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Since the turn of the century, the United States, Canada, and Western Europe have been moving toward service and information economies and away from an agricultural and manufacturing economies (Euromonitor, 1990; Machlup, 1962; Rubin and Huber, 1986; Porat, 1977). The fraction of workers using information to produce economic value has been rising, and the fraction working with their hands in factories or on farms has been declining. In the United States, the percentage of jobs in manufacturing fell from 27 percent in 1920 to 17 percent in 1990. In the European Community, the value-added by manufacturing grew at an average annual rate of 6.2 percent from 1960 to 1970, but this growth rate was only 0.7 percent from 1980 to 1985. Among white-collar workers, the fastest growing occupations have been clerical, professional, and technical workers, and managers and administrators (Wolff and Baumol, 1987).

Six factors have been involved in this shift. First, third-world and developing societies have become centers of manufacturing, while the so-called advanced societies have shifted toward services. In Europe, the telecommunications sector has been growing about 9 to 11 percent annually, and the software and computing services sector has been growing 15 to 20 percent annually (Sema Group, 1991). Second, knowledge-intense and information-intense products and services have grown rapidly, and the production of traditional products has also been using knowledge more intensively. Third, business has invested heavily in equipment to support information work. In the United States, information-related equipment accounted for 20 percent of capital investment in 1979; this figure had become 40 percent of capital investment by 1986. Fourth, knowledge workers and information workers have replaced manual production workers within the manufacturing sectors. Machine-tool operators, for instance, have often been replaced by technicians who monitor computer-controlled machine tools. Fifth, workers have increased education and information-processing skills (Howell and Wolff, 1991). Sixth, new kinds of knowledge-intense and information-intense organizations have emerged that are devoted entirely to the production, processing, and distribution of information. These new kinds of organizations employ millions of people (Office of Technology Assessment, 1988).

As early as 1976, the value of information-sector products and services had already exceeded that of the manufacturing sector in the U. S. By 1990, the information sector (including services) accounted for $3 out of every $4 of GNP, and over half of the U. S. workers were doing some type of information work (Howell and Wolff, 1993; Roach, 1988). The U. S., however, represents an extreme case. For instance, in the software and computing services sector, the United States has about 55 percent of the world market, the European Community has about 25 percent, and Japan has about 8 percent (Sema Group, 1991).

This article surveys information work, information workers, and the computer systems that support such work. It then examines the organizations that are most dependent on knowledge and information work -- knowledge-intensive firms.

INFORMATION, KNOWLEDGE, AND INFORMATION WORK

Information is a flow of data that has meaning, and knowledge is a stock (or inventory) of information. In one sense, knowledge is to information as assets are to income. However, knowledge is more than an accumulation of information: It is an organized collection that reflects the intentions of the humans who create and interpret it. Thus, knowledge resembles an organized portfolio of assets.

Some activities draw on extensive knowledge without processing large amounts of current information. Management consulting would be one example. Conversely, an organization can process much information without using much knowledge. For instance, Automatic Data Processing (ADP) produces payroll checks. ADP processes vast amounts of information, but it is probably more capital-intensive than knowledge-intensive. Producing a payroll check requires little expertise, and many people have this expertise.

Distinctions between data, information, and knowledge are often difficult to apply. From one perspective, ADP merely processes information for other firms, using mainly capital in the forms of computers and software. From another perspective, ADP succeeds because it does its specialized task better than its customers can do it themselves. This superior performance likely comes from both expertise and returns to scale, so knowledge and large scale reinforce each other.

Economists use the term "information workers" to denote everyone who primarily creates, works with, or disseminates information (Machlup, 1962; Howell and Wolff, 1993). They include in the information-worker category: (a) clerical workers who mainly process data or preserve it without attempting to understand it, (b) clerical workers, librarians, and sales personnel who interpret information and act upon it, (c) detectives, journalists, and researchers who mainly generate new information, and (d) experts such as consultants, lawyers, and certified accountants who mainly apply accumulated knowledge.

