamphlets and held seminars touting the benefits of pollution prevention.

## **Sample**

We collected data on Pollution Prevention practices in U.S. information and communications technology manufacturers during the period 1991 through 1996. We identified an initial population of 221 publicly traded firms that were included in the Standard & Poor's Compustat Annual Database<sup>©</sup> and who had U.S. manufacturing facilities in the ICT industry.<sup>3</sup> We collected data in two phases. Firm attribute data were collected from Compustat as well as other archival sources. Data on managerial strategies were collected using a survey of corporate environmental managers within each firm. Field study indicated that corporate environmental managers were, in general, best suited to reflect on corporate Pollution Prevention efforts. While Pollution Prevention programs may or may not be administered by such a manager, corporate environmental managers were found to be extremely knowledgeable of such efforts given the relationship between Pollution Prevention and their responsibilities. This company-level survey was mailed to all 221 firms. Two follow-up mailings were administered. Seventy-two responses were received from corporate environmental managers for a response rate of 33%. A number of firms entered or exited (due to closure or sale) during the period 1991-1996 and were

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<sup>3</sup> We defined the ICT industry by the following 4-digit Standard Industrial Classification (SIC) codes: semiconductors (3674), printed circuit boards (3672), components & peripherals (3577 & 3679), storage (3572

consequently excluded for those years, leaving a final sample of 473 firm-year observations for the 72 participating firms.<sup>4</sup>

## Measures

**Dependent Variable.** Our primary dependent variable is the level of information provision used by top management to promote the adoption of Pollution Prevention practice within their facilities. We created two measures that capture information provision both absolutely and relative to other advocacy efforts. *Inform-Relative* is the percentage of effort spent on information provision relative to the total effort spent advocating Pollution Prevention adoption within the firm. This total effort includes not only time spent providing value-revealing information but also time spent monitoring adoption and providing technical support. *Inform-Absolute* is measured as the number of full time equivalents (employees) at the corporate level providing value-revealing information on Pollution Prevention and was created by multiplying *Inform-Relative* by the total number of full-time equivalents dedicated to advocating Pollution Prevention adoption within the firm.

These data were gathered via the survey mechanism mentioned earlier. In the survey, we first defined Pollution Prevention as “the prevention of pollution through the design or redesign of products and/or manufacturing processes.” We asked whether anyone at the corporate level (headquarters) ever promoted Pollution Prevention practices within the company and, if so, to

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& 3695), computers (3571 & 3575), imaging technology (3579), and telecommunications equipment (3661, 3663, & 3669).

<sup>4</sup> Using archival data collected for all 221 firms, we found that the final sample did not differ significantly from the initial population with one exception. Larger firms (measured as the natural logarithm of firm assets) were found more likely to respond to the survey. The test for respondent bias was conducted using a probit model with archival data as independent variables and the dependent variable indicating whether or not a firm was a respondent.

please indicate the overall level of that activity in full-time equivalents for each year from 1990-1996. To prime the respondents on the type of activities that may constitute information provision, we asked a series of questions concerning the degree to which they engaged in specific information provision activities.<sup>5</sup> We then asked survey respondents to indicate the percent of effort communicating the value of Pollution Prevention within the firm relative to the total full-time equivalents dedicated to promoting pollution prevention.<sup>6</sup>

The survey instrument was constructed using insights from a field study of four firms' attempts to diffuse Pollution Prevention practices. Approximately a half-dozen open-ended interviews were conducted in each firm over a three-month period. Interviewees included corporate-level environmental managers as well as designers and product managers on the establishment level. These interviews were supported with additional information from company publications, journal articles, and news releases. The four companies were selected because of their status as widely recognized leaders in Pollution Prevention practice. Four additional corporate environmental managers and ten product managers reviewed survey items. Pilot testing demonstrated that the measures were consistently well understood.

**Independent Variables.** To test Hypotheses 1 and 2, we measure the degree to which production in the company is concentrated in a few facilities (*Concentration*) and the degree to which facilities' output is diversified into various lines of business (*Diversification*).

*Concentration* is calculated as the sum across all facilities of the squares of the percent of total

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<sup>5</sup> Activities include communicating past experiences, providing information on future regulation or customer demand, using demonstration projects, and distributing brochures. Respondents were asked to judge the firms use of each activity on a scale of 1 (not at all) to 7 (very much).

