Information Technology and Internal Firm Organization: An Exploratory Analysis

LORIN M. HITT AND ERIK BRYNJOLFSSON

LORIN M. HITT is an Assistant Professor of Operations and Information Management at The Wharton School, University of Pennsylvania. He received his Ph.D. in management from the MIT Sloan School of Management and his Sc.B. and Sc.M. in engineering from Brown University. His current research is on the role of strategic and organizational factors in the productivity of information systems investments and the economics of contracting for IS outsourcing arrangements. His work has appeared in *Management Science, MIS Quarterly,* and *Economics of Innovation and New Technology.*

ERIK BRYNJOLFSSON is an Associate professor at MIT, where he holds the Douglas Drane Chair, and is currently visiting Stanford Business School. His research analyzes the organizational and performance implications of advances in information technology and develops optimal pricing strategies for digital information. His teaching focuses on the strategic uses of IT and electronic commerce. He received A.B. and S.M. degrees from Harvard University and a Ph.D. from MIT. Dr. Brynjolfsson lectures internationally for business and academic audiences. His research has won numerous awards and has frequently been cited in publications such as *Fortune, Business Week, The Economist,* and *Scientific American.* Research papers are available from his Web page: **http://ccs.mit.edu/erik.html**.

ABSTRACT: This paper examines the relationship between information technology (IT) and the organizational architecture of firms. Firms that are extensive users of information technology tend to adopt a complementary set of organizational practices that include: decentralization of decision authority, emphasis on subjective incentives, and a greater reliance on skills and human capital. We explore these relationships using detailed data on work systems and information technology spending for 273 large firms. Overall, we find that increased investment in IT is linked to a system of decentralized authority and related practices. Our findings may help resolve some of the questions about the relationships of information technology to internal organization and provide insight into the optimal organization of knowledge work.

KEY WORDS AND PHRASES: information, overload, information technology incentives, organizational architecture, technology usage.

AS THE INDUSTRIAL ERA GIVES WAY TO THE INFORMATION AGE, there has been a shift in the internal organization of many large firms away from hierarchical structures

Eric K. Clemons served as guest editor for this paper.

Journal of Management Information Systems / Fall 1997, Vol. 14, No. 2, pp. 81–101

0742–1222 / 1997 $9.50 + 0.00

toward a greater reliance on decentralized authority, teamwork, and supporting incentives. This shift has been compared in scale and scope with the organizational changes associated with the earlier industrial revolutions. For example, Piore and Sabel [48] write of a "second industrial divide" between centralized mass production and knowledge-intensive "flexible specialization." Drucker [11] calls it the "third period of change: the shift from the command-and-control organization . . . to the information-based organization, the organization of knowledge specialists."

This trend has been analyzed in a number of books and articles,[1] but its underlying causes are not well understood. One possibility is that the exhaustion of mass markets may have undermined the traditional organizational form to the extent it depended on sustained growth [48]. Other possible causes include the emergence of new competitive pressures that eliminate the slack required by the old system [32] or the appearance of a growing supply of educated workers willing and able to take on the demands of information work [11]. Alternatively, the new system may represent a "workplace innovation" that had not been discovered in the past [28].

Just as the rise of large corporations coincided with a shift from handicraft to machine production and the development of new technologies such as the railroad and the telegraph [42], so the information-based organization coincides with the widespread diffusion of modern computing technology. Increasingly, computing technology can improve coordination and communications abilities throughout the firm. The development of the personal computer in the early 1980s shifted the location of computing power from large centralized "utilities" to workers' desktops. In 1987, there was a personal computer (PC) for every thirty employees in Fortune 1000 firms; by 1994, there was one PC for every six.[2] In the same time period, there has been tremendous growth in technologies such as local area networks, databases, and "groupware." These changes have transformed computers from their traditional role as "back-office" support for accounting, finance, and logistics into tools that are fully integrated into all aspects of production. The development of decentralized computing technologies has also coincided with the emergence of business process redesign, which emphasizes radical changes in work organization supported by investments in information systems [20, 21].

This paper probes the possible relationship between information technology and internal organization by examining how information technology affects the location of knowledge within an organization; how IT interacts with limits to human information processing; and how new capabilities enabled by IT affect optimal incentives for knowledge workers. We first examine these relationships and predict what types of organizational practices are likely to support the changes enabled by IT. We then test whether the predicted set of practices actually appears in large firms using an exploratory dataset on organizational practices and information technology investments for 273 large firms.

Overall, we find that information technology is broadly related to a work system that emphasizes decentralized authority and supporting practices such as teamwork, subjective incentives, and increased levels of skills and training in the work force. This is consistent with the idea that line workers have information that is valuable and difficult to communicate and that the increased flow of information enabled by IT is best utilized by distributing information processing tasks throughout an organization.

Information Technology and New Work Systems

A NUMBER OF RECENT STUDIES HAVE EXAMINED THE DIFFUSION of work practices collectively termed "high performance work systems" [28] using case studies [12], industry studies [29, 38], and broad-based cross-industry comparisons [27, 36]. For the purpose of our discussion, these practices can be grouped into three areas; *decision authority*, which includes teams and individual decision rights as well as related cultural practices (team building); *knowledge work and skills*, which includes skills, training and supporting practices (incentives for training and education, preemployment screening); and *incentives*, which includes various aspects of performance-based pay increases and promotions.

Very few of the analyses on changes in work systems have considered the role that technology may play.[3] Yet there are at least three reasons why information technology is potentially related to this organizational transition [10]. First, growth in information technology investment is of a large enough magnitude to be economically significant. Currently, over forty percent of new capital equipment investment in the United States is spent on information technology, resulting in a tenfold increase in its share of total capital stock since 1970. In addition, the quality-adjusted price of computers has declined 6,000-fold in the past thirty years [15].

Second, the recent advances in information technology are both novel and largely exogenous. Most of the fundamental technological breakthroughs that have enabled today's vast information infrastructure were made in the past three decades and were driven more by progress in physics and engineering than by business demand.[4] The ever lower prices for IT are consistently delivered by the computer industry without any unusual effort on the part of computer users. Furthermore, the rapid accumulation of IT is primarily driven by these price declines and thus is relatively exogenous to other events in the economy. Interestingly, the period of greatest growth in the acquisition of computer equipment (from 1982 to the present) coincides with the emergence of new work systems, which suggests at least circumstantial evidence of a link.