Information workers can be distinguished by their formal educations and cognitive skills (Berndt et al., 1992; Berndt and Morrison, 1992). Some information workers -- such as sales personnel, real-estate agents, and secretaries -- typically do not have advanced educational degrees. On the other hand, experts -- such as engineers, judges, scientists, writers, and architects -- usually must obtain advanced degrees or professional certifications because they exercise independent judgment and creativity based on their mastery of specialized knowledge.

Workers often draw distinctions that an outside observer cannot. For instance, experts gather information through interviews or reading; they analyze and interpret this information; and they make written and oral reports to clients and colleagues. There are strong similarities across people, sites, and projects. Nevertheless, some experts say that they are applying old knowledge to new problems, others that they are creating new knowledge, and still others that they are preserving knowledge that already exists.

The experts who see themselves as producing new knowledge emphasize the recency or originality of their information and the differences between their findings and those of predecessors. They may classify such work either as basic scientific research or as applied research on markets, products, or processes. Other experts see their work mainly as applying existing knowledge to current problems. For instance, when most lawyers do research, they analyze and interpret previous cases and they emphasize the continuity over time of knowledge and its meaning. To gain acceptance of their rulings, most judges de-emphasize the innovative quality of their reasoning. Distinguishing between creating knowledge and applying can be difficult. Lawyers may be more successful if they reinterpret precedent cases imaginatively, or if they conceive original strategies. Basic research may have direct applicability, and applied research may contribute fundamental knowledge. When it comes to systems as complex as a human body or an economy, people may only be able to create valid knowledge by trying to apply it.

Some experts describe themselves as memory cells. They say their jobs are to preserve information that their clients have difficulty preserving. Because the US military services rotate assignments frequently, military personnel lack job experience and cannot manage long-term projects. Also, military wage scales are too low to attract and retain highly educated experts. To compensate, the military services sign contracts with firms that provide long-term continuity of management and expertise. These firms employ civilian experts who do not rotate assignments frequently and who either manage long-term projects directly or advise military managers.

Creating, applying, and preserving complement each other. At least over long periods, merely storing knowledge does not preserve it. For old knowledge to have meaning, people must relate it to their current problems and activities. They have to translate it into contemporary language and frame it within current issues. Effective preserving looks much like applying. As time passes and social and technological changes add up, the needed translations grow larger, and applying knowledge comes to look more like creating knowledge. Conversely, for new knowledge to have meaning, people must fit it into their current beliefs and perspectives, and familiarity with existing knowledge signals expertise. Evaluators assess completed research partly by its applicability, and they judge research proposals partly by the researchers' mastery of past research. Thus, Rand Corporation, which derives some income from research grants, makes elaborate literature searches before writing grant proposals. Rand also employs public-information staff, who highlight the relevance of research findings.

In the US, capital investment in information-work machinery -- primarily computers and systems -- surpassed investment in traditional capital goods in the 1980s

(Hudson Institute, 1987; Office of Technology Assessment, 1988). However, firms have found it difficult to make capital-budgeting decisions about information technology because it is so difficult to measure the productivity of information work. It appears that information-technology investments in U. S. factories did raise productivity during the 1980s. On the other hand, in industries like finance, insurance and real estate, huge investments in information technology did not increase productivity. The results differed vastly from one firm to another, suggesting that management and organizational design were key factors.

Office Automation

Information work concentrates in offices, and office automation systems facilitate the processing, distribution, and coordination of information. No longer a mundane clerical pool or a "bureaucratic nightmare," the office is one of the most important work sites. Offices today house diverse arrays of professional, managerial, sales, and clerical employees. Office work is complex and cooperative, and yet highly individualistic. It resembles an orchestra of highly-trained individuals who collaborate more than a factory of workers who perform preplanned tasks (Laudon and Laudon, 1991;1993).

Offices perform three critical organizational roles: They coordinate and manage the work of professional and information workers at one site. They link the work being performed across all levels and functions throughout an organization. They couple an organization to its environments, including clients and suppliers (Laudon and Laudon, 1993).