<sup>6</sup> The Cronbach alpha among the responses to the list of common mechanisms and the number of FTE's doing information provision is 0.87 indicating strong inter-item correlation and increasing our confidence that FTE's is an accurate reflection of information provision.

employees in each single facility. *Diversification* is measured as one minus the sum across all facilities of the squares of the percent of total employees in each industry segment as specified by the firm's facilities' 4-digit SIC codes. In both cases, facility employee data were gathered from the Dun & Bradstreet Million-Dollar Database.

To test Hypotheses 3 and 4, we measure the distribution of Pollution Prevention expertise across facilities in the firm. We capture this distribution in two ways. Our first measure, *Expertise-Average*, reflects the average expertise of each facility within the firm. Our second measure, *Expertise-Variance*, is the standard deviation of the distribution of expertise across firm facilities. To measure the Pollution Prevention expertise of individual facilities, we adopt King & Lenox's (2002) approach and calculate the difference between the expected waste generation of a facility given its industry segment and size and its actual waste generation. This measure has the desirably property of reflecting a facilities expertise in reducing waste at the source rather than the use of end-of-pipe pollution control technology.

Following King & Lenox (2002), we first measure the total toxic waste generated at a facility in a given year by calculating the sum of 246 toxic chemicals that have been released into the environment, treated onsite, and transferred offsite while weighting each chemical by its toxicity using the Reportable Quantities (RQ) list in the CERCLA statute. Data for this calculation were collected from the U.S. EPA's Toxic Release Inventory (TRI).<sup>7</sup> Next, we estimate a quadratic function between facility size and total waste generation for each 4-digit Standard Industry Classification (SIC) code within each year using standard OLS regression.

$$W_{it} = e^{\alpha_{jt}} s_{it}^{\beta_{1jt}} s_{it}^{\ln(s_{it}) * \beta_{2jt}} e^{\varepsilon_{jt}} \quad (1)$$

$$\ln W_{it} = \alpha_{jt} + \beta_{1jt} (\ln s_{it}) + \beta_{2jt} (\ln s_{it})^2 + \varepsilon_{jt} \quad (2)$$

where  $W_{it}$  is aggregate waste generated for facility  $i$  in year  $t$ ,  $s_{it}$  is facility size,  $\alpha_{jt}$ ,  $\beta_{1jt}$ , and  $\beta_{2jt}$  are the estimated coefficients for sector  $j$  in year  $t$ , and  $\varepsilon_{jt}$  is the residual. We use the estimated function to predict the amount of waste each facility would generate given its size, industry, and year.

$$W_{it}^* = e^{\alpha_{jt}} s_{it}^{\beta_{1jt}} s_{it}^{\ln(s)^* \beta_{2jt}} \quad (3)$$

$$RW_{it} = -e^{\varepsilon_{jt} / \sigma_{\varepsilon_{jt}}} \quad (4)$$

where  $W_{it}^*$  is predicted waste generation for facility  $i$  in year  $t$ ,  $RW_{it}$  is the standardized relative performance for facility  $i$  in year  $t$ , and  $\sigma_{\varepsilon_{jt}}$  is the standard error of the residual for the SIC and year pair. We change the sign of the residual so that positive scores indicate more Pollution Prevention expertise.

**Control Variables.** Since we are interested ultimately in why managers use information provision versus other options, we control for other types of managerial intervention. *Total PP Effort* reflects the total full-time equivalents dedicated to promoting Pollution Prevention activity in the firm. As described earlier, this measure reflects effort not only towards information provision but also time spent monitoring adoption and providing technical support. We tease this out further by including a measure of monitoring activity. *Monitoring* reflects the total full-time equivalents dedicated to monitoring adoption of Pollution Prevention practices. This measure is highly correlated (>90%) with the degree to which corporate headquarters provides explicit rewards (or punishment) for adoption (or failure to adopt) pollution prevention.<sup>8</sup>

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<sup>7</sup> Since 1987, all U.S. manufacturing facilities have had to complete TRI reports if they manufacture or process 25,000 pounds of any listed chemical during a calendar year, use more than 10,000 pounds, and employ ten or more full-time people. All the firms in our sample have facilities listed with the TRI.

