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Monitoring Technical Agents: Theory, Evidence, and Prescriptions

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Abstract

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Published: 2009
URL: http://www.business.uiuc.edu/Working_Papers/papers/09−0103.pdf

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Monitoring Technical Agents: Theory, Evidence, and Prescriptions

In the modern economy, a division of labor is a division of knowledge (Sharma 1997). Managers often find themselves supervising individuals whose specialized knowledge exceeds their own, and this is especially true of general managers and "C-level" executives. Senior executives must monitor individuals with significant, and significantly different, education and experience in multiple functions such as finance, marketing, technology, operations, and law. Such a problem presents a theoretical conundrum. In the language of agency theory, principals (executives) monitor agents (specialists) with hidden knowledge, and must induce them to employ that knowledge in products, services, and projects. But the effectiveness of monitoring hinges on a crucial assumption: the monitor must know as much as the monitored (Fama and Jensen 1983a, b; White 1985). Whether the monitor knows as much as the monitor is an empirical question. In the context of certain manufacturing processes or routine clerical duties, such an assumption is perhaps justified. In the case of technology or other advanced skills, the assumption would appear to be questionable.

In this paper we empirically investigate how executive human capital affects the ability to monitor better-informed technical professionals. The empirical setting is information technology (IT). The role of IT in today's firm can hardly be overstated. As reported in the US Department of Commerce's "Survey of Current Business," today IT spending consumes over 50% of corporate capital budgets. Theoretically, IT shares properties with all forms of technology: it is complex and cumulative, and often requires specialized expertise. And the close link between information and managerial decision making gives information technology significant organizational impact (Campbell-Kelly and Aspray 1996; Dewett and Jones 2001).

The study proceeds as follows. Theory is reviewed in the first section, and hypotheses proposed. The second section presents data and the third results. The fourth section discusses results, and introduces the concept of staged commitment as a solution to the problem of monitoring technical agents. A conclusion follows.

MONITORING TECHNICAL AGENTS

An agency relationship exists whenever one party (the principal) delegates authority to another (the agent). Because agents are assumed to be self-interested and to possess goals that diverge from the principal's goals, the principal must expend resources to insure that agents act in the principal's interests (Eisenhardt 1989; Jensen 1986; Jensen and Meckling 1976). Otherwise, the agent has incentive to indulge its own interests at the expense of the principal.

In the usual formulation of the agency problem, agents are presumed to put forth less than full effort into their tasks (Eisenhardt 1989; Holmstrom and Tirole 1989; Jensen and Meckling 1976). Agents are thus characterized as shirking. Much work has examined how to deter shirking by top management teams (as agents) and the Board or shareholders (principal) (e.g., Dalton et al. 1998). A second line of research notes that executives are rarely shirkers; they put forth considerable effort but such effort may not benefit the firm. The agency problem can take the form of *misdirected* effort rather than *lack* of effort. In particular, executives can take actions to increase the value of their human capital at the expense of the shareholders of the firm (Morck et al. 1990; Shleifer and Vishny 1989). Individuals are heterogeneous in their human capital, and the returns to human capital depend in part on the activities the firm undertakes. For example, in the absence of other evidence, size and scope of activities under a manager's control may signal the "quality" of a manager to the external labor market. If employees can turn the firm's activities in a direction that is more complementary to their human capital, they stand to gain (Holmstrom 1982; Morck et al. 1990). In a variant of this, employees turn the firm's activities in such a way as to make their human capital indispensable, thus entrenching themselves (Shleifer and Vishny 1989). Or managers may prefer to manage some projects over others (Demsetz 1983; Holmstrom and Ricart I Costa 1986).

As these examples demonstrate, agency theory stresses the role of opportunism, defined as self-interest seeking with guile, to justify the need for monitoring. Although sufficient, the strong assumption of opportunism is not necessary to show the need for monitoring. From the standpoint of the principal, "honest incompetence" can require monitoring even of altruistic, non-opportunistic agents (Hendry 2002). If the principal cannot completely define the objective, the agent must use initiative and discretion to achieve the objective. An agent with a successful career to date in an organization is likely to have overconfidence in judgment, such that the agent presumes the best path to achieve the goal involves more use of the agent's human capital (Beach and Connolly 2005; Levitt and March 1988; March 1994). So honest incompetence by the principal coupled with the natural (over)confidence of the agent can lead to overuse of the agent's human capital in the absence of monitoring. For analytical simplicity, we describe this as "misdirected effort" to avoid requiring that the agent is opportunistic.