Third, a number of authors have proposed a direct link between the diffusion of information technology and changes in the economics of organizations. Malone, Yates, and Benjamin [40] argue that, to the extent that IT reduced coordination and transaction costs, it would differentially favor market-based coordination over hierarchical organization. Milgrom and Roberts [41] cite the exogenous price decline of IT as the primary driver in the shift from "mass production" to "modern manufacturing." Ichniowski and Kochan [28] argue that one possible reason why many of the new ways of organizing have not diffused rapidly, despite large economic benefits, is that they must be coordinated with changes in information technology.

Toward a Theory of IT and Organizational Architecture

IN THIS SECTION, WE CONSIDER HOW IT MIGHT ALTER the optimal organizational architecture of a firm. As Jensen and Meckling [30] argue, organizational design involves the specification of decision rights, performance evaluation systems, and compensation systems, which Brickley, Smith, and Zimmerman [9] collectively term *organizational architecture*.

Many different types of information are used in organizations, and people have a finite ability to process and communicate this information. While cheaper information can provide top management with more of the data needed to make decisions, issue instructions, and monitor the compliance of the work force, it can also provide lower-level workers with the information they need to make decisions without as much direction from upper management, provided workers have complementary skills and appropriate incentives to act on their private information. Furthermore, the growing flood of information can overwhelm the capacity of any given decision maker, which may require a reallocation of decision rights.

Decision Rights and the Specificity of Information

Hayek [25] distinguishes between "general" and "specific" knowledge; this distinction was elaborated and applied to organizations by Jensen and Meckling [30] and further analyzed by Anand and Mendelson [1]. Specific knowledge is difficult to convey to others and is possessed by a limited number of individuals. As Jensen and Meckling write, " The more costly knowledge is to transfer, the more specific it is, and the less costly the knowledge is to transfer, the more general it is" [30]. Knowledge is specific in part because individuals know more than they can state [49], and also because information can be expensive to communicate and process. Jensen and Meckling argue that decision rights should be collocated with the necessary knowledge. Organizations should be structured so that actors with specific knowledge have the decision rights, and complementary general knowledge is made available to them.

Information technology can lower the cost of some types of knowledge transmission, enabling firms to take previously specific knowledge and reallocate it throughout the firm. As a result, the optimal allocation of decision rights will be determined by the relative importance of the knowledge that still cannot be transferred even with an information system.

If the "residual" specific knowledge resides at the top of the organizational hierarchy, information systems will generally facilitate more centralized decision-making (see [8, 37]). However, if, as Aoki [2] argues, the residual specific knowledge is increasingly held by workers,[5] information systems should lead to decentralized control. For example, the current trend toward increased customer focus, product customization, and responsiveness may increase the importance of the time-critical, difficult-to-communicate information held by line workers.

Decision Rights and Information Overload

The tradeoffs between communications costs and humans' bounded rationality also affect a firm's degree of centralization. When communication is costly and central decision makers have an infinite capacity to digest information, it is often optimal to centralize decision making in order to economize on communications costs. Rather than provide all relevant information to all agents, information can be collected centrally, processed by a single decision maker, and returned to agents in the form of relatively simple commands. This allocation of decision rights is also favorable when it is important to coordinate agents' activities, or when central decision makers have a cost advantage in decision making.

Such a structure places heavy burdens on central decision makers. If there is a point at which the marginal cost of decision making increases with the information processing load, it may become necessary to offload some of the burden on other agents. Even if central decision makers are initially advantaged in the decision-making process as the load increases, their induced efficiency will actually drop below that of the other agents [5], leading to increased decentralization. In addition, if the cost of coordinating multiple decision makers represents a barrier to decentralization, information technology can lower these costs [39, 40].

In this argument, whether IT leads to increased centralization or decentralization depends on two factors. The first is the extent to which computers can decrease communication costs, potentially making decision-making knowledge less "specific."[6] However, this cost reduction in information transmission may result in increased information flow as well as a shift toward information-intensive work structures [40]. Therefore, the ability of computers to relieve the burden of handling the increased flow of information or, in economic terms, their ability to substitute for or complement human judgment, becomes a key factor.

Computers are sometimes characterized as electronic brains that can replace mental effort much as other machines have been substituted for the physical work of humans. In this role, they relax the limits on human information processing capacity. For instance, complex planning algorithms allow airlines to schedule routes, departure times, and seat pricing in ways that would have been impossible a decade ago. In contrast, Simon [51] stresses the limitation of computers as substitutes for managerial attention; he focuses on their role in generating information overload. IT may be effective in creating cheap data, but a human must usually analyze the data and make decisions based on it.

> The scarce resource is not information, it is the processing capacity to attend information. Attention is the chief bottleneck in organizational activity, and the bottleneck becomes narrower and narrower as we move to the tops of organizations. [51]

While IT has automated and vastly accelerated the chain of communication, human information processing abilities have changed little and are still a strict complement for many types of data.[7]

Incentive Systems and Observability

Jensen and Meckling [30] point out that, while decentralizing decision making may enable the firm to take better advantage of local information, it can also exacerbate agency problems. In the absence of an appropriate incentive system, workers will not necessarily use their decision-making authority in the interests of the firm. Information technology can be used to monitor work or aggregate information in ways useful for performance measurement, thus improving the quality of objective incentives. For example, Kaplan [33] describes a measurement system in one chemical plant that tracks 40,000 process variables every hour. However, knowledge work is notoriously difficult to measure. Zuboff [53] describes how workers at one newly computerized factory would leave their computer terminals and move about the shop floor in order to appear to be "doing something" whenever the supervisor visited. Sitting and thinking, which may have been the best use of time in the computerized environment, was too easily confused with shirking. Similarly, applications like Lotus Notes can enable workers to share more information, but without proper incentives little sharing will actually take place [45]. Because sharing is difficult to quantify and measure objectively, a culture of teamwork and reciprocity seems to be the most effective way to encourage cooperation in knowledge work [13].