To fulfill these roles, nearly all offices perform five major activities: creating documents, filing information, managing projects, coordinating individuals and groups, and scheduling individuals and groups. Document management typically consumes about 40 percent of the total effort, with the other activities splitting the remaining 60 percent in roughly equal shares. Further, many offices house specialized experts who perform creative tasks such as calculating, drawing, and simulating.

The first wave of office automation supported only clerical activities such as word processing and simple task coordination, but in the 1990s, new software supports a diverse range of office activities.

Document-Management Technologies support word processing, desktop publishing, document imaging, and workflow management. Document-imaging systems store, retrieve, and manipulate digitized images of documents. The documents themselves can be discarded. Two or more people can work simultaneously on the same document; work need not be delayed because a file is out or a document is in transit. Workflow systems automate processes such as routing documents to different locations, securing approvals, scheduling, and generating reports. With effective indexing, users can retrieve files based upon their contents.

Groupware is software that supports collaboration within work groups. It seeks to improve groups' effectiveness by providing electronic links that help them to schedule meetings, to meet, to communicate with each other, to develop ideas collaboratively, to share the preparation of documents, to share knowledge, and to exchange information on the work of members. Groupware usually provides electronic group calendars, electronic mail, and software that permits members in remote locations to have video conferences. These functions presuppose powerful electronic networks. Products such as Lotus Notes, Higgins, and Microsoft's Workgroup permit workers to share information and to create information-sharing applications.

Personal Information Managers: Firms have traditionally maintained huge corporate databases on mainframe computers, but microcomputers offer office workers the opportunity to develop their own personal databases for clients, customers, suppliers, or vendors. However, few office workers have created such databases because database languages are difficult to use. Instead, software firms are producing personal information managers, which are database systems customized for the needs of salespersons, managers, real estate agents, or stockbrokers.

Project-Management Software portrays a complex project as an assembly of simpler subtasks, each with its own completion time and resource requirements. Once a user specifies what each subtask requires, the software can produce delivery schedules and resources allocations. Two project-management techniques are Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). In the 1990s, project managers have begun to use graphical user interfaces that permit workers to operate the programs with a mouse. Project managers also have access to high-quality presentation graphics, permitting photographic slide and overhead transparency output. Whereas older project-management software focused on single users, contemporary packages offer access to many members of a work group.

Investment Work Stations: Chancellor Capital Management, Inc., developed its own investment workstations to help it manage $25 billion for 300 clients. Chancellor's former systems were mainframe-based, incompatible, error-prone, and difficult to use. They stored data separately in accounting, trading, research, and analytical systems. That arrangement compromised data integrity, and it impeded searches for information. Thus, Chancellor wanted to reduce drudgery and to give traders and asset managers more time to concentrate on making decisions and developing strategies. They wanted to integrate their front and back offices so that data-integrity issues would disappear and all systems would report identical information.

Chancellor built a network of powerful workstations that integrate data from the firm's investment-management systems and its portfolio-accounting systems. Chancellor also installed a user interface with a number of windows; different users have different windows, depending upon their own needs. Instead of having to switch from one database to another, a user can easily switch from one window to another. Some formerly time-consuming calculations have become automatic. Trading within the firm has become paperless, as have communications with brokers, and Chancellor can now handle any trade volume it wishes. For example, in a few days during September 1992, Chancellor spent a large amount of cash, executing 1200 to 1500 trades per day (Michaels, 1993).

Computer Aided Design (CAD) automates the creation and revision of designs. For instance, Alan R. Burns, a mining engineer from Perth, Australia, used CAD to turn an innovative idea into reality. The tires of off-road vehicles take a terrible beating that produces frequent tire replacements and costly downtime. Mr. Burns conceived a tire with independent tread segments that could be replaced individually. The segments are not pneumatic so they are not subject to punctures; and people can replace them quickly, without removing the wheel from the vehicle. Burns used a CAD workstation to develop a visual representation of a segment, and he modified thickness, tread shape, and other factors until he achieved an acceptable design. The CAD software enabled him to simulate operational characteristics for each visual model and to calculate the tire's stresses and strains under specified loading and usage conditions. Once Burns approved a design, he used the same software and the same model data to design a mold for the tire segments. The software could perform flow analysis to locate potential problems such as uneven cooling or shrinkage. One output was instructions for the milling machines that cut the mold from tool steel (Shapiro, 1993).