<sup>8</sup> *Monitoring* was created in the same way that *Inform-Absolute* was created. The degree to which adoption was rewarded was measured using our survey through a seven-item scale where one indicates that pollution prevention adoption is rewarded “not at all” and seven indicates pollution prevention adoption is rewarded “very much”.

A number of factors beyond managerial intervention may influence the extent of information provision within firms. Larger firms with more facilities may realize economies of scale in information provision and therefore may be more likely to use information provision. We measure firm size as the log of employees (*Firm Size*). We measure *Firm Facilities* as the log of the count of firm manufacturing facilities. R&D intensive firms may also realize economies in information provision to the extent that they are more likely to generate value-revealing information on individual practices and technologies. We measure *R&D Intensity* as the ratio of research expenditures to total firm assets.

Finally, as the number of facilities within a firm adopting Pollution Prevention practices increases, the marginal return from information provision decreases. This is due not only to the fact that there are fewer potential adopters, but also because facilities are more likely to receive value-revealing information from other facilities rather than corporate managers. First, there is a greater likelihood that a facility has heard of a practice the more others have adopted (Ryan & Gross, 1943). Second, previous adopters may provide information about the costs and benefits of engaging in the practice (Mansfield, 1968). Finally, previous adoption may provide an incentive for adoption if facility managers are concerned about maintaining legitimacy (Tolbert & Zucker, 1983). To capture these effects, the percent of all facilities within the firm adopting Pollution Prevention practices was calculated for each year (*% of facilities adopting*). We code a facility as adopting Pollution Prevention practices if the facility indicates in the Source Reduction Activity (SRA) fields of the Toxic Release Inventory that they ever have reduced pollution through a product or process modifications.<sup>9</sup>

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<sup>9</sup> The SRA fields list a number of practices that facilities may engage in to reduce pollution. “Process Modifications” (elements W51, W52, W53, W54, W55, W58) and “Product Modifications” (elements W81, W82, W83, W89) are a subset of those practices.

Summary statistics and descriptions of all our variables are provided in Table 1. Pair-wise correlations between our variables are provided in Table 2.

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Insert Tables 1 & 2 about here  
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## **Analysis & Results**

Descriptive data on our survey of managerial activity reveals that firms increasingly advocated the use of Pollution Prevention during the time frame of the study. In 1990, over 60% of the firms in our sample had adopted a policy advocating the adoption of Pollution Prevention techniques within the firm (see Figure 1). However, less than 5% had actually dedicated any effort to promote compliance with the policy either through information provision, implementation support, or monitoring adoption. By 1996, nearly all the firms in our sample had adopted a Pollution Prevention policy and nearly 50% had put forth some effort to encourage its adoption among their manufacturing facilities. Of those putting forth effort, over three-fourths engaged in some level of information provision during the year.

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Insert Figure 1 about here  
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To test our hypotheses, we begin with a series of models using *Inform-Absolute* as our dependent variable. Since this is an absolute level measure, we include our measure for the overall level of promotional effort firms put forth (*Total PP Effort*) to control for the overriding incentives the firm has to adopt Pollution Prevention practice that might otherwise effect the

overall level of information provision. We make full use of our panel and include firm and year fixed effects to control for stable sources of unobserved heterogeneity. We estimate our model using ordinary least squares.

We begin with a base model not including any of our independent variables (Model 1, Table 3). We find, not surprisingly, the greater the overall promotional effort (*Total PP Effort*), the greater the absolute level of information provision. Interestingly, we find a positive, significant coefficient on *Monitoring*. This suggests that there may be complementarities between monitoring and information provision. (We leave speculation to what these complementarities may be to the discussion section.) Our base model explains 90% of the overall variance, 84% of which is picked up by our year and firm fixed effects.

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Insert Table 3 about here  
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In Model 2, we add our two organization structure variables, *Concentration* and *Diversification*. We estimated a negative, significant coefficient for *Concentration*, i.e., the more concentrated the firm the less the use of information provision. We estimate a weak significant, positive coefficient for *Diversification*, i.e., the more diversified the firm the more the use of information provision. Thus, we find support for both Hypotheses 1 and 2.