To prevent misdirected effort, the principal engages in monitoring (Eisenhardt 1989; Jensen and Meckling 1976; Ouchi 1979). With monitoring, executives supervise managers in an effort to detect misdirected effort. But the effectiveness of monitoring hinges on a crucial assumption: the monitor must know as much as the monitored (Fama and Jensen 1983a, b; Sharma 1997; White 1985). In the extreme case, when the knowledge of the agent is the primary contribution to the value of the firm, the principal cannot effectively monitor (Allen and Sherer

1995; Fama and Jensen 1983a, b; Sharma 1997). As a result, the agent buys out the principal and eliminates the agency problem entirely (Jensen and Meckling 1976). In the extreme case, when the knowledge of the agent is the primary contribution to the value of the firm, the principal cannot effectively monitor (Allen and Sherer 1995; Fama and Jensen 1983a, b). Theory prescribes that the agent buys out the principal and eliminates the agency problem entirely (Jensen and Meckling 1976)—a solution that is not practical in most settings. More generally, whether the monitor knows as much as the monitor is an empirical question.

In a technical environment, the general manager, as monitor, must evaluate whether technical managers are misdirecting effort by proposing projects or expenditures. For the monitor to know as much as the monitored, the general manager would be expected to have knowledge of, or access to knowledge about, technology in order to manage subordinate managers of technology. Managers need absorptive capacity, a prior knowledge that "permits the assimilation and exploitation of new knowledge." (Cohen and Levinthal 1990: 135.) The necessary absorptive capacity to manage technology, however, may be different than absorptive capacity needed for other managerial tasks. Monitoring technology requires "an ability to evaluate projects and programmes where the normal financial accounting techniques are often inoperable and inappropriate" (Pavitt 1998: 445).

A fundamental property of technology makes management of technology more difficult for general managers. Technical knowledge contains "cumulative features" (Dosi, 1982: 154). Technical knowledge is organized into paradigms, defined as patterns of solutions to specific technical problems with specific principals and technologies (Dosi 1982; Patel and Pavitt 1997). A technical trajectory is the pattern of normal problem solving within a paradigm (Dosi 1982). But the conclusions of these paradigms and trajectories cannot be easily obtained, acquired, or absorbed without possessing capabilities regarding these paradigms and trajectories (Brusoni et al. 2001; Cohen and Levinthal 1990; Dosi 1982). As noted by Cohen and Levinthal 1990: 128, "The ability to evaluate outside knowledge is largely a function of the level of prior related knowledge….Prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it to commercial ends." Nor can the knowledge be easily summarized. The cumulative nature of technical knowledge is unlikely to allow a significant reduction of information to facilitate monitoring. By contrast, financial information is routinely summarized into one or a few metrics (e.g., Hoskisson et al. 1993).

Given the cumulative nature of technical knowledge, generalists will not easily acquire such knowledge without retraining. Thus the general manager is often a poor monitor of the technical manager. In all likelihood, a reversal of agency will occur (White 1985), by which the general manager becomes the agent of the better-informed technical manager.

Information technology is chosen as the venue to test for the possibility of the failure of monitoring of technical managers. In the late 20th century advances in computer technology of personal computers, local area networks, and wide area networks, as well as the older investment in mainframes, were in existence but not widely adopted or integrated (Campbell-Kelly and Aspray 1996; Hevner and Berndt 2000). The convergence of technologies presented an enormous opportunity for firms to fit existing business processes with IT, in the process automating them and making them more effective (Hevner and Berndt 2000). Such a conclusion is supported by the research on the effect of IT on firm performance, reviewed in several places (Dehning and Richardson 2002; Devaraj and Kohli 2003; Dewett and Jones 2001; Indjikain and Siegel 2004; Link and Siegel 2007; Melville et al. 2004). In general, IT is most effective when coupled with other organizational changes to adapt the new technology to specific business purposes (Brynjolfsson and Hitt 2000; Simmons 1998; Walton 1989). Contingencies affecting the workforce have been examined. Upgrading skill levels of the workforce and decentralizing decision making can enhance the gains from IT (Bresnahan et al. 2002; Brynjolfsson and Hitt 2000; Indjikain and Siegel 2004; Siegel 1999). In summary, how work is organized affects IT's impact on performance.

Such an opportunity may also afford the chance for IT managers to misdirect effort, however. Top management and board members are likely to have experience in other functional areas of business, such as finance, marketing, or operations (Barker and Mueller 2002; Fligstein 1990). In the period under study, many senior executives rose to the top without significant information systems experience. A review of the leading business directory of CEO backgrounds reveals that no CEO during the period under study had IT functional experience (Business Week 1988-1992). Lacking such expertise, many CEO's appear to find it difficult to manage the IT function, enhancing power of IT managers (Jarvenpaa and Ives 1991).

If IT managers engage in misdirected effort, they are likely to overestimate the effects of their technology. Whether such overspending represents a cognitive bias or a deliberate effort to enrich themselves by enhancing the value of their human capital, the result is the same: overspending. Hence overspending would lead to negative effects on firm performance. This suggests two hypotheses:

Hypothesis 1: Spending on information technology <u>hardware</u> will negatively affect firm performance.

Hypothesis 2: Spending on information technology <u>staff</u> will negatively affect firm performance.