More generally, a variety of incentive instruments can foster the effective use and dissemination of information, depending on the degree of observability. One can describe a *ladder of observability* with the following four categories:

1. If decisions and the information on which they are based are directly observable and verifiable to an outside party (or can be deduced from other data), and if the environment is not too complex, then an explicit contract can prespecify appropriate actions and rewards. For instance, workers can be offered piece-rate performance incentives.[8]
2. If the decision actions can be assessed by the decision maker's supervisor, but not prespecified and verified by an outside party, then implicit contracts such as subjective performance bonuses and promotions can be an effective instrument. For instance, the possibility of promotion to a higher-paying job can be a powerful incentive.
3. When the appropriateness of actions is not observable by outside parties or supervisors but can be assessed by peers and teammates, Kandel and Lazear [31] argue that team-building exercises and cultural efforts to create a sense of group cohesion are needed. This will create a dynamic in which teammates punish shirkers and shirkers feel a sense of shame. For example, many Japanese firms rely on this type of peer pressure to encourage hard work.
4. Finally, when even teammates cannot observe the appropriateness of an agent's actions, one option is to try to improve goal alignment so that the agent internalizes the interests of the firm [2], perhaps by creating a sense of a shared vision through inspirational leadership.[9] In addition, it may be possible in this situation to get agents to reveal their private information by offering them a menu of contracts. Agents with different information will choose different incentive schemes, revealing their knowledge but typically collecting an information rent in the bargain. For example, by offering multiple plans to sales agents involving different combinations of fixed salary and sales-related bonuses, a firm can learn which territories have the

highest potential by observing which agents choose high-variable pay plans.

To the extent that IT makes formerly unobservable activities more observable, firms will tend to use more explicit contracts. However, team building and goal alignment are more likely to be found if IT leads to decentralization of decision making and greater reliance on team production because of the difficulties inherent in prespecifying and monitoring information work, information sharing, and teamwork.

Complementarities

We argue that the components of organizational architecture discussed above—decision rights (DR), knowledge work and inputs (KW), and incentives (IN)—and information technology (IT) are complementary: The marginal benefit of adopting one set of practices increases with the adoption of the others [41]. While the complete mathematical model of this relationship is beyond the scope of this exploratory exercise, we will argue how each pair of characteristics is mutually supporting, and various exogenous variables drive a firm to choose one complementary system of these variables over another.

For clarity, the arguments for complementarity between each pair of the four design components (DR, KW, IN, IT) will be identified after each sentence of the argument with the symbol "+" representing "is complementary to." Pairwise complementarity between all design variables is a sufficient condition for arguing the complete complementarity of the system (see, e.g., [41] for a discussion of the mathematical issues of modeling complementarities).

Information technology is complementary to decentralized authority when valuable specific knowledge that is not amenable to electronic transfer resides at the periphery of the organization, or when information overload creates potentially binding constraint on central decision makers (IT+DR). Since the key reason that authority is being decentralized is that workers may have knowledge that is needed to make an optional decision, decentralization should work best if workers are able to use their knowledge effectively or have complementary human capital (DR+KW). If workers have valuable knowledge and use private information, their effort will be implicitly difficult to measure. Appropriate incentive structures must accommodate decreased observability by moving down the "ladder of observability" (DR+IN, KW+IN). As discussed above, when people have limited information processing capacity, information technology is likely to be a complement to knowledge work (IT+KW), and this work may be particularly difficult to measure and reward (IT+IN).

Case Evidence

To summarize, if IT is associated with an increased importance of specific knowledge, with easier transmission of coordination information or with more severe information overload at the tops of hierarchies, we can predict that firms will adopt a work system that incorporates decentralized decision authority, increased reliance on knowledge work and knowledge workers, incentives that are adjusted for the decreased observability of the work, and greater use of information technology.

A number of case observations in the manufacturing and service industries are consistent with this prediction. For example, at Phillips 66 [24], pricing decisions had traditionally been made by a centralized staff of experts who monitored market trends, analyzed purchasing data, and made pricing decisions for local markets. Recognizing that these central experts lacked timely and accurate knowledge of local market conditions, the firm built an information system provide local managers with information about broader market trends, enabling them to adapt pricing decisions more effectively to local market conditions. This decentralization of decision rights was coupled by centralized performance monitoring, which was used to "coach" the local decision makers and make subjective judgments about their performance. At the same time, systems were installed to help central managers screen and assimilate information on market conditions, better enhancing their ability to make strategic decisions and monitoring the actions of line managers without becoming overloaded by information. The combination of these organizational changes and information systems innovations was regarded as instrumental in returning the company to profitability in the late 1980s and can be linked directly to at least $30 million in revenue increase or cost savings.

Other firms have implemented such "empowering" information technologies without making the complementary investments in organizational change. For example, when automated process controls were introduced at the Tiger Creek Mill[10] [23, 53] that gave workers direct information and control over production cost, benefits from the technology were only realized for a short "honeymoon" period. Part of the problem was that the mill's previous "command and control" style hierarchy was not changed to give workers either the explicit rights or the incentives to improve the process, even though they were best positioned to make process improvements.

Similarly, Orlikowski [45] describes the experience of a consulting firm "Alpha Corp.," whose executives decided to install Lotus Notes on all the computers in the firm. Management at Alpha believed that the need to share specialized knowledge across the firm could be addressed simply by making collaboration technologically feasible. Initially, however, most employees took little advantage of the newly introduced information sharing capabilities. One possible reason is that the incentive systems at Alpha stressed individual effort and expertise, rather than group or organization-level performance. Because time spent making one's private information widely available through Lotus Notes came at the expense of "billable hours," there was little incentive to do so.

In contrast, Infocorp installed Lotus Notes in the telephone customer support area, a group with a long history of collaborative work and a team-based subjective incentive system [13]. The system was fully accepted almost immediately, leading to substantial improvements in service levels without staffing increases. Over time, Infocorp expanded the range of capabilities of the system by linking the telephone support group to other departments in the firm and altering the structure of work groups to utilize workers' specialized skills better.

These cases suggest several economic insights. First, not all managers know how to combine technology and organization appropriately. Some firms are experimenting with new technologies and not all of these experiments are successful, particularly when technologies are implemented with little change in other aspects of the organization. Second, organizations often gain considerable benefits by decentralizing decision authority when they also provide the necessary information and implement the appropriate management controls. However, if the incentives are provided to the wrong parties, as at Tiger Creek, or if incentives are too individually oriented, as at Alpha Corp., information sharing and the effective use of information to improve production may not occur.

Exploratory Empirical Analysis

Firm-level, Multi-industry Data

WE NOW EXAMINE THE RELATIONSHIPS PROPOSED IN THE THEORETICAL discussion using multi-industry, firm-level data on information technology characteristics and human resource practices.

When comparing the costs and benefits of alternative work systems, it is important to define the boundaries of the unit of analysis clearly. While plants or other business establishments within a firm may differ in their business, for many types of costs and benefits, it may not be meaningful to treat different establishments within a firm as separate entities. Incomplete contracts theory [17, 22] argues that, because firm boundaries are set to solve problems of contractual incompleteness, the presence of multiple establishments in a single integrated firm suggests some difficulty that prevents these establishments from operating on a stand-alone basis. In particular, information technology networks often span multiple establishments within the same firm, as do managerial decision-making activities, yet neither is likely to be reflected in the accounting ledgers of the individual establishments. The common management and technology infrastructure of establishments within a firm may be associated with common HR practices, incentive and decision systems, and "corporate culture" [42].