Virtual Reality systems offer visualization, rendering, and simulation capabilities far beyond those of conventional CAD systems. They use interactive graphics software to create computer-generated simulations that are so close to reality that users believe they are in a "real" situation. Virtual reality is interactive in such a way that the user actually feels immersed in a "world" that exists only in a computer. To enter that world, a user dons special clothing, headgear, and equipment. The clothing contains sensors that record the user's movements and immediately transmit that information back to the computer.

For example, Japan's Matsushita Electric Works has developed an virtual-reality application it calls Virtual Kitchen to help stores sell kitchen appliances and cabinets. Prospective buyers bring their kitchen layouts to a department store, where staff enter the design into a computer. The customers then don the appropriate equipment and suddenly find themselves in the kitchen they designed. They can try the appliances in various sizes, colors, and locations. They can open and close cabinet doors and drawers. They can walk around and discover the feel and ambiance of the new kitchen.

Although virtual reality may appear fantastic, its benefits may turn out to be very concrete. Berlin, Germany, is using virtual-reality equipment to design a new subway system. The University of North Carolina is using a virtual-reality system to design a new computer-sciences building (Newquist, 1992). Many major pharmaceutical firms are using the University of North Carolina's virtual-reality system to create computer- generated molecular worlds. General Electric's scientists in Schenectady, New York, are working with surgeons from Boston's Brigham and Women's Hospital to develop a virtual-reality system for surgery.

KNOWLEDGE-INTENSIVE FIRMS

Knowledge has great importance for knowledge-intensive firms (KIFs). KIFs derive substantial revenues from products or services that incorporate expertise, and most KIFs employ many experts -- such as auditors, computer programmers, consultants, researchers, lawyers, market researchers, or medical doctors (Starbuck, 1992).

KIFs share some similarities in their internal structures and operations, but they also differ from each other. Sveiby and Lloyd (1987) divided "knowhow companies" into categories reflecting their managerial or technical expertise. They said law firms have high technical expertise but low managerial expertise, whereas McDonald's fast-food chain has high managerial expertise and low technical expertise. On the other hand, Ekstedt (1988; 1989, pp. 3-9) distinguished "knowledge companies" from industrial companies, high-technology companies, and service companies "such as hamburger chains". In his schema, both high-technology companies and knowledge companies have high knowledge intensity, but high-technology companies have higher intensity of real capital than do knowledge companies.

Although KIFs may be professional firms, many KIFs are not professional firms because not all experts belong to recognized professions. A profession has at least four properties besides expertise: an ethical code, cohesion, collegial enforcement of standards, and autonomy (Schriesheim et al., 1977). Professionals' ethical codes require them to serve clients unemotionally and impersonally, without self-interest. Professionals identify strongly with their professions, more strongly than with their clients or their employers. They not only observe professional standards, they believe that only members of their professions have the competence and ethics to enforce these standards. Similarly, professionals insist that outsiders cannot properly supervise their activities. Management consulting and software engineering, for example, do not qualify as recognized professions even though the people who do these jobs well have rare expertise. They are not professionals because the ultimate judges of their expertise are their clients or their supervisors, and because their employers set and enforce their ethical codes and performance standards.

KIFs form a broader category, in which many issues reflect labor markets, interpersonal networks, and experts' individuality, self-interest, and social standing. Yet, most KIFs have nearly all the properties that observers have assigned to professional firms. For instance, many experts design their own roles, divide work to suit their interests, compete for resources, and emphasize autonomy, collegiality, informality, and flexible structures.

Sveiby and Risling (1986) argued that KIFs call for new definitions of ownership and new ways of controlling the uses of capital. Traditional notions of ownership, they said, assume that financial or physical capital dominates labor, whereas human capital dominates in KIFs.