The task of IT staff is not purely technical, but instead to embed IT in business applications, such as matching IT to the needs of the business, anticipating IT needs of customers, and working with the firm's non-technical managers (Davis 1998; Henderson and Venkatraman 1999; Walton 1989). In short, it is the task of IT staff to adapt IT to the firm. As a result, top managers may be more adept at judging the success of the staff at adapting IT to the firm than judging whether the quantity of hardware is appropriate. Therefore:

Hypothesis 3: Spending on IT staff will have a less negative effect on corporate performance than spending on IT hardware.

Because there are multiple influences on performance, all hypotheses should be interpreted ceteris paribus, controlling for other factors. Hypotheses are tested after the data are described.

It is well established that executives of different backgrounds will approach problems differently and make decisions differently based upon their managerial human capital (e.g., Barker and Mueller 2002; Dearborn and Simon 1958; Hambrick and Mason 1984; Kor et al. 2007; Wiersema and Bantel 1992). It would seem that some kinds of managerial human capital might make it easier to manage technical professionals. We propose:

Hypothesis 4: Managerial human capital will affect monitoring of spending on IT staff and spending on IT hardware.

This dull hypothesis is dull for a reason. The proposition that "the monitor must know as much as the monitored" suggests that lawyers would be better at managing lawyers, marketing professionals at managing marketing staffs, and the like. Beyond this simple distinction, theory offers little guidance, leading to armchair theorizing about what marketing professionals know relative to finance professionals. To avoid such impressionistic hypothesizing (and angering our disciplinary colleagues), in the spirit of Hambrick 2007; Locke 2007 we simply report our results and offer interpretation to suggest further inductive theorizing.

DATA AND METHODS

Data Sources

The overall research design is to estimate a performance equation including various measures of IT investment with appropriate controls. There are two primary sources for the data used in the analysis: Computerworld surveys over the period 1988-1992 for IT investment, and the Compustat database for non-IT variables. The surveys targeted firms in the top half of the Fortune 500 Manufacturing and Fortune 500 Service listings. About two-thirds of the data set consists of firms from the manufacturing sector while the rest are service firms. Not all firms are observed for each of the five years. On average the firms are observed three of the five years, but about 50 firms are observed only once. Previous researchers have extensively documented the nature and content of these surveys (e.g., Brynjolfsson and Hitt 1996). These data are the only data available on firm level IT spending at the level of depth required for this study.

The historical period under study offers a unique opportunity to examine misdirected effort. At this time, the primary business imperative for IT was “characterized by efforts to apply the wide range of technologies to better support existing business processes, as well as to enable the design of entirely new processes.” (Hevner and Berndt, 2000: 14.) Therefore the situation did create opportunities for agency. And, as noted above, executive experience in the MIS function was lacking (Business Week, 1988-1992). The business press has anecdotally documented that overspending on IT was a common problem at that time (Anthes 2001; Farrell et al. 2003; Losee 1996 (Sept. 9)). One author argued to “give your MIS department a time-out—as if they were a bunch of unruly toddlers—and freeze your IT budget" (Losee, 1996: 112). Thus the period offers a good test for the theory.

Measures

Construction of the variables is as follows. The dependent variable of firm performance is measured alternatively by two variables: a simplified form of Tobin's Q, and Return on Assets (ROA). Accounting measures are frequently criticized for failing to measure properly knowledge and other intangible assets (Quinn and Baily 1994). These intangible assets are likely to be especially important in the case of IT (Quinn and Baily 1994). The simplified form of Tobin's Q employed is computed as the market value of the firm divided by the book value of its assets, termed market to book ratio and abbreviated MVA. Both market to book ratio and return on asset measures are analyzed.

Among the independent variables, a measure for the hardware investment of the firm is constructed by aggregating the market value of computers owned by the firm, the market value of central processors and an estimated value of PCs and Terminals, as estimated by management. The other key IT variable, Spending on IT Staff, is reported directly by management, and includes the dollars spent on salaries, benefits, and training. To control for possible size effects, both are normalized by dividing by firm sales.

The hypotheses are to be tested in the context of a performance model for firms that must control for other influences. In order to suggest possible control variables, we use as a starting point the meta-analysis of firm performance reported by Capon et al. 1990. From their list, we select variables that have been shown to have significant effects on performance. The control variables included in the performance equation are: R&D intensity (annual R&D expenses divided by total assets), debt to equity ratio, average three-year sales growth rate, market share, size, diversification, and vertical integration. The first three are available in Compustat directly. We compute a sales-weighted composite market share variable as $\sum_{j=1}^{N} m_{ij} s_{ij}$, where m_{ij} is the market share of firm i in industry j and s_{ij} is the sales share of industry j in the total sales of firm i. Firm size is measured as the natural logarithm of total sales. Related and unrelated diversification are measured by the entropy measures (Palepu 1985), using Compustat business segment data. Finally, vertical integration is measured by the ratio of value added to sales (Scherer and Ross 1990a). Value added to sales is probably the best measure available, and it is commonly used in the literature (Scherer and Ross 1990b). Annual value added is measured as Sales minus Materials, each deflated by the GDP deflator.