Substantially more data are publicly available on firms than on plants or business units. This information is important for various parts of this analysis, particularly for performance measurement. Unlike firms, individual establishments do not have audited financial statements, and the data that are available at an unconsolidated level are subject to intrafirm reporting biases that add substantial error [33].

We employ a multi-industry approach for two reasons. First, case studies and industry-specific cannot determine whether findings generalize to the broader economy [28]. Second, since the factors that determine whether IT leads to centralization or decentralization are difficult to measure for specific firms, but may vary systematically across the economy (for example, the value of local knowledge may be higher in a specialty retailer than in a steel mill), we can use industry variation as the source of exogenous variation that drives different choices of work systems.

Data Sources

Our data set is a cross-sectional survey of human resource practices conducted in 1995 and matched to firm-level data on information technology spending. A brief description of each data source follows.

Computer Technology

For our measures of technology usage, we used the Computer Intelligence Corporation installation database, which details information technology spending by site for companies in the Fortune 1000 (approximately 25,000 sites were aggregated to form the measures for the 1,000 companies). This database is derived from telephone surveys of establishments that detail the ownership for information technology equipment and related products at each site. Most sites are surveyed at least annually, with a greater sampling for larger sites. We use the state of the database at year-end 1994 for our measures of information technology. From this database, we can construct measures of the total capital stock of information technology (central processors, PCs, and peripherals) as well as measures of computing power, number of PCs, and the use of networking technology.

Human Resource Practices Survey

This survey was based on the human resources practices[11] identified in the theoretical section, with questions adapted from prior surveys on human resource practices and workplace transformation [27, 29, 46]. Survey questions address various types of incentive programs and modes of delegating decision authority, the extent of computerization, the effects of computers on various organizational dimensions, and other miscellaneous characteristics of the workplace. We discuss these measures in our Results section.

The survey, which was administered to senior human resource managers or their designees, asked questions about human resource practices for production workers at the *most typical plant*. We follow the approach of Osterman [46] in focusing on a single class of employee, which we call "production employees" (corresponding to Osterman's "core employee"), these are the "non-managerial, non-supervisory personnel directly involved in producing a firm's product or delivering its service." We focus on production workers rather than ask questions about the entire firm in order to avoid aggregation problems. While our results can be interpreted as measures of the specific working conditions of a large, relatively uniform class of employees, an alternative and consistent interpretation is that they are noisy indicators of an overall firm culture that incorporates these sorts of work practices.

Data collection was accomplished in two waves, using phone interviews targeting a subsample of the Fortune 1000. The first wave, conducted in summer 1995, yielded 135 usable responses from a population of approximately 447 relevant firms.[12] The instrument was then revised and administered by a different research company in fall

1995 to an additional target sample of 250 firms, netting an additional 138 responses, for a total of 273 used in this analysis. The most common explanations for nonresponse were "company policy" or "didn't have time."

Compustat

Where available, Compustat data were used to provide additional firm information such as industry, output, capital stock, and total employment not provided by other sources.

Because our analysis is cross-sectional, we cannot address issues of causality or temporal precedence. However, to the extent that there is variation in the data for exogenous factors (such as institutional adjustment costs, or past investments in technology for other reasons), we expect to see firms using different levels of technology and organizational practices that will allow these relationships to be identified.

Summary statistics on the sample are provided in Table 1. The firms included and excluded from our sample are roughly similar in terms of financial performance and production inputs, although our average firm is slightly smaller and uses slightly more IT (at least compared with those for which productivity can be calculated from Compustat). Approximately 53 percent of our sample is in manufacturing, mining, or construction, and 47 percent is in services. To validate our data collection procedures, the revised instrument contained questions about how representative production workers were in terms of total employment as well as how uniform HR practices were for production workers. Overall, for the average firm in the second survey subsample, production workers accounted for 65 percent of total employment, and HR practices are reported to be fairly uniform: On average, 88 percent of production workers were covered by same practices, and 65 percent of the firms reported complete uniformity of practices. This suggests that our analyses of production workers are likely to generalize fairly well to the entire firm.

Evidence of Complementarities

As proposed by Holmstrom and Milgrom [26], one test of a complementarities argument is to compute rank order correlations among various design variables. Rank order tests are preferred because complementarities models generally argue for a monotonic, but not necessarily linear, relationship. For our purposes, rank ordering tests are also preferable because we have nonmetric scales for many of the HR variables, and rank order methods tend to be more robust to the presence of outliers. If our arguments are correct and all firms are behaving optimally, we should see high rank order correlations among the design variables. Lower correlations could result from both suboptimization and violations of the model. In addition to examining individual practices, we also use principal components analysis to investigate whether IT and the work practices tend to be adopted together to allow the construction of a single variable representing the use of these systems for later analysis.

Table 1. Summary Statistics (Year End 1994)—Mean Firm

Variable	Sample	Remainder of Fortune 1000
Employment	25,400	29,300
Capital stock (non-IT)	$4.47 Bn	$4.58 Bn
Labor costs	$910 MM	$1060 MM
Computer capital	$75 MM	$66 MM
Value added	$1.70 Bn	$1.81 Bn
Pretax return on assets	4.5%	4.5%
Shareholder return (1 year)	17.6%	18.2%
Sales growth (1 year)	9.8%	9.9%
Number of firms	260	532

Note: Sample sizes reduced because we limit the calculations to firms with a complete set of production inputs (capital, labor, value-added, IT). Total sample size $N = 273$.

Results

TO INVESTIGATE THE RELATIONSHIP BETWEEN INFORMATION TECHNOLOGY and organizational architecture, we compute conditional correlations between individual organizational practices and various measures of information technology use. We then construct a variable representing the adoption of the system we have described using principal components analysis and examine the relationship between IT and this work system.

All correlational analysis in this and subsequent sections is done using Spearman rank order correlations between various measures of IT and our work system variables (which tend to be nonmetric),[13] controlling for firm size (employment), production worker occupation, and industry.[14] Five measures of IT are considered, four from the CI database—total value of installed based (ITCAP); total central processing power in millions of instructions per second (MIPS); [15] number of PCs (TOTPC); and the number of local area network nodes (LAN)—and a five-point measure of the computerization of the workplace on the HR survey (COMP). These multiple measures capture slightly different aspects of computerization (for example, MIPS measures centralized computing, while TOTPC measures decentralized computing), and also allow us to examine the consistency of the results across measures. We begin by investigating the correlations between these measures of IT and various indicators of the locus of decision making. We then look at correlations with human capital, incentive systems, and with a system that simultaneously includes all the components of organizational architecture.

