ONE POINT OF VIEW

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CLOSING THE TECHNOLOGY IMPACT GAP: MANDATE FOR THE '90s

Since 1970, we have seen considerable summary-level evidence that despite a massive investment in information technology (IT), the productivity of service sector, white-collar (knowledge) workers has been flat. This contradiction, labeled the "productivity paradox," has been contrasted with the manufacturing sector of the economy, where the use of technology has enhanced productivity (*1–3*).

The decade of the 1980s saw information technology investment by U.S. business grow by almost 350 percent to $1 trillion, $800 billion of which is in the service sector (*4,5*). For many large firms, allocations for computers and telecommunications had grown to almost half of their capital budget (*5*). An end-of-decade evaluation by the Massachusetts Institute of Technology's Management in the 1990s program documented occasional high-impact productivity gains from information technology at a local level, but even the most dramatic examples failed to translate to a measurable productivity improvement in industry overall (*6*). And consultants Nolan, Norton, and Company measured a 1 percent slump in office productivity during the period 1978 to 1985 (*7*).

It has been commonly believed that the efficiency of the computer will lead to massive reductions in clerical and office staff. Yet Peter Drucker observed as recently as 1991 that despite massive investments in data-processing equipment, "office and clerical forces have grown at a much faster rate since the introduction of information technology than ever before." He emphasized that management's ability to raise the productivity of knowledge and service workers would "determine the very fabric of society and the quality of life in every industrialized nation" (*8*).

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The productivity problem has been further exacerbated by the structural change, alluded to by Drucker, currently underway in the U.S. Ninety-one percent of the increase in the number of jobs since the 1982 recession has been in services, and, remarkably, as of 1991, 73 percent of private-sector employees were working in service businesses, which include computer software and systems integration (*9*). We are evolving into a service and information society, rather than a manufacturing one. Paradoxically, the service sector is where productivity has been the poorest (*2,10*).

Amid the Paradigm Shift

The apparent failure of technology to have had the predicted impact on white-collar, knowledge work has given rise to the term "technology impact gap" (*11*). Evidently, past processes for determining and designing information systems and organizational infrastructure failed to reveal how to gain increases in knowledge worker productivity. As the sobering evidence mounted, industry analysts concluded: "The presumption that high tech offers a guaranteed productivity payback is a luxury the U.S. economy can no longer afford" (*12*).

We are in the midst of a paradigm shift. Applying the beliefs and methodologies that previously were successful will bring failure in the new order. The rules have changed.

Unlike farming and manufacturing, where machines replaced human labor, increased office productivity will depend on augmenting, rather than automating, human information processing. It will also depend on reengineering the firm in terms of work process, individual and group dynamics, facilities and environment—and the interaction of all these elements (*13,14*).

The office needs to be viewed as the *strategic cockpit* for information/knowledge workers. Duncan Sutherland, a consultant who has studied office productivity in Japan, states:

> *Why have approaches that worked so well in the factory largely failed in the office? American companies are slowly coming to the realization that it is management's concept of the office itself—how companies organize people, technology and facilities to accomplish the knowledge work required to carry out their mission—that lies at the heart of the nation's productivity dilemma. It is not simply the "low productivity" of individual office workers. The truth is that American companies have been trying to solve the wrong problem* (*15*).

An historical analogy is useful for examining the movement from potential to actual productivity gains. The major technical innovations in electric power were made between 1860 and 1880. By 1890, electric motors had replaced steam engines, but they remained connected to the old shaft and belt power distribution systems. Only the *front end* of the system had been modified. The *model* of the system itself remained unchanged. It was not until after 1900 that manufacturers began to realize that the indirect benefits of unit electric drives were far greater than the direct energy-saving benefits.

Unit drives allowed much greater flexibility in plant floor layout. No longer did machines need to be placed in line with shafts. The U.S. Government Printing Office was able to add 40 presses in the same floor space. Trolleys and overhead cranes were now unobstructed by shafts, countershafts and belts. Factories could be made brighter. Working conditions, product quality and process efficiency were improved. Production capacity could more easily be expanded. Thus, a new paradigm of production design—a redesign of work—had as much to do with the increased benefits of electric power as the technical innovations did (*10*).

Hindsight reveals that most of the benefits derived from the implementation of industrial electric power were unanticipated at the onset. The nature of the paradigm shift was not fully appreciated until some 50 years after the technical innovation. We might conjecture that we have been experiencing a similar dilemma with our computer and information revolution. Have we had a revolution? Or did we modify our *front end* while continuing to operate based on a familiar, but outdated, model?

A Technology Payoff?