In addition, industry and time indicator variables were also employed in order to control for industry and year effects. The firm's major line of business was identified and classified into one of ten categories, and nine indicators employed in the regression. Potential industry effects of monopoly power or industry concentration are captured in market share (Schmalensee 1989), as employed above. Indicators were also added for the year of observation.

Research Design and Methodology

Multiple regression is used to test the hypotheses. Specifically, the performance equation estimated is given by

$$\pi_{it} = A + \beta_1 (MS)_{it} + \beta_2 (GS)_{it} + \beta_3 (DE)_{it} + \beta_4 (R\&D)_{it} + \beta_5 (LS)_{it} + \beta_6 (RD)_{it} + \beta_7 (UD)_{it} + \beta_8 (VS)_{it} + \beta_9 (IT)_{it} + \beta_{10} (Staff)_{it} + \varepsilon_{it} \qquad (1)$$

where i and t index the firm and year, respectively, and the variables are (construction of proxies for the variables is described in the following section): π = firm performance or profitability; MS = sales-weighted market share of the firm in the various industries in which it operates; GS = sales growth rate; DE = debt to equity ratio; $R\&D$ = research and development intensity (ratio of R&D spending to sales); LS = proxy for firm size (logarithm of dollar value of sales); RD = entropy measure of related diversification, UD = entropy measure of unrelated diversification; VS = degree of vertical integration (ratio of value added to sales); IT = ratio of IT hardware to sales; $Staff$ = ratio of spending on IT staff to sales.

The panel data structure needs to address issues of autocorrelation and heteroscedasticity. Estimating using ordinary least squares on panel data is not appropriate because of the possible violation of the OLS assumption of the error term being independent and identically distributed. First, errors are not likely to be independent. Errors of the same firm at different times are likely to be autocorrelated. For example, if the model overshoots American Airlines in 1989, it is likely to overshoot American Airlines in 1990 as well. Second, cross sectional data frequently display heteroscedasticity; variance of the error is not identical across firms.

To correct for heteroskedasticity and autocorrelation, one appropriate technique is generalized least squares with clustering (sometimes called generalized estimating equations) (Greene 1997; Liang and Zeger 1986). The technique of generalized least squares adjusts the estimation of the variance matrix of the error term to allow for possibly non-independent and non-identically distributed errors. First, the firms are clustered, and an autocorrelation coefficient is computed for each firm. Second, a heteroskedastic consistent covariance matrix across clusters/ firms is employed. A necessary adjustment for degrees of freedom must be done. In a panel, the degrees of freedom of all statistical tests are lowered by using the number of clusters (firms) not observations (firm-years) because the observations are not independent.

As a result, the GLS procedure gives more conservative significance tests than OLS. But interpretation of signs and significances is the same as OLS.

RESULTS

Table 1 presents summary statistics, including mean, standard deviation, and correlations for all variables in the performance equation.

Is IT Effectively Monitored?

The results for testing Hypothesis 1, 2, and 3 are reported in Columns 1 and 2 of Table 2. Equation (1) is estimated using MVA (market value to book ratio) and ROA (return on assets) as the dependent variable using generalized least squares. The equations using both MVA and ROA (columns 1 and 2) are significant at conventional levels, and they explain between 20-40% of the variance in the respective performance variable. Further confidence in the results is warranted by the coefficients on the control variables. All have signs that are consistent with the results of the meta-analysis of Capon, Farley, & Hoenig (1990). A better fit is obtained using the market-based MVA measure as compared to the accounting-based ROA measure, offering support that accounting measures are inferior to market-based measures to identify the impact of IT on performance.

To facilitate interpretation, variables **bolded** are the subject of discussion with regard to hypotheses. Hypothesis 1 argued that managers would overspend on hardware, so hardware would negatively affect performance, and the coefficient on hardware spending as a percentage of sales should be negative. As shown in Table 2, spending on IT hardware has a negative and significant coefficient ($p<.05$), using either measure of performance, supporting Hypothesis 1.

Hypothesis 2 argued that technology managers would overspend on staff as well, and negatively affect performance. As shown in Table 2, spending on IT staff has a positive and significant coefficient ($p<.05$), using either measure of performance. Hypothesis 2 is not supported. The effect of IT is independent from any effect from research and development spending, since that variable was included as well. The high bivariate correlation of R&D and Staff IT suggests possible multicollinearity, but a test using variance inflation factors showed no evidence of the problem.

Hypothesis 3 predicted that the negative effect of IT staff spending would be less than that of hardware spending. Because each variable is measured in the same units (percentage of sales), a simple test of the difference of coefficients will suffice. As reported at the bottom of the table, a test of the difference of coefficients shows a significant difference; significant at the 1% level for ROA (F-statistic 7.13) and the 5% level for market to book (F-statistic 3.95). It appears that staff expenditures are easier to monitor than hardware purchases.