One should not, however, assume that knowledge resides only in people. Besides the knowledge held by individual people, one can find knowledge in: (a) capital such as plant, equipment, or financial instruments; (b) firms' routines and cultures; and (c) professional cultures. People convert their knowledge to physical forms when they write books or computer programs, design buildings or machines, produce violins or hybrid corn, or create financial instruments such as mutual-fund shares (Ekstedt, 1988; 1989). Organizations seek to capture the knowledge and expertise of their workers in various knowledge-based systems -- decision support systems, databases, and case files, some of which are automated (Laudon, and Laudon 1993). Conversely, people may gain knowledge by reading books, studying buildings, buying shares, or running computer programs. People also translate their knowledge into firms' routines, job descriptions, plans, strategies, and cultures. Nelson and Winter (1982) treated behavioral routines as the very essence of organizations -- the means by which firms can produce predictable results while adapting to social and technological changes. Simultaneously, Deal and Kennedy (1982) and Peters and Waterman (1982) were saying it is cultures that perform these functions.

Both KIFs and individuals can gain new expertise by buying capital goods. Computer software affords obvious examples. Not long ago, expertise was uneven across accountants who handled income taxes. Now, every accountant has low-cost access to software that makes no arithmetical errors, omits nothing, incorporates the latest changes in tax codes, and warns of conditions that might trigger audits by tax authorities. Lawyers have recently begun to use a computer program, CLARA, to help them do legal research. CLARA helps small law firms compete more effectively against large firms, and helps novice lawyers produce results comparable to experienced lawyers (Laudon and Laudon, 1991, chapter 4). Although unfinished, CLARA does research nearly as well as law professors. On reading of this achievement, one practicing lawyer sniffed: "Too bad. Maybe it will get better someday."

Describing McDonald's as a firm with low technical expertise overlooks the expertise in McDonald's technology and organization. McDonald's success stems from its ability to deliver consistent quality across diverse environments and despite high turnover of low-skilled workers. To get such results, the firm operates extensive training programs and conducts research about production techniques and customers' tastes. Although training at Hamburger University may give McDonald's managers more skill than those at most restaurants, McDonald's managers likely have no more skill than those in most production firms. Also, McDonald's uses technology and routines to control workers' activities.

Converting Knowledge Into Capital

KIFs convert individual expertise into organizational property. These conversion processes produce at least three types of organizational property: physical capital, routines, and organizational culture.

Physical Capital KIFs may be able to turn expertise into concrete capital. For instance, decades of experience enabled the large public accounting firms to create systematic auditing procedures. The firms then turned these procedures into checklists that novice accountants and clerical staff can complete. Similarly, research occasionally produces databases that have value beyond the projects that created them. KIFs exploit these databases by proposing new projects that would draw upon them. So-called "knowledge work systems" are investments in information technology that are designed to increase a firm's knowledge base (Laudon and Laudon, 1993).

Converting a KIFs knowledge into capital can fundamentally alter the nature of the firm, turning it into an ordinary production firm and losing its knowledge base while strengthening its financial base. For instance, Orlikowski (1988, pp. 179-267) detailed a consulting firm's efforts to capture its experience as software. Over ten years and many projects, consultants built various software "tools" that help them plan projects and carry them out efficiently. The tools originated separately when consultants saw needs or opportunities, but the firm's general production philosophy implicitly guided these developments and rendered the tools mutually compatible. Also, at first, isolated people used these tools voluntarily, but informal norms gradually made their use widespread and mandatory. Thus, the tools both expressed the firm's culture in tangible form, and reinforced the culture by clarifying its content and generalizing its application. Generalization made the differences among clients' problems less and less important, and it weakened the contributions that clients could make to problem solving. Generalization also reduced the influence of more-technical consultants and increased the influence of less-technical consultants. In their interviews, the consultants stressed the tools' strong influence on their perceptions of problems and their methods of solving them. Eventually, the firm started to sell the tools to other firms. At that point, the firm's culture, methods, and experience became products that other firms could buy.