Recent data suggest we may be making progress in closing the technology impact gap. Since 1991, productivity gains have outpaced overall economic growth, and service-sector productivity has matched the gains that began in manufacturing in the 1980s. Also, corporate profits are up—often a harbinger of employment growth (*4*).

Case studies have documented dramatic improvements in productivity through the careful application of appropriate information technology. Linking suppliers directly to a corporation's computer systems, for example, can eliminate the need for paper-based bills and purchase orders. Hand-held scanners reading universal product codes can transmit on-the-spot inventory requests back to headquarters via satellite, thereby eliminating paperwork and the laborious effort of recording inventory. Such examples reflect a reduction in staffing requirements, increased responsiveness as a result of a hastened information flow, and the maintenance of lean inventories.

Skeptics are quick to point out, however, that the economic indicators usually associated with a productivity boom are still missing. Real wages are stagnant, job growth is lagging, and unemployment remains high. They argue that only a handful of large, high-profile companies have successfully combined technological investment with structural change (*4*).

The degree to which case studies are representative of overall productivity improvements remains to be seen. "Best case" examples of dramatic improvement in programming efficiency through the use of "object-oriented" languages are similarly cited. To date, however, no large-scale conversion has occurred among the rank-and-file of programmers—perhaps reflecting management's difficulty in evaluating new paradigms.

Furthermore, it is important to note that impressive uses of information technology are usually accompanied by several other critical success factors: a redesign of work and organizational structure, capable management, and firm-wide commitment. Evidence indicates that without these prerequisites, large investments in information technology are often disappointing (*5,6*).

The lag between the introduction of a new technology and the ensuing period of innovation can be many years—50 in the case of industrial electrical conversion. Many of the benefits of IT will come from rethinking old ways of operating and from new services. Moreover, some of information technology's impact is difficult to quantify, especially when it serves to enable creativity. It may just be too early in the process to determine whether information technology is driving a productivity-led recovery.

Information technology is also responsible for displacing many now-superfluous workers, including purchasing agents, billing clerks, designers, and draftsmen. Furthermore, corporations have been laying off large numbers of their middle-management personnel no longer needed to coordinate and relay information—databases and computer networks do the job better and faster, for less.

There is a belief that, in time, new computer-based services and industries will spring forward as a result of the ongoing transformation and absorb many of these displaced workers. Perhaps. But unlike the industrial revolution, when farmers and blacksmiths could find new employment in burgeoning industry, many U.S. computer companies have been experiencing the same woes as the general economy.

Economic Implications

Productivity can most generally be defined as the ratio of output to input. The current U.S. trend of downsizing (headcount reduction) attempts to increase productivity by reducing the input factor in the equation. We see this reflected in some of the new productivity numbers measured in output per hour. Information technology allows us to do more with less, but this penchant for efficiency obscures a more profound issue: using IT for the leveraging of intellectual resources and the creation of knowledge—the new critical commodity (*16,17*).

This issue should command our attention. The commercialization of new knowledge-based concepts is the means by which we can generate a propulsive economy. Increases in efficiency are insufficient to catalyze the processes that are necessary for the creation of sustained growth in competitive, global markets. The Japanese use "venturization" to translate increased efficiency into growth—focusing on the output factor of the productivity equation. In a knowledge-creating company, new ideas and product concepts are continuously generated and readily nurtured, and are often spun off as independent enterprises. For example, Hitachi has over 500 subsidiaries and Matsushita nearly 400 (*18*).

The pump that drives knowledge creation is research and development.

The creation of wealth, therefore, is a function of R&D investment. Other nations should be alarmed that, starting in 1986, annual R&D investments by Japanese manufacturers exceeded investments in plant and equipment. In fact, Japanese investments in industrial R&D increased by an astounding 14 percent in the year ending March, 1990. "In comparison, U.S. industry increased R&D spending in 1989 by only three percent, which in real terms represents net decline" (*19*).

Fumio Kodama, research director of Japan's National Institute for Science and Technology Policy, concludes that "the change [in investment strategy] represented a permanent transformation of the Japanese corporation from a place for producing things [production] to a place for producing knowledge [R&D]" (*19*). This change, or ***technoparadigm shift,*** assimilated by Japanese manufacturers, embodies a cycle whereby production leads to more R&D, which leads to enhanced production, and so on.

The Japanese create new knowledge through technological "fusion"—the long-term cross-fertilization process whereby companies from different industries contribute their expertise to collaborative R&D efforts. Japan's first fiber optics were "fused" from glass, cable and electronics technologies. They now control a significant share of the world's fiber optic equipment market. "Fusion" is promoted through participation in consortia, joint ventures and partnerships. Most importantly, it is accepted that each research project cannot be evaluated on a short-term financial basis (*20*).