Interpreting the results of the hypotheses, it appears that monitoring problems exist in the hardware purchases of the firm but not in the staffing. Each result is discussed in turn.

Indulging the preferences of agents is one well-known manifestation of agency. For top management, command of corporate jets is a desired perk of office (Burrough and Helyar 1990). For engineers, having the latest and most powerful technology is likely to be the desired perk. As with corporate jets, justification surely exists for such expenditure, yet the results has shown that, on average, this tendency of engineers has negative performance consequences.

The positive effect of staff suggests that the monitoring problem is mitigated with respect to staff. Perhaps the opportunism of engineers extends only to things, not people; engineers are unwilling to pad the staff. Implicit social norms or expectations of co-workers may constrain the willingness of engineers to hire not-so-necessary staff, or perhaps the staffers themselves are unwilling to work if their talents are not fully employed. How social forces limit opportunism of engineers would be a valuable subject for further research.

An alternative, consistent with misdirected effort by technical professionals, is that monitoring by top management is more effective for staff than hardware. We suspect but cannot show that this is because staff is engaged in producing business solutions, and such solutions can indeed be judged by managers. Although individuals may not be able to monitor specific purchases, they can identify whether particular projects meet customer or internal needs.

The role of managerial human capital

To test Hypothesis 4, that managerial human capital affects monitoring, additional data and variables are required. To measure managerial human capital we adopt the categories of Hambrick and Mason 1984, grouping executives into those with experience in output functions, throughput functions, and peripheral functions. Output functions are "marketing, sales, and product R&D-[that] emphasize growth and the search for new domain opportunities and are responsible for monitoring and adjusting products and markets." Throughput functions are "production, process engineering, and accounting-[that] work at improving the efficiency of the transformation process." Peripheral functions are "law and finance."

For background on the chief executives in the above data set, we consulted the Business Week Corporate Elite special issues corresponding to the year the firm's IT spending was observed. This data source has been used successfully by others (e.g., Barker and Mueller 2002). The data was compiled by survey and confirmed by reporters and staff of the magazine, allowing for a high degree of confidence. The CEO's career experience was reported in six categories:

marketing/sales, productions/ operations, engineering/R&D, finance/accounting, legal, and administration.[1] Interestingly, no executive was listed as having IT experience. The categories do not perfectly correspond to Hambrick and Mason 1984, but the overlap is significant. Marketing/ sales was coded as "output," finance/accounting, legal, and administration were coded as "peripheral," and productions/ operations plus engineering/R&D[2] were coded as "throughput." and These indicator variables were then interacted with spending on IT hardware and IT staff to determine if some executives were better able to monitor technical agents. To avoid confounding effects, the only executives used were ones who had only a single functional expertise among the three proposed.[3] Overall there were 647 observations on 239 firms. Of 647 CEO-year observations, 228 were classified as firms with "throughput" executives, 204 as "output", and 215 as "peripheral."

Results are reported in Table 3. Again, variables **bolded** are the subject of discussion. Interestingly, peripheral functions did not affect performance differently than throughput functions, suggesting that neither were especially effective at monitoring. But executives from marketing showed a significant difference, supporting Hypothesis 4. Their negative coefficient on hardware spending was larger than others, suggesting that marketers were poor judges of equipment purchases. And their positive coefficient on staff spending suggests that they were better-than-average monitors of staff tasks. Because the two variables are measured in the same

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[1] In a few cases, experience was listed as "founder" or "entrepreneur." These individuals were omitted from the analysis.

[2] The data did not allow the distinction suggested by Hambrick and Mason, new product development, but it is likely that these two categories share a similar familiarity with IT, offering further validity.

[3] We omitted executives with more than one function. The data source does not distinguish duration of experience, an important loss. And the test is more powerful if focused on a single function.

units (percentage of sales), one can compare effects. The ability to focus staff spending appears to offset the lack of control of hardware spending, and marketing professionals appear to make better monitors.

IMPLICATIONS

> *From Star Trek V: The Final Frontier:*
>
> *Starship Captain Kirk: "Tell me, Mr. Scott. Why do you always multiply your repair estimates by a factor of four?"*
>
> *Starship Chief Engineer Scott: "To preserve my reputation as a miracle worker, Sir!"*

The notion that the "monitor must know as much as the monitored" creates a special challenge in the world of technology. Call it Jensen's curse. It is unlikely that managers can understand the technological frontier as well as the engineers and scientists whose schemes they are charged to evaluate and manage. Yet manage they must. In this research results suggest that engineers did overspend on hardware but that managers were capable of directing staff spending to advance business goals. An obvious managerial suggestion is to monitor hardware spending more closely to improve corporate performance, given that computers are the dominant item in corporate capital budgets. However, managers have sought to control agency through supervisory monitoring previously, with what appear to be poor results. Therefore, to provide prescriptions we use a broader approach. First, a brief theoretical examination of the effectiveness of other controls for agency might help. Here we discuss incentives, alternative forms of monitoring, and socialization. Second, we review a suggested control from the practitioner literature in order to incorporate it into the scholarly conversation.