IT and Decision Rights

The survey captures two aspects of decision authority: structures that decentralize authority, such as self-managing teams and employee involvement groups, and the

Table 2.

Spearman rank order correlations controlling for size, industry, and production worker occupation ($N = 242–260$)

a. Correlations between IT and Decision Authority

Measure (scale in parenthesis: 1 = "low"; 3 or 5 = "high")	IT capital	MIPS	LAN	TOTPC	COMP
Structural decentralization					
Self-managing teams (1–5)	0.18***	0.29***	0.33***	0.27***	0.20***
Employee involvement groups. (1–5)	0.04	0.07	0.08	0.08	0.05
Broad jobs (1–5)	0.09	0.19***	0.15**	0.13**	0.21***
Individual decentralization					
Pace of work (1–3)	0.07	0.08	0.05	0.07	0.12*
Method of work (1–3)	0.11*	0.13**	0.05	0.10	0.16**
Composite: pace/method	0.11*	0.12*	0.06	0.10	0.17**
Composite: 7 measures[a]	0.16*	0.15	0.14	0.24***	0.26***
Individual control & DA[a]	0.14	0.24**	0.01	0.12	0.21***

b. Correlations between IT and Human Capital

Measure	IT capital	MIPS	LAN	TOTPC	COMP
Overall human capital					
Skill levels (1–5)	0.12*	0.21***	0.08	0.16**	0.40***
Education (1–6)	0.07	0.05	–0.05	0.08	0.22***
Work-force composition					
Clerical (%)	–0.10	–0.03	–0.03	–0.09	–0.04
Unskilled blue collar (%)	–0.17**	–0.14*	–0.17**	–0.16**	–0.14*
Skilled blue collar (%)	0.00	–0.06	0.00	0.11	0.03
Managers (%)	0.19***	0.16**	0.08	0.14*	0.09
Professionals (%)	0.37***	0.44***	0.30***	0.29***	0.12
Human capital acquisition					
Training (% staff)	0.14**	0.14**	0.12*	0.13*	0.22***
Pay-for-skills (0/1)	0.06	0.05	0.22***	0.16**	0.05
Promote for skill (1–5)	–0.03	0.12*	0.02	0.04	0.13**
Screen for education (1–5)	0.14**	0.17***	0.13**	0.23***	0.32***

c. Correlations between IT and Incentives

Measure (scale in parenthesis)	IT capital	MIPS	LAN	TOTPC	Prod. comp.
Contractual incentives ($N = 160$)					
Variable incentive pay (%)	–0.14*	–0.14*	–0.17**	–0.16**	0.00
Group incentives (%)	0.09	0.10	0.00	0.08	0.01
Company incentives (%)	0.05	0.12	0.09	0.04	0.05
Supervisory incentives					
Subjective perf. pay (0/1)	0.02	0.01	0.13*	0.08	0.16**
Promote on performance (1–5)	0.00	0.13**	0.08	0.04	0.02
Promote on seniority (1–5)	–0.08	–0.08	–0.21***	–0.08	–0.18*
Team incentives					
Team building	0.24***	0.25***	0.31***	0.29***	0.14**
Promote for teamwork	0.08	0.15**	0.12*	0.05	0.09
Private info incentives					
Use menu of contracts (0/1)	0.02	–0.02	0.01	0.10	0.27***

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

[a] Limited to second survey ($N = 130$).

allocation of individual decisions about various aspects of the production process, such as the pace or method of work. The correlations of these measures with IT are shown in Table 2a. In terms of structural decentralization, we found very strong correlations between the use of self-managing teams and IT as well as some evidence that high IT firms employ broader job classifications. However, we found little relationship with employee involvement groups. In terms of individual decision rights, the results consistently indicate that IT is associated with increased decentralization, but the strength of the relationship varies substantially by measure of IT.

To investigate the possibility that the variability of the individual decision authority results is a product of measurement error, the revised survey expanded the individual decision authority scale to cover seven distinct measures and broadened the scale from three points to five. The individual measures are almost all positively correlated with the various measures of IT. When a composite scale is created by adding up the standardized values of the seven decision authority variables (Cronbach's alpha = 0.73),[16] we found consistent positive correlation with decentralization, significant at $p < 0.01$ for two of the measures. Unfortunately, this improved measure was only available for 135 observations. Therefore, we computed a similar measure for all the observations: It is the sum of the standardized values of the pace and method decisions variables (Cronbach's alpha = 0.41); this measure also shows positive correlation, although the strength of the relationship appears to be weakened by measurement error. As before, we found substantial evidence that information technology is broadly related to decentralized authority.

IT and Human Capital

We next examined the relationship between IT and various aspects of human capital: work force composition, skills and education, and human capital acquisition (Table 2b). In terms of work-force composition, we found that IT across a number of measures is related to a higher proportion of managers and professionals and lower proportions of unskilled workers. There is little net correlation with clerical or skilled blue-collar workers. In terms of education level and work skill content, we found a consistent positive relationship among skill levels and IT use, and a positive but insignificant relationship with education level, although this appeared to be a product of the measure we were using.[17] These results are broadly consistent with the conjecture of capital-skill complementarity [16] and recent empirical work investigating the effect of "high-tech" capital on skills and work-force composition [7].

These results suggest that firms using substantial IT have higher levels of human capital on average. To probe this result further, we considered measures of human capital acquisition: preemployment screening for education and incentives for human capital acquisition ("pay-for-skills" programs and the weight of skill acquisition on the promotion decision). Consistent with our earlier arguments, various measures of IT are correlated strongly with the percentage of the work force receiving training and the importance of education in hiring. In addition, we found some weak evidence of a relationship between the use of pay-for-skills programs and promotion based on skill acquisition.[18] This provides additional, albeit circumstantial, evidence of a complementarity between IT and human capital.