Applying the "fusion" of collaborative R&D to the productivity paradox, the Japanese have established the 271-corporate-member New Office Promotion Association (NOPA). With sponsorship and funding from the Ministry of International Trade and Industry, NOPA has embarked on a research agenda dedicated to developing the kinds of IT products, services and environments that will aid knowledge/white-collar workers and ***knowledge-intensive organizations*** in the creation of new knowledge (*21*). If sustained by the technoparadigm shift and coupled with "venturization," the Japanese may capture the world's knowledge work industry—as some suggest is their intent.

Will other nations offer a competitive response? In the United States, this issue needs to be elevated to the country's list of critical technologies, from which it is currently absent.

Knowledge as an Enabler

In response to the technology impact gap, many organizations are making a determined effort to better understand the dynamics and fit of information technology vis-a-vis their business strategies. The success of these efforts is dependent on viewing the productivity paradox as a multi-dimensional system problem. Closure of the technology impact gap will require optimizing the relationships among the various system elements: individuals, the organizational culture in which they are immersed, the physical environment in which they work, and the information technology they use.

Organizations must become more adept at managing the knowledge within this system if increases in productivity and innovation are to be realized.

In an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge. And yet . . . few managers grasp the nature of the knowledge-creating company—let alone how to manage it. The reason: They misunderstand what knowledge is and what companies must do to exploit it. (*17*).

The essence of knowledge and the manner in which agents construct and possess it must be understood. Knowledge can be differentiated into two discrete components—codified (explicit, symbolic or declarative) and tacit (implicit, latent or procedural). Codified knowledge is the more easily discernible of the two. It is factual, concise and more easily transmitted to decision agents. Tacit knowledge, because it tends to be obscure, contextual and difficult to communicate, is often ignored.

Such an omission mistakenly implies a lack of significance. However, some of an organization's most important knowledge is tacit—contained in the "know-how" and interaction of individuals and processes, but never articulated or documented. Attempts at technology transfer are sometimes disappointing due to the failure to also communicate the vital complementary tacit knowledge on which success depends (*22*). Organizational learning is often compromised for similar reasons.

Too often, firms have applied technological solutions to antiquated practices.

The apparent importance of exploiting tacit knowledge suggests a new requirement for appropriate IT disclosure tools. "Microscopes" are needed for discovering latent processes and capturing the knowledge buried within them. "Micrometers" are needed for measuring changes in knowledge creation and innovation generation as a result of manipulating the components within the people–facilities–information technology system.

Reengineer Business Processes

Any attempt to leverage knowledge for organizational transformation should begin by reengineering all business processes and work flows. Too often, firms have applied technological solutions to antiquated practices, thereby ensuring the perpetuation of inefficient operations. Reengineering methodologies and appropriate IT knowledge tools can expose, and subsequently address, inefficiencies and bottlenecks hidden in tacit processes—outmoded persistent procedural methods taken for granted.

Alternative organizational architectures offer another opportunity for knowledge to increase productivity. Empowered, self-governing teams can eliminate the need for much of middle management. Driving decisions downward places problem resolution in the richest knowledge environment. People closest to the problem, and most experienced in its systemic context, possess the greatest degree of tacit understanding.

When decisions are moved up the bureaucratic hierarchy, the tacit knowledge is frequently lost. Consequently, the problem becomes more difficult to solve, resulting in a greater expenditure of resources with a diminished likelihood of successful closure. Self-governing teams point to the continuing evolution of collaborative work and the need for associated IT computer support tools that assist in the coordination and retention of both codified and tacit knowledge.

Organizational Evolution

Variation and selection are important determinants of an organism's evolution. If an organization is modeled as a set of organic processes, then producing sufficient decision alternatives (variation) coupled with the ability to properly assess them (selection) are of fundamental importance to organizational evolution—a tacit process. Knowledge defines an organization's capability and drives its goals and actions. Learning, a function of institutional memory and experience, increases knowledge (capability), which generates more ambitious goals and a richer array of decision alternatives. This is an upward, iterative capability cycle. The productivity paradox can be seen as poor evolutionary adaptation to the challenge of allocating scarce resources.

Therefore, an increased emphasis on rational decision-making (the identification and assessment of alternatives) can aid in closing the technology impact gap. Information systems, inadequate for "mining" the latent potential within their associated databases, are consequently truncated in their ability to directly address decision-making. Embedding statistical methodologies and robust modeling and simulation features within these systems are important next steps. Visualization techniques (e.g., geographical mapping of data, animated 3D molecular models, tree diagrams, etc.) facilitate the discovery of tacit structures and meaning within data, and add clarity and insight to the decision process. Similarly, the decision sciences provide important ways of calibrating risk, return and the value of information.