Alternative Controls

Compensating individuals based upon their contribution is a powerful idea, one used with success in many management settings. To do so requires that the individual's contribution be effectively measured (Alchian and Demsetz 1972; Barzel 1982; Holmstrom 1982). For some technology projects, such measurement would be possible. However, given that information systems are deeply embedded in the organization, "team production" is likely to make measurement difficult. Hence incentives have limited use.

A second possibility is to separate the task of evaluating the project from the task of doing the project. One route to do this is to hire a consultancy with expertise and use them to evaluate internal projects such as hardware upgrades. Because such individuals are paid by the hour, not the project, their success is not dependent upon the adoption of the project, and they may be more likely to give unbiased responses. The success of this approach depends on whether external forces can evaluate internal technology, which, in turn, depends upon whether the technical trajectory is public or private. If the work that gives rise to the particular problem is developed through a private trajectory, then an outsider is unlikely to be able to offer an effective evaluation. Also, the firm managing the project may desire to protect proprietary assets which the consultancy may or may not be able to protect.

A third option is socialization, here defined as training that inculcates values of the organization. Charting a clear vision of the success of the company, and the need for the individual's participation, has been argued as a solution to other problems within the management of technology (Tushman and O'Reilly 1997). In many cases engineers and scientists take a parochial view of their research project; the success of the firm depends upon the success of their project. This in turn could lead to the distortion of information that agency theory predicts. To get engineers to see beyond their projects to corporate goals, and to see the success of the company as the objective should be the goal of socialization. Existing socialization through corporate training programs is short and not specialized to engineering; one to two days is the norm. Firms should consider adopting specialized training and socialization explicitly for engineers. An important caveat affects doctoral level employees, however. Research has suggested that Ph.D.'s are particularly difficult to socialize, and are unlikely to ever adopt fully corporate goals as their own (Katz and Allen 1997) . Hence in the hiring decision one might trade off the powerful intellectual capital of a Ph.D. against the increased possibility of agency.

An inferior choice is to rely on the socialization of engineers and scientists through their professional training. Professional training in other areas, such as medicine and law, includes socialization regarding responsibility to clients, presumably intended to curb opportunism. In each a professional society also operates to curb opportunism through public exhortation and private discipline of wayward members. Unlike doctors and lawyers, however, engineers and scientists have almost no training in professional ethics, nor does their professional training discuss responsibilities towards clients. Their professional societies cannot remove an engineer from practice. Hence relying on professional socialization is a poor choice.

Another possibility is to promote engineers more aggressively. Japanese companies have long been noted for the number of engineers in the top ranks of their organization, while American firms have used finance and marketing as routes to the top. Engineers are likely to make better monitors of engineers. In a related vein, an opportunity exists for continuing education of managers in technology. Such courses should share common characteristics. First, they should draw on common fundamentals in, say, physics and chemistry, and computer science to acquaint managers with capabilities and trends in a field. They should be delivered in shorter formats than a semester, and not require extensive prerequisites. The focus should be on tool using rather than tool building. An interesting contrast is the case of statistics. In the university one can find similar statistical material covered in ways appropriate to sophisticated statisticians and also in ways appropriate to undergraduate social science majors. The second approach is rare in other areas of science and engineering, and not a part of professional programs.

An Alternative Implementation of Control: Staged Commitment

A number of practices used by industry to manage technical projects might very well be subject both to theoretical analysis and prescriptive recommendations. Such practices have been rarely discussed by academic researchers, although some of the topics are covered in different practitioner literatures. To integrate across these literatures, I term the proposed implementation of control as “staged commitment.” Before I state more precisely what staged commitment is, it is useful to give several examples that illustrate its generality.

- Most firms use a stage gate system for managing technical products and projects (Cooper 2001). Rather than a single effort, “develop a new product and launch it,” projects and products are broken into a series of activities that are then organized into stages. As activities within a stage are completed, a stage is reviewed at a gate. At the gate, the product manager can pass the project to the next stage, return the project to the same stage for more activities, or kill the project outright. Criteria used at the gate can include technical specifications but also includes timeliness and market criteria as well. Stage gate systems are widely discussed in the marketing practitioner literature.

- Venture capital frequently proceeds in rounds, with the VC infusing a sum of money to move the product one step closer to market (Gompers and Lerner 1999). Rather than turning over funds for an entrepreneur to take a product to market, investments are made in rounds. A first round of funding might allow the development of a prototype, the second round to allow for scale-up of the concept, and the third for rollout. A new round requires the entrepreneur to complete certain steps to which the entrepreneur and the VC have previously agreed.