Routines Like all other firms, KIFs develop routines to handle familiar situations efficiently (Nelson and Winter, 1982; Starbuck, 1983). Routines are a form of social capital -- assets that, once learned and honed, become bases success in the marketplace. But formalized routines look bureaucratic, and highly educated experts dislike bureaucracy: Much research has pointed to conflicts between professions and bureaucracies, and some of these conflicts apply to expertise in general (Schriesheim et al., 1977). Most experts want autonomy, they want recognition of their individuality, and they want their firms to have egalitarian structures. Among the service KIFs, only those having long-term contracts with a very few clients seem able to bureaucratize. Even such

KIFs must bureaucratize cautiously, for their expert employees have external job opportunities.

Organizational Culture Cultures must be built gradually because they are delicate and poorly understood. Building a special organizational culture takes much effort as well as imagination. Imitating another firm's culture is usually impossible because every culture involves distinctive traditions.

Maister (1985, p. 4) wrote admiringly of "one-firm firms", which stress "institutional loyalty and group effort." In contrast to many of their (often successful) competitors who emphasize individual entrepreneurship, autonomous profit centers, internal competition or highly decentralized independent activities, one-firm firms place great emphasis on firmwide coordination of decision making, group identity, cooperative teamwork, and institutional commitment. Maister also warned that one-firm firms may become complacent, lacking in entrepreneurship, entrenched in their ways of doing things, and inbred.

Orlikowski (1988, pp. 152-160) studied a consulting firm in which the overtly "technical training" program functioned as a culture incubator. Most consultants seem to agree with the one who said: "The biggest advantage of the school is the networking and socializing it allows. It really is not that important as an educational experience." Alvesson (1991; 1992) too described a consulting firm that spent much effort on formal socialization. The top managers ran a "project philosophy course." They also sought "to sell the metaphor the company as a home to the employees." Designed to foster informal interaction, the building has a kitchen, sauna, pool, piano bar, and large lounge area. The firm supports a chorus, art club, and navigation course. All personnel in each department meet together every second week. Every third month, each department undertakes a major social activity such as a hike or a sailing trip. The firm celebrated its tenth anniversary by flying all 500 employees to Rhodes for three days of group activities.

It appears that many KIFs attempt to build cultures by selecting experts carefully, by using teams extensively, developing very serious mission orientations, managing growth cautiously, and encouraging open talk. But very few KIFs discourage internal competition, emphasize group work, disclose information, and elicit loyalty to the firm.

Most KIFs seem to deviate from the one-firm model in having multiple profit centers, assessing the productivities of individual experts, revealing only the financial information that laws require, decentralizing activities, encouraging entrepreneurship, and not involving everyone in decision-making.

Precarious Monopolies

Stinchcombe and Heimer (1988) described successful software firms as "precarious monopolies." They are monopolies insofar as they exhibit unusual abilities. Niches evolve naturally as individuals and small groups concentrate on specific streams of innovation. The firms also strive explicitly to develop and maintain unusual abilities. Unusual abilities help the firms to market their services and to avoid head-on competition.

This may be a common feature of many KIFs. Many KIFs have unstable knowledge monopolies. Stinchcombe and Heimer pointed out that the partial monopolies enjoyed by software firms are constantly at risk, both because technological changes may make unusual abilities obsolete and because key experts may depart. Computer technology has been changing especially rapidly, and the software firms' relations with clients and computer manufacturers repeatedly expose their experts to job offers. To sell their services to clients, software firms have to publicize the talents of their key experts, and this publicity creates job opportunities for the touted experts.

Professional firms find it especially hard to sustain monopolistic positions because the recognized professions work at keeping their control of knowledge and at preserving their members' autonomy: KIFs would run into strong opposition if they would try to convert professional expertise to organizational property. Moreover, many products of professional firms are easy to imitate. For example, Martin Lipton invented the "poison pill" defense against unfriendly corporate takeovers; but, after other law firms saw examples, Wachtell, Lipton was no longer the sole source for poison pills (Powell, 1986).

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