The use of object-oriented technologies represents another dimension in which most firms can improve productivity. Heralded for its efficiency and reusability, this radical departure from conventional programming practices requires a total transformation of most data processing and management information systems (DP/MIS) shops—a Herculean feat. Moreover, objects contain knowledge (methods or "know-how") by virtue of class inheritance (evolution). Object modeling offers a superior means of making explicit what would otherwise remain tacit. This exercise frequently leads to new levels of abstraction that result in better problem definition. Use of this methodology to model the enterprise preserves institutional history (evolution of knowledge, goals and actions). Similarly, expert and fuzzy systems capture the tacit knowledge of "know-how" as "rules," thus articulating knowledge and making it accessible to all.

Office as Strategic Cockpit

The tacit knowledge of custom and culture has long been viewed by anthropologists as important. The office must be seen as the strategic cockpit and social milieu of knowledge workers. Therefore, the configuration and deployment of the physical facilities supporting knowledge work as social interaction (tacit knowledge) must be considered. Project clusters that support group activities, preserve knowledge, and increase both communication and privacy need to be deployed. Most enterprises have facilities standards that are outmoded.

Knowledge diffuses throughout an organization by having overlapping communities of practice, and via knowledge brokers who bridge the span across these communities. The traditional organizational chart misrepresents the tacit processes by which work is actually accomplished. Tools, techniques, methods, and metrics for understanding and supporting the human interactions that create knowledge and facilitate innovation will be increasingly important in the Fifth Generation workplace—an environment that redefines work as dialogue.

Rethinking Management Control

Existing cost accounting and management control practices have not kept pace with organizational and technological change. Static for many decades, these systems are increasingly viewed as inadequate for the needs of contemporary management decision-making (*23*). A new philosophy of management control must be instituted, based more on the company's extended balance sheet and less on its income statement.

The extended balance sheet more broadly defines the assets that constitute the firm's competitive position. Such tacit assets (e.g., knowledge base, brand names, market share, customer satisfaction, technological capabilities, etc.) should be included along with financial measures of investment return (*24*). Moreover, the general ledger should be re-cast to reflect the tacit knowledge of indirect functions and processes—what most people and equipment do within the firm.

Accurate management accounting has important implications for directing and assessing the often tacit operations of dialogue, decision and action of organizational knowledge work. New performance measures are required to trace the effects of these activities, including the contributions of R&D, in order to demonstrate value and thereby justify resource allocation. Without such measures, R&D units, driven by traditional reward systems, will remain focused on "breakthroughs" at the expense of "follow through" efforts.

The Japanese believe their follow-through philosophy of *Kaizen*—the process of constant ongoing improvement, no matter how small—is more valuable than great leaps forward for winning technology wars. Although television and audio and videotape recorders were pioneered in the U.S., the shelves of consumer electronics stores reflect Japanese dominance (*25*).

Optimize the System

White-collar, knowledge work can benefit from the values, system thinking and statistical theory and methodology of the quality movement as embodied in the teachings of W. Edwards Deming (*26*). Knowledge workers (embedded in organizational structure and culture), the supporting physical facilities, and information technology need to be explicitly understood as a system. Any change to this system or its components necessitates an accompanying assessment for the express purpose of evaluating system performance.

According to Deming, management's primary responsibility is the optimization of the system. Continual improvement of this system is required if we are to successfully manage knowledge and innovation. Arbitrary or capricious changes to the system amount to little more than "tampering."

Transforming organizations into innovative knowledge-based enterprises will demand new leaps of understanding, requiring in turn the systematic application of science and the adoption of an R&D perspective into daily activities. Knowledge Infrastructure Engineering (KIE) describes a new multidisciplinary approach to this problem space. Conceived at a workshop of concerned scholars and practitioners representing industry, academia and government (*27*), KIE is a formative attempt at theory development and requirements definition for the tools to observe, measure, and model knowledge work, comprised of both tacit and codified components. The workshop, convened in response to concern over the productivity paradox and the future of knowledge work, concluded that collaborative R&D development of appropriate IT products, services and environments for exploiting knowledge was the key to generating sustained economic growth.

Rapid organizational transformations require firm theoretical underpinnings. Management quick fixes and fads should be avoided, for in Deming's words, "There is no learning without theory." Ⓐ

Transforming organizations into innovative knowledge-based enterprises will demand new leaps of understanding.

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