In Model 3, we add our expertise variables. Consistent with Hypothesis 4, we find a significant, positive coefficient on the variance in expertise. We estimate significant, negative coefficients on both average expertise and the square of average expertise. Graphing the combined effect of these two estimates reveals a concave curvilinear relationship between expertise and information provision (see Figure 2). Consistent with Hypothesis 3 we find that

for levels of expertise well below the mean, firms are less likely to use information provision. As average expertise increases, firms are more likely to use information provision until a point at which the use of information provision declines.

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Insert Figure 2 about here  
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As a robustness test, we make use of our second measure of information provision, *Inform-Relative*. Recall that *Inform-Relative* is the ratio of information provision to total effort ( $Inform-Absolute / Total\ PP\ Effort$ ). The advantage of this measure is that it factors out the incentives to promote Pollution Prevention directly rather than through the inclusion of *Total PP Effort* as a control. The disadvantage of this measure is that it removes from our sample all firms who do not put forth any effort to promote Pollution Prevention practice adoption (due to the zero in the denominator). To address this sample selection bias, we adopt a two-stage Heckman selection model (Heckman, 1979). In the first stage, we estimate the likelihood that a firm puts forth any effort to promote Pollution Prevention using a Probit model. In the second stage, we regress our independent variables and controls on *Inform-Relative* correcting for the first-stage selection.

For our first stage model, we include a series of regressors that attempt to capture the private incentives the firm may have to reduce their pollution. These include the relative waste generated by the firm across all of its facilities, the total count of regulatory permits that the firm has received, the average industry toxic emissions for the firms primary industry classification, and the average industry compliance costs of the firm estimated using the U.S Census Bureau's pollution abatement cost and expenditure (PACE) data. In addition, we include firm size and

firm facilities to capture scale effects that might drive action (e.g., larger firms are more visible and may find themselves under greater scrutiny from environmental activists and consumers.)

Since we are pooling across individual firm-year observations, we run the risk of underestimating our standard errors. To correct for this, we cluster on firm. Note that this does not address the lack of independence between firm-year observations. As a robustness test, we also collapsed the panel into a cross-section by averaging observations for each firm across time and found similar results. (While both the panel with clustering and the collapsed cross-section models have their short-comings, together they provide greater confidence in our results.)

Our results are consistent with our previous results with two exceptions. First, we find a significant, negative coefficient on monitoring in Model 4. This is not surprising since our dependent variable is the *relative* use of information provision. Greater use of monitoring reduces the relative use of information provision holding the absolute level of information provision constant. Second, we are no longer confident that our estimate for *Expertise-Variance* is different than zero though the magnitude of the coefficient remains consistent with previous models. We should not mistake a lack of significance, however, for disconfirming evidence given the constraints of this specification. We continue to find that less concentrated and more diversified firms are more likely to use information provision and that the use of information provision is concave with the average expertise of decision making units.

## **Discussion**

In summary, we find support for each of our hypotheses. Less concentrated, high diversified firms with high variance in expertise across their facilities use greater levels of information provision to promote the diffusion of practice within their firm. Furthermore, we

observe a concave, curvilinear relationship between the average expertise of facilities and the use of information provision. Information provision is most used when, on average, facilities possess enough expertise that they are receptive to the information provided by not so much expertise that the information adds little value.

Our findings are robust to a number of specifications and controls. We adopt firm and year fixed effects and adopt a two-stage model to handle selection issues in some of our models. While we find only weak significance ( $p < 0.10$ ) for some of our variables of interest, this may be attributed in part to our use of firm fixed effects in a relative wide (number of firms) but short (number of years) panel. Removing our firm fixed effects from our estimation, each of our independent variables is significant at the 0.01 level.

Our hypotheses are built on an assumption that managers believe that adoption of the practice is valuable for units of the firm at least on average (otherwise, management would be unlikely to advocate adoption). While it is an open question whether managers are likely to have better information than lower-level decision makers within the organization, we believe this to be a reasonable assumption. First, given the nature of hierarchy within organizations, it is likely that top managers are privy to information that others within the organization are not. Second, the issue of whether managers are correct in their beliefs is largely irrelevant to the question of the actions they may take based on those beliefs. While this has important prescriptive implications for managers, it should not impact our hypotheses or results. With respect to information provision, the possibility of manager error, in fact, increases the value of information provision vis-à-vis alternative strategies such as fiat and monitoring.