IT and Incentives

Our survey contains some measures relevant to each level on the "ladder of observability": (1) objective contractual incentives involving overall incentive pay and the various types of pay for performance systems, (2) subjective incentive pay and promotion incentives on individual performance, (3) team building and team-based promotion incentives, and (4) "menu of contracts" performance pay. The results of these correlational analyses are in Table 2c. We found some evidence that high IT firms may be *less* likely to use objective incentive pay, although the limited sample size makes it difficult to draw strong conclusions. Objective pay measures were only available for about 60 percent of the firms in our sample, and a substantial number of those use no variable pay incentives. In contrast, we found evidence that IT is correlated with the use of subjective incentives and promotions, and even stronger evidence of a relationship with team-based incentives, particularly team building. We also found some evidence, with one measure, that more computerized firms are more likely to use a "menu of contracts" incentive plan. Overall, this suggests that IT is associated with *decreased* observability of work and thus systems that rely less on third-party observability and more on team-based incentives.

IT Technology and Work Systems

Our preliminary results show that our work system components are broadly related to measures of IT, but they do not confirm that these factors operate as a system rather than as a set of independent practices. To examine whether these practices tend to be adopted together, we conducted a principal components analysis of the measures described previously (using Spearman correlations to generate a correlation matrix for factoring). We included all variables that we hypothesized were complementary and that were available for the majority of the sample. The correlation matrix between aggregates of our work system measures is shown in Table 3a, and the full principal components analysis in Table 3b. The first principal component accounts for approximately 25 percent of the variance of the measures included in the analysis and a Scree plot (figure 1) suggests that this is the only non-noise factor.

The factor loadings are broadly consistent with our work system arguments and weights most of the work system measures at 0.4 or higher. The only unusual result is the relatively low loading on education (which appears with a high loading on the second factor). To examine this further, we repeated the analysis using only the revised survey, which includes more accurate measures of both education and individual decision authority. As expected, the loadings on both these variables improved, suggesting the presence of some measurement error in the original education measures, but confirming the overall factor structure. The self-managing teams and decision authority variables show the highest loading, thus confirming the conjecture

Table 3.

a. Correlation Matrix of Four Work System Components

Spearman rank order correlations controlling for size ($N = 230$)

	Teams/DA	Incentives	Human capital
Teams/DA variables (4)			
Incentives (7)	0.41***		
Human capital (3)	0.25***	0.31***	
IT capital (1)	0.14**	0.13**	0.23***

** $p < 0.05$; *** $p < 0.01$.

b. Unrotated Principal Components for System Variable Construction

	Full sample		Second wave survey	
Variable	First PC	Second PC	First PC	Second PC
Self mg. teams	0.74	–0.28	0.53	–0.24
Composite: DA	0.57	–0.13	0.64	–0.19
Employee inv. grps	0.51	–0.43	0.32	–0.32
Skilled work	0.55	–0.11	0.42	–0.49
Education	0.26	0.39	0.55	–0.00
Training	0.39	–0.19	0.38	–0.45
Screening for education	0.57	–0.03	0.31	–0.10
Promote skill	0.33	0.57	0.43	0.61
Promote performance	0.38	0.68	0.39	0.69
Promote seniority (–)	0.36	0.52	0.57	0.26
Subjective incentive pay	0.42	0.04	0.30	0.19
Pay-for-skills	0.54	–0.24	0.03	–0.06
Team building	0.65	–0.26	0.56	–0.31
Promote for teams	0.46	0.44	0.55	0.36
Percent of variance explained	25	13	20	13

c. Correlations between SYSTEM and IT Variables

Spearman rank order correlations controlling for size, industry, and production worker occupation

Measure	IT capital	MIPS	LAN	TOTPC	COMP
Base (occupation, size)	0.15**	0.33***	0.33***	0.28***	0.31***
+ industry	0.15**	0.26***	0.31***	0.24***	0.27***
+ individual human cap.	0.13*	0.22***	0.30***	0.20***	0.19***
+ work-force comp.	0.09	0.17**	0.27**	0.15*	0.18**

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

that the system we identified primarily represents organizational characteristics that support decentralized decision authority. We thus constructed a variable (SYSTEM) using the sum of the sign-corrected standardized values of all variables included in the factor analysis. The resulting Cronbach's alpha is 0.76, which indicates adequate reliability.

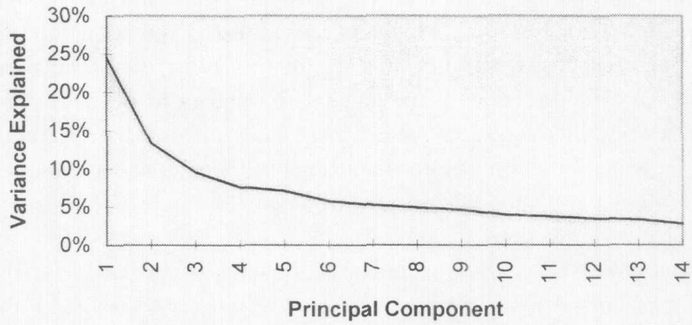

Figure 1. Scree Plot of Work System Factor Analyis

The IT correlation analysis was repeated for the system variable in Table 3c. On all measures, IT is strongly correlated with the work system variable, confirming our earlier analysis. To probe this relationship further and consider the possibility that IT leads to decentralization in some cases and centralization in others, we repeated this analysis by industry for the ten industry groups represented in our dataset (see note 14). The correlations are positive for every industry except finance and services, where they are insignificant and negative for some IT measures. Interestingly, the subset of the case evidence linking IT to centralization is drawn mostly from financial services firms [14]. On balance, with a possible exception in some financial and other services, the evidence appears to be consistent with a broad correlation between IT and decentralization.

However, it is possible that this relationship is due to work-force composition or industry rather than a direct relationship with IT. Firms that employ a disproportionate number of professionals are likely candidates for both increased use of information technology and adoption of decentralized work structures. To test for this possibility, the correlations were repeated without controls and then successively controlled for firm size (employment), production worker occupation, industry, and work-force composition. While the correlations (Table 3c) appear to decline somewhat as additional control variables are added, the results do not appear to be driven only by occupation, skill, or educational differences in the work force across firms. Interestingly, the results are strongest for the local area networks variable, which is possibly the closest measure of decentralized IT use.

Summary and Discussion

We have outlined and tested a theory that suggests how organizational architecture must be matched to the use of information technology. In short, since people are limited as information processors, highly specific information is likely to reside at lower levels of an organization, knowledge is likely to be complementary to technology use, and knowledge work is likely to have a substantial intangible component, we hypothesized that information technology would be associated with a decentralized organizational architecture.

Using data collected specifically for this analysis, we found that IT is broadly associated with a work system that includes decentralized authority, incentives that account for decreased observability, and the increased importance of knowledge workers and knowledge work. This relationship appears to be consistent across different industries and robust to variations of our measures. In addition, after controlling for work-force composition in our analysis, we found that this relationship does not simply depend upon whether the firms employ more skilled, professional workers or blue-collar workers.