- Production of a new television series does not proceed by a network giving funds to a producer to develop a full set of 26 episodes required for a season's viewing. Instead, one or several pilots are made (Vogel 2007). A television pilot is a test episode of an intended television series. Networks use pilots to discover whether an entertaining concept can be successfully realized, and to see how the various themes and characters interact. After seeing this sample of the proposed product, networks will then determine whether the expense of additional episodes is justified.

- A homeowner contracts with a carpenter to remodel his kitchen. The homeowner makes only partial payment while the work is in progress, and retains the right not to pay in full until the carpenter accomplishes the work to the homeowner's satisfaction.

These dissimilar situations display a common structure. In each case, the principal, who must monitor the agent, has some knowledge of *what* needs to be done, but is ignorant of *how* the work can be done. Subject to Jensen's curse, the monitor does not know as much as the monitored. Yet the solution to the problem is staged commitment. In each case the principal, as monitor, effectively commissions the monitored agent to engage in a creative act. The monitor then judges the efficacy of the attempt, and chooses whether to release the project to a subsequent stage. In each case, the monitor sets objectives for the agent to meet. If those objectives are met, the monitor then pays the agent—an incentive is left for completion.

Two important amplifications need to be made.

First, whether the objectives are met is left exclusively to the judgment of the principal. There is no explicit contract with specific objective criteria that requires the principal to release the product and pay the agent. Instead, the judgment is subjective, usually based in part based upon market criteria that the principal can judge. This uncertainty induces a best effort from the agent, and prevents "gaming the system" by satisfying, for example, technical criteria that may have no effect on market needs or demand. It also gives the monitored agent an incentive to reveal at least some information to develop a better-informed principal.

Second, the incentive for the agent may be cash, or it might be the release of the product into the next stage of development, and ultimately the marketplace. In cases where agents are paid through royalty or other "percentage of sales" compensations, denying the product access to the market costs the agent. Or releasing the product may simply offer the incentive of publicity, use, and fame to generate future business opportunities or internal satisfaction for the agent. Thus the incentive can be but need not be financial.

A system of staged commitment need not yield an optimal outcome. Consistent with the general principle of comparative institutional analysis (Demsetz 1969; Williamson 1985), staged commitment systems need only generate enough savings to justify the added cost. In other words, staged commitment must be cheaper than alternative institutional arrangements. The widespread use of staged commitment in multiple and varied settings testifies to the likelihood that it is successful. Research into the stage gate system suggests that overall it is cheaper than other methods for organizing product development (Cooper 2001).

Staged commitment is a control for agency that has not been analyzed before. Thus it is important to examine the relationship of staged commitment to existing theories of organization.

One existing explanation for such behavior might be real options reasoning, specifically as the application of the principle of waiting to invest (Mahoney 2005). Such theory has been offered to explain the rounds of venture capital investment (Gompers and Lerner 1999). Rather than making a single upfront investment, the VC makes a series of staged investments in order to reveal information. At each step, more information is revealed, and technology risk and/or market risk declines. The VC reevaluates the proposed venture to determine whether it is worth a further investment. This is the prevailing explanation for this practice.

Undoubtedly, staged commitment reduces technology risk or market risk if uncertainty is resolved through the passage of time or the completion of stages of the product. However, the system of staged commitment also prevents reversal of agency. Nowhere is this more evident than in the last example. Remodelling a kitchen is not really subject to significant technical or market risk—the only explanation for the practice can be control of misdirected effort. In addition, projects within companies vary in their degree of technical and market risk, yet all use stage gate systems.

Others might suggest that this is a simple application of property rights theory from economics (Mahoney 2005). In the face of incomplete contracts, property rights theorists argue that residual claimant status falls to the party with the largest sunk cost investment. In other words, the party that makes the larger investment in a transaction-specific asset should, for the sake of inducing efficient investment, own the asset in the long run. Although such an assessment is correct, the theory of staged commitment adds several important pieces to this analysis. First, in the traditional property rights formulation, the dynamics of the problem are ignored. By contrast, staged commitment specifically introduces the dynamics, stating the temporal sequence of investment. The dynamics highlight an important part of the incentive structure, which is more likely to induce information from agents. Second, it highlights the role of ex post incentives, and highlights that the release of the product to the marketplace is itself a motivation. Third, it demonstrates the logic in use by managers and uses that to develop theory to provide a base for further analysis.

In summary, controlling misdirected effort by engineers requires a more sophisticated approach than simply monitoring by uninformed principals.

CONCLUSION

Agency theory has attracted research attention to the information and incentives of individuals within organizations. The role of incentives has been extensively studied, and has led to a number of normative prescriptions. In addition to incentives, however, economic actors must also have sufficient information, a less studied implication of agency theory. In order to manage technologists, general and top managers must manage a process that causes individual engineers to reveal information regarding technology. Such information comes from their own experience, from reliable and unbiased third parties, or from firm insiders. Also, processes can be developed using the principles of staged commitment that can induce the revelation of information and mitigate the effects of misdirected effort. These principles can only become more valuable, both for theory and for practice, as the division of knowledge in the economy grows.