While our hypotheses center around the relative costs and benefits between information provision and other advocacy strategies, it is important to recognize that these strategies need not

be pure substitutes. We present evidence that information provision and monitoring may be correlated and, in even, complementary at some level (Models 1-3). Monitoring, for example, may make potential adopters more attentive to information provision. Most firms in our sample evoke a mixture of information provision and managerial oversight (monitoring). At the margin, however, we believe that firms are deciding about the relative use of one strategy versus another. Supporting this claim is the significant negative coefficient between monitoring and the relative use of information provision (Model 4). In the end, we believe that firm strategies may evolve over time and reflect differences in the likelihood to adopt among organizational units. We leave such an exploration to future research.

## **Conclusion**

Within the resource-based view of strategy there has been considerable progress in identifying why certain resources and capabilities once acquired may be a source of enduring competitive advantage (Barney, 1986). Recently, progress has been made in identifying how firms acquire these desirable resources and capabilities in the first place. Scholars have proposed that some firms possess a “dynamic capability” to form more accurate expectations about the future benefits of specific resources and capabilities (Teece & Pisano, 1994). Differences in expectations arise because of causal ambiguity between organizational actions and economic outcomes (Lippman & Rumelt, 1982) and information asymmetries between firms (Arrow, 1974). Some firms are more skilled at others at processing value-revealing information and consequently are more likely to make good resource and capability decisions over time (Teece & Pisano, 1994; Cohen & Levinthal, 1990).

Absorptive capacity is central to this acquisition and development of rent-producing resources and capabilities and is thus critical to sustained competitive advantage. This paper furthers our understanding of how firms build the absorptive capacity to recognize the value of new resource and capabilities. We present evidence that organizational structure influences the strategic choices of managers to use information provision. Less concentrated, more diversified firms with greater variance in expertise are found to more likely pursue a strategy of information provision. These findings suggest that managers of large, diverse firms may be able to build absorptive capacity within their organizations (Cohen & Levinthal, 1990; Lenox & King, 2004). Managers may observe a lack of proficiency in various knowledge domains and consciously work to build new knowledge bases. For example, research and development labs could play an important role, not only as innovation generators, but also as information-acquisition centers. These groups may be very effective at scanning the environment and collecting practice-relevant information that managers can subsequently use to help diffuse valuable new practices and technologies within their organizations.

By exploring the conditions under which an information provision strategy may be useful, we provide guidance for how managers may facilitate the flow of information within the organization and, in doing so, help develop a more robust understanding of how firms build and sustain competitive advantage.

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**Table 1. Descriptive Statistics (ICT Industry: 1991-1996)**

Variable	Description	Mean	Standard Deviation	Min.	Max.
Inform – Absolute	Log of information disseminated by headquarters (measured in full-time equivalents)	0.106	0.273	0.000	1.792
Inform – Relative	Ratio of information dissemination to total Pollution Prevention advocacy effort	0.361	0.254	0.000	1.000
Concentration	Sum of squares of facility percent production	0.708	0.334	0.019	1.000
Diversification	1 - sum of squares of sector percent production	0.142	0.241	0.000	0.850
Expertise - Average	Average facility deviation in waste generation (positive values indicate less waste)	-0.041	0.798	-2.289	2.266
Expertise - Variance	Variance in facility deviations in waste generation	0.426	0.541	0.000	2.541
Total PP Effort	Log of total Pollution Prevention advocacy effort (measured in full-time equivalents)	0.121	0.358	0.000	2.398
Monitoring	Log of monitoring by headquarters (measured in full-time equivalents)	0.203	0.160	0.143	1.000
Firm Size	Log of employees	6.901	2.052	2.303	12.569
Firm Facilities	Log of plants	0.825	1.038	0.000	4.913
R&D Intensity	Research expenditures / total assets	0.044	0.048	0.000	0.219
% of facilities adopting	% of firm facilities adopting Pollution Prevention practices	0.446	0.421	0.000	1.000

Note:  $n = 473$  except for *Inform - Relative* where  $n = 119$ .