Three limitations of this analysis should be addressed in further work. First, we were limited to broad but relatively shallow measures of work systems and information technology. It may be possible to get stronger results by targeting specific industries that would allow very specific work systems analysis and a finer partition of the uses of IT. Second, we were unable to examine the dynamic process of the IT–work system interaction due to the cross-sectional nature of our survey. Panel data on organizational measures would facilitate the construction and testing of models that directly examine the question of mutual causation through a simultaneous equation framework. Finally, a more stringent test would be to tie our results to firm performance, which would provide further and very strong evidence of complementarities.

These limitations notwithstanding, we provide some of the first large-sample evidence of a link between information technology and new ways of organizing work such as the "knowledge-based organization." We have also been able to harness some of the recently developed tools in organizational economics to explain productivity differences in the use of a key enabling technology. The quality-adjusted investment in IT by firms is likely to continue to increase by 20 percent annually for at least a decade; the issues addressed in this paper will become increasingly important in the future.

NOTES

Acknowledgments: We are grateful to Eric Clemons, Zvi Griliches, Maryellen Kelley, Thomas Kochan, Thomas Malone, Jim Rebitzer, Albert Wenger, and seminar participants at WISE '95, Boston University, Carnegie Mellon, MIT, NBER, Stanford, USC, and The Wharton School for valuable comments. This research has been generously funded by the Industrial Performance Center and the Center for Coordination Science at MIT. We would also like to thank Marty Roth of Incon Research, Brian Clarridge and his staff at the Center for Survey Research (UMass Boston), Harry Henry of Computer Intelligence Infocorp, and John McCormick of *Information-Week* magazine for providing or collecting essential data.

1. See, for example, [3, 28, 35, 44, 52].

2. This number was computed from one of our datasets on computer expenditures. It refers to all Fortune 1000 firms with publicly reported employment information.

3. Kelley [34] is an exception, although her work on computerized machine tools represents only one aspect of IT.

4. IBM originally estimated the total worldwide market for computers at just ten units; with the advent of cheap, miniaturized components and microcomputers, over 10 million computers are currently sold annually [18].

5. Aoki [2] writes that: "The tendency towards the delegation of decision making to the lower levels of organizational hierarchies, where economically useful on-the- spot information

is available, as well as the non-hierarchical communication among operating units, is becoming a more discernible phenomena on a world-wide scale, wherever conditions permit."

6. Bolton and Dewatripont [8] show that lower communication costs can enable greater specialization, which arguably could make knowledge more specific.

7. Simon (1976) has estimated that "we can handle only 50 [bits per second]," and that our short-term memory can store "seven plus or minus two items" [43]. Whatever the true numbers, human processing capacity is bounded and not easily augmentable.

8. For decision making, unlike physical work, specifying the actions to take in each contingency and observing them will often be unrealistic. For one thing, determining what actions to take in each contingency is presumably the reason the decision maker was hired in the first place. However, in some cases, it may be possible to base compensation on final output, leaving the methods unspecified.

9. As Radner [50] has noted, this strategy has received little formal analysis by economists, but Peters and Waterman [47] emphasize its importance: "[What is] the one truth that we were able to distill from the excellent companies research? . . . 'Figure out your value system.' Decide what your company stands for. What does your enterprise do that gives everyone the most pride?"

10. Company names in these case studies are disguised.

11. In our discussion, we use HR characteristics or HR practices as all-encompassing terms to describe our measures of internal organization. We do not make the finer distinction that sometimes appears in the literature between work organization (e.g., teams) and human resource practices (e.g., hiring policies).

12. The firms sampled in the first round also included some private firms not in the Fortune 1000. The actual list was drawn from the largest computer users tabulated in the Computer Intelligence database. This analysis is restricted to public firms on the database.

13. Results are similar when probit or ordered probit regression is used. We report Spearman correlations because they are easier to interpret, given the multilevel nature of most of our work system variables, and do not require removing firms with extreme values of information systems inputs.

14. Industry controls are included at the 1½ digit level. We include separate controls for mining/construction, high technology manufacturing (instruments, transportation, electronics, computers), process manufacturing (paper, chemicals, petroleum), other nondurable manufacturing, other durable manufacturing, transport, utilities, trade, finance, and services.

15. Total central processing power does not include the processing power of PCs.

16. This approach entails the assumption that the decision authority variables, which are measured on a five-point scale, can be treated as metric variables. Despite the statistical problems with this approach, this strategy is quite common in the psychometric research literature.

17. In the second wave of the survey, we refined the education question to have a continuous distribution and found stronger correlations between the use of PCs and total computer processing power. The original question asked the respondent to rate the average level of education of the work force on a five-point scale, and most of the respondents replied "high school" or "some college." The revised measure had the respondent allocate the percentages of the work force among three categories: high school or less, some college, and college or more. The correlations generally improve and tend to be significant with the new measure, despite the smaller sample size. Furthermore, we found that IT is a complement to college-educated workers, neutral for workers with some college, and negative for those with a high school or less education.

18. The relatively low correlations may again be partially caused by the lack of variation in these measures: Pay-for-skills programs are relatively uncommon (adopted by only 28 percent of the firms), and are particularly uncommon outside of manufacturing, and most firms rate skill acquisition as very or extremely important (4 or 5 on a 5-point scale).

REFERENCES

1. Anand, K., and Mendelson, H. Information and organization for horizontal multimarket coordination. Stanford University Working Paper, 1995.

2. Aoki, M. The participatory generation of information rents and the theory of the firm. In M. Aoki, B. Gustafsson, and O. Williamson (eds.), *The Firm as a Nexus of Treaties*. London: Sage, 1990, pp. 26–52.

3. Appelbaum, E., and Batt, R. *The New American Workplace*. Ithaca, NY: ILR Press, 1994.

4. Applegate, L.; Cash, J.; and Mills, D.Q. Information technology and tomorrow's manager. *Harvard Business Review* (November–December 1988), 128–136.

5. Athey, S.; Gans, J.; Schaefer, S.; and Stern, S. The allocation of decisions in organizations. Stanford University Working Paper, 1995.

6. Attewell, P., and Rule, J. Computing and organizations: what we know and what we don't know. *Communications of the ACM, 27* (December 1984), 1184–1192.

7. Berndt, E.R.; Morrison, C.J.; and Rosenblum, L.S. High-tech capital, economic performance and labor composition in U.S. manufacturing industries: an exploratory analysis. MIT Working Paper, 1992.