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Table 1
Means and Correlations among the Variables

Name	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11
1. Market to book (Tobin's q)	1.11	0.75	1										
2. ROA	4.76	6.49	0.58**	1									
3. Weighted market share	0.33	0.53	0.04	0.09**	1								
4. Growth in sales	3.83	9.35	0.22**	0.20**	0.02	1							
5. Debt to equity	2.22	14.96	-0.03	-0.15**	-0.03	-0.08**	1						
6. R&D to sales	1.98	2.81	0.22**	0.11**	0.07	0.03	-0.07*	1					
7. Log of sales	8.36	1.21	-0.03	0.05	0.13**	-0.14**	-0.10*	0.06	1				
8. Related div.	0.22	0.33	0	-0.04	0.13**	-0.18**	-0.06*	0.30**	0.06	1			
9. Unrelated div.	0.43	0.44	-0.15**	0.12**	0.40**	-0.18**	-0.01	-0.02	0.15**	-0.05*	1		
10. Hardware spending to sales	1.05	210	-0.10	0.23**	0.1	-0.12**	0.04	-0.04	0.53**	-0.04	-0.09	1	
11. Value added to sales	0.41	0.16	0.02	-0.28**	0.08**	0.10**	0	0.12**	0.15**	0.01	0.01	-0.02	1
12. Staff IT spending to sales	0.63	136	-0.11**	-0.27**	-0.10*	-0.06	0.05	0.83**	0.55**	-0.03	0.09	0.75**	0

Significance level indicated with $p<0.05$ = *, $p<0.01$ = **.

Table 2
Performance Effects in Information Technology

	(1)	(2)
Performance measure	*ROA*	*MVA*
Constant	4.682	0.936
	(1.84)+	(2.81)**
Weighted market share	0.940	0.138
	(1.77)+	(1.68)+
Growth in sales	0.089	0.013
	(2.90)**	(3.20)**
Debt to equity	-0.210	-0.010
	(2.70)**	(1.17)
Log(sales)	-0.117	-0.012
	(0.47)	(0.34)
Related div. (RD)	-0.593	-0.275
	(0.73)	(2.32)*
Unrel. div. (UD)	-1.001	-0.244
	(1.62)	(2.56)*
Value added	7.815	0.964
	(4.28)**	(3.78)**
R&D / Sales	0.521	0.964
	(3.25)**	(3.78)**
Computer hardware / sales	**-0.106**	**-0.110**
	(2.84)**	**(4.20)****
IT staff spending / sales	**0.095**	**0.008**
	(2.49)*	**(2.09)***
Observations	878	876
R-squared	0.27	0.35
F-statistic for the equation	8.23**	6.13**
F-statistic for the test of equality of coefficients of Hardware and Staff Expense	**7.13*****	**3.95****

Robust t-statistics in parentheses; significance levels marked with + significant at 10%; * significant at 5%; ** significant at 1%; all in two-tailed tests. Industry and time indicators included but not reported for space.

Table 3
CEO Experience Impacts on Information Technology Performance

	(1)	(2)
Performance measure	*ROA*	*MVA*
Constant	10.468	1.286
	(4.34)**	(3.21)**
Weighted market share	0.835	0.093
	(1.26)	(0.94)
Growth in sales	0.080	0.017
	(2.63)**	(3.08)**
Debt to equity	-0.331	-0.026
	(2.71)**	(2.15)*
Log(sales)	-0.671	-0.039
	(2.71)**	(1.00)
Related div. (RD)	-1.261	-0.361
	(1.45)	(2.75)**
Unrel. div. (UD)	-1.341	-0.240
	(1.94) +	(2.08)*
Value added	7.926	1.073
	(3.48)**	(3.15)**
R&D / Sales	0.424	0.099
	(2.24)*	(3.45)**
IT hardware / sales * Peripheral executive	**0.019**	**-0.018**
	(0.06)	**(0.44)**
IT staff spending / sales * Peripheral executive	**-0.844**	**-0.091**
	(1.27)	**(0.95)**
IT hardware / sales * Throughput executive	**0.120**	**-0.057**
	(0.19)	**(1.21)**
IT staff spending / sales * Throughput executive	**0.058**	**0.005**
	(0.18)	**(0.11)**
IT hardware / sales * Output executive	**-0.583**	**-0.103**
	(2.21)*	**(2.70)****
IT staff spending / sales * Output executive	**1.349**	**0.133**
	(2.87)**	**(2.04)***
Observations	647	647
F-statistic (24, 238)	6.36**	5.03**

R-squared	0.32	0.39

Robust t-statistics in parentheses; significance levels marked with + significant at 10%; * significant at 5%; ** significant at 1%; all in two-tailed tests. Industry and time indicators included but not reported for space.