**Table 2. Correlations (ICT Industry: 1991-1996)**

	1	2	3	4	5	6	7	8	9	10	11	12
1.Inform – Absolute	1.00											
2.Inform – Relative	0.49 *	1.00										
3.Concentration	-0.12 *	0.04	1.00									
4.Diversification	0.14 *	0.10	-0.76 *	1.00								
5.Expertise - Average	-0.16 *	-0.20 *	0.01	-0.05	1.00							
6.Expertise - Variance	0.15 *	0.06	-0.66 *	0.50 *	0.04	1.00						
7.Total PP Effort	0.82 *	0.02	0.09	-0.06	-0.13 *	-0.04	1.00					
8.Monitoring	0.25 *	-0.19 *	-0.23 *	0.18 *	-0.01	0.14 *	0.20 *	1.00				
9.Firm Size	0.15 *	-0.23 *	-0.68 *	0.64 *	-0.02	0.54 *	0.05	0.20 *	1.00			
10. Firm Facilities	0.09	-0.10	-0.89 *	0.82 *	-0.03	0.63 *	-0.08	0.20 *	0.79 *	1.00		
11. R&D Intensity	0.03	-0.22 *	-0.18 *	0.15 *	0.10	0.20 *	0.07	-0.07	0.31 *	0.18 *	1.00	
12. % of facilities adopting	0.06	0.01	0.12	-0.05	0.03	0.03	0.02	0.12 *	0.07	-0.05	0.05	1.00

Note:  $n = 473$  except for *Inform-Relative* where  $n = 119$ , \*  $p < 0.01$

**Table 3. The extent of information provision by firms to encourage Pollution Prevention within their facilities (ICT Industry: 1991-1996)**

<i>Specification</i>	OLS with Fixed Effects	OLS with Fixed Effects	OLS with Fixed Effects	Heckman Selection <sup>a</sup>
<i>Dependent Variable</i>	Inform - Absolute	Inform - Absolute	Inform - Absolute	Inform - Relative
<i>Model</i>	1	2	3	4
Concentration		-0.158 ** (0.054)	-0.146 ** (0.055)	-0.245 + (0.143)
Diversification		0.090 + (0.053)	0.091 + (0.053)	0.614 *** (0.127)
Expertise -- Average			-0.014 + (0.007)	-0.063 * (0.031)
Expertise -- Average <sup>2</sup>			-0.011 + (0.006)	-0.057 + (0.032)
Expertise -- Variance			0.027 * (0.013)	0.035 (0.047)
Total PP Effort	0.377 *** (0.023)	0.390 *** (0.023)	0.398 *** (0.023)	
Monitoring	0.377 *** (0.043)	0.366 *** (0.043)	0.375 *** (0.043)	-0.275 ** (0.090)
Firm Size	0.003 (0.009)	0.011 (0.008)	0.011 (0.009)	0.043 (0.035)
Firm Facilities	0.013 (0.017)	-0.073 * (0.029)	-0.074 * (0.029)	-0.198 ** (0.067)
R&D Intensity	0.128 (0.188)	0.186 (0.186)	0.168 (0.185)	-0.906 (0.569)
% of facilities adopting	0.028 + (0.016)	0.029 + (0.016)	0.029 + (0.016)	0.099 + (0.061)
Year Dummies	included	included	included	included
Firm Dummies	included	included	included	
Mill's Ratio				0.283 ** (0.109)
n	473	473	473	473 <sup>b</sup>
firms	72	72	72	72
F-stat (Wald $\chi^2$ in Model 4)	59.74 ***	53.74 ***	45.11 ***	113.71 ***
Adjusted R <sup>2</sup>	0.9072	0.9218	0.9226	