8. Bolton, P., and Dewatripont, M. The firm as a communication network. *Quarterly Journal of Economics, 59*, 4 (1994), 809–839.

9. Brickley, J.A.; Smith, C.W.; and Zimmerman, J.L. *Organizational Architecture: A Managerial Economics Approach*. New York: Irwin, 1996.

10. Brynjolfsson, E. Information technology and the "new managerial work." In Norwegian Academy of Technological Sciences (ed.), *Organizational Learning and Experience Transfer*. Trondheim, Norway: NTVA, 1994, pp. 27–100.

11. Drucker, P.F. The coming of the new organization. *Harvard Business Review* (January–February 1988), 45–53.

12. Dunlop, J.T., and Weil, D. The diffusion of human resource innovations: lessons from the apparel industry. Harvard University Working Paper, 1993.

13. Gallivan, M.; Goh, C.H.; Hitt, L.M.; and Wyner, G. Incident tracking at Infocorp: case study of a pilot Notes implementation. MIT Center for Coordination Science Working Paper, 1993.

14. George, J.F., and King, J.L. Examining the computing and centralization debate. *Communications of the ACM, 34*, 7 (1991), 63–72.

15. Gordon, R.J. *The Measurement of Durable Goods Prices*. Chicago: University of Chicago Press (for NBER), 1990.

16. Griliches, Z., Capital-skill complementarity. *Review of Economics and Statistics, 51*, 4 (1969), 465–468.

17. Grossman, S., and Hart, O. The costs and benefits of ownership: a theory of vertical and lateral integration. *Journal of Political Economy, 24*, 4 (1986), 691–717.

18. Grove, A.S. The future of the computer industry.33, 1 (1990), 148–160.

19. Gurbaxani, V., and Whang, S. The impact of information systems on organizations and markets. *Communications of the ACM, 34*, 1 (1991), 59–73.

20. Hammer, M. Reengineering work: don't automate, obliterate. *Harvard Business Review* (July–August 1990), 104–112.

21. Hammer, M., and Champy, J. *Reengineering the Corporation*. New York: Harper Business, 1993.

22. Hart, O.D. Incomplete contracts and the theory of the firm. *Journal of Law, Economics and Organization* (Spring 1988), 119–139.

23. Harvard Business School. The expense tracking system at Tiger Creek. HBS Case 9–485–057, 1984.

24. Harvard Business School. Phillips 66: controlling a company through crisis. HBS Case 9–189–006, 1988.

25. Hayek, F.A. The use of knowledge in society. *Economica, 35*, 4 (1945).

26. Holmstrom, B., and Milgrom, P. The firm as an incentive system. *American Economic Review, 84*, 4 (September 1994), 972–991.

27. Huselid, M. The impact of human resource management practices on turnover, productivity, and corporate financial performance. *Academy of Management Journal* (1994).

28. Ichniowski, C., and Kochan, T.A. What have we learned from workplace innovations? MIT Working Paper, 1995.

29. Ichniowski, C.; Shaw, K.; and Prunnushi, G. The effects of human resource management practices on productivity. Columbia University Working Paper, 1994.

30. Jensen, M., and Meckling, W. Knowledge, control and organizational structure. In L. Werin and H. Wijkander (eds.), *Contract Economics*. Cambridge, MA: Basil Blackwell, 1992, pp. 251–274.

31. Kandel, E., and Lazear, E.P. Peer pressure and partnership. *Journal of Political Economy*, *100* (1992), 801–817.

32. Kanter, R.M. The new managerial work. *Harvard Business Review*, *67*, 6 (November–December 1989), 85–92.

33. Kaplan, R. Management accounting for advanced technological environments. *Science*, *245* (September 1989), 819–823.

34. Kelley, M.R. Productivity and information technology: the elusive connection. *Management Science*, *40*, 11 (1994), 1406–1425.

35. Kochan, T.A.; Katz, H.C.; and McKersie, R.B. *The Transformation of American Industrial Relations*. New York: Basic Books, 1986.

36. Lawler, E.E.; Mohrman, S.A.; and Ledford, G.E. *Creating High Performance Organizations*. San Francisco: Jossey-Bass, 1995.

37. Leavitt, H.J., and Whisler, T.L. Management in the 1980s. *Harvard Business Review* (November–December 1958).

38. MacDuffie, J.P. Human resource bundles and manufacturing performance: organizational logic and flexible production systems in the world auto industry. *Industrial and Labor Relations Review* (January 1995).

39. Malone, T.W., and Crowston, K. The interdisciplinary study of coordination. MIT Center for Coordination Science Working Paper, 1992.

40. Malone, T.W.; Yates, J.; and Benjamin, R.I. Electronic markets and electronic hierarchies. *Communications of the ACM*, *30*, 6 (1987), 484–497.

41. Milgrom, P., and Roberts, J. The economics of modern manufacturing: technology, strategy, and organization. *American Economic Review*, *80*, 3 (1990), 511–528.

42. Milgrom, P., and Roberts, J. *Economics, Organization and Management*. Englewood Cliffs, NJ: Prentice-Hall, 1992.

43. Newell, A., and Simon, H.A. *Human Problem Solving*. Englewood Cliffs, NJ: Prentice-Hall, 1972.

44. Nohria, N., and Eccles, R., eds. *Networks and Organizations*. Boston: Harvard Business School Press, 1992.

45. Orlikowski, W.J. Learning from Notes: organizational issues in groupware implementation. In J. Turner and R. Kraut (eds.), *Conference on Computer Supported Cooperative Work*. Toronto: Association for Computing Machinery, 1992, 362–369.

46. Osterman, P. How common is workplace transformation and who adopts it? *Industrial and Labor Relations Review*, *47*, 2 (1994), 173–188.

47. Peters, T., and Waterman, J. *In Search of Excellence*. New York: Knopf, 1982.

48. Piore, M., and Sabel, C. *The Second Industrial Divide*. New York: Basic Books, 1984.

49. Polanyi, M. *The Tacit Dimension*. New York: Doubleday Books, 1966.

50. Radner, R. Hierarchy: the economics of managing. *Journal of Economic Literature*, *30* (September 1992), 1382–1415.

51. Simon, H.A. Applying information technology to organization design. *Public Administration Review* (1973), 268–278.

52. Van Alstyne, M. The state of the network organization: a survey in three frameworks. *Journal of Organizational Computing* (forthcoming).

53. Zuboff, S. *In the Age of the Smart Machine: The Future of Work and Power*. New York: Basic Books, 1988.