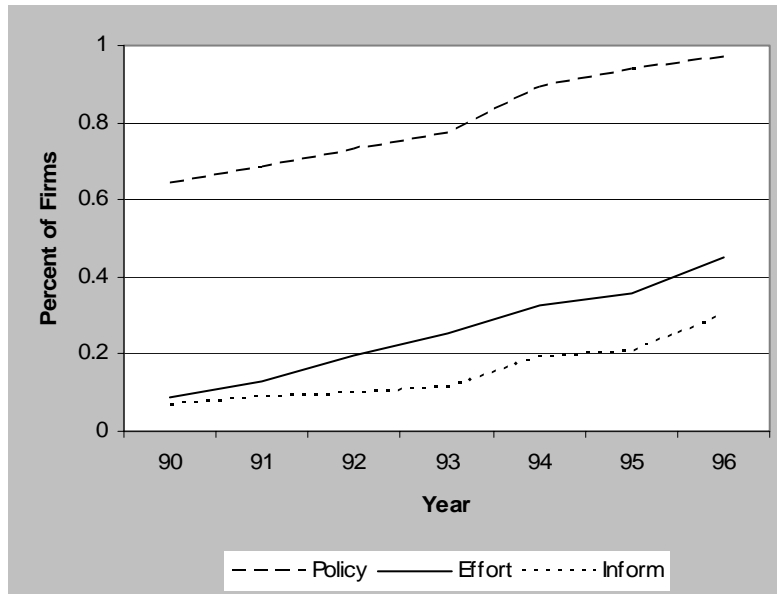
Standard errors in parentheses

<sup>+</sup>  $p < 0.10$ , \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

<sup>a</sup> The first stage of the selection model uses a probit specification where the dependent variable is whether or not a firm puts forth any effort to advocate Pollution Prevention within the firm. The coefficients and standard errors for our independent variables in the probit model: relative waste generated (0.119, 0.158); total permits (0.075, 0.036); sector emissions (-2.598, 1.249); compliance costs (0.001, 0.003); firm facilities (-0.063, 0.026); firm size (0.372, 0.091). Wald  $\chi^2 = 22.80$  \*\*\*. Pseudo R<sup>2</sup> = 0.1691.

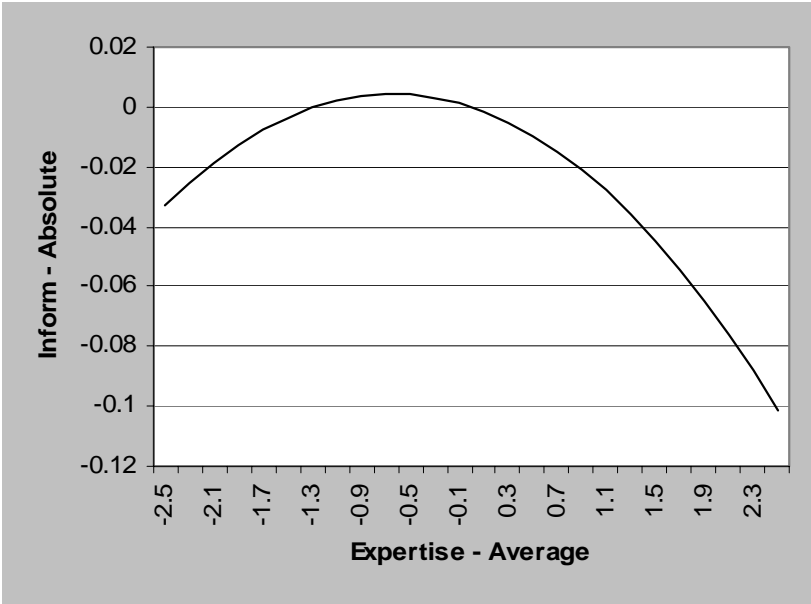
<sup>b</sup> 119 uncensored and 354 censored observations.

**Figure 1. Growth in Pollution Prevention advocacy over time**



“Policy” refers to whether or not the firm had a policy advocating the adoption of Pollution Prevention practices. “Effort” refers to whether or not the firm put forth any effort to promote adoption. Specifically, whether they dedicated person-hours to provide information, support implementation, or monitor adoption. “Inform” refers to whether or not the firm engaged in any information provision. Sample is 72 U.S. public firms in the information and communication technology sector.

**Figure 2. Marginal effect of expertise on the use of information provision**



*Expertise-Average* is the average Pollution Prevention expertise of facilities within the firm standardized within a facility size and industry sub-sector. A score of one reflects that on average a firm’s facilities are one standard deviation above the mean (given their size and sector). *Inform-Absolute* is the number of full-time equivalents dedicated to providing information on the value of adopting Pollution Prevention practices within the firm.