

# THE KNOWLEDGE ECONOMY

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■ **Abstract** We define the knowledge economy as production and services based on knowledge-intensive activities that contribute to an accelerated pace of technical and scientific advance, as well as rapid obsolescence. The key component of a knowledge economy is a greater reliance on intellectual capabilities than on physical inputs or natural resources. We provide evidence drawn from patent data to document an upsurge in knowledge production and show that this expansion is driven by the emergence of new industries. We then review the contentious literature that assesses whether recent technological advances have raised productivity. We examine the debate over whether new forms of work that embody technological change have generated more worker autonomy or greater managerial control. Finally, we assess the distributional consequences of a knowledge-based economy with respect to growing inequality in wages and high-quality jobs.

## INTRODUCTION

Over the past several decades, a number of scholars and commentators have argued that the leading edge of the economy in developed countries has become driven by technologies based on knowledge and information production and dissemination. These new technologies—which emerged in the late 1950s, expanded with the proliferation of personal computers, and then surged dramatically with the widespread use of email and the Internet—have considerable potential to remake the nature of work and the economy. Nevertheless, our understanding of the purported knowledge economy remains rather hazy, clouded by both enthusiasts and doomsayers who are quick to offer labels and assessments without much attention to evidence. Still others see a growth industry in providing professional services to organizations and nations to assist them in the transition to knowledge-intensive modes of production. If the knowledge economy is measured by the rise in knowledge management services among consulting firms or by the rapid growth in intellectual property as a legal specialty, then its growth has been considerable. Critics, however, argue that much of the growth is precisely in selling information

technology and related services. Our aim in this chapter is to sort through these debates and provide an overview of the scholarly literature in the social sciences on the knowledge-based economy. We present evidence for the acceleration in knowledge production and discuss the key issues that have been addressed by the empirical literature.

The broad label "knowledge economy" covers a wide array of activities and interpretations. At least three lines of research fall under this umbrella. The oldest approach, with its origins dating back to the early 1960s, focuses on the rise of new science-based industries and their role in social and economic change. Some analysts include professional services and other information-rich industries such as publishing in this category, noting the marked growth in employment in these sectors of the economy over the past three decades (Machlup 1962, Porat 1977, Stanback 1979, Noyelle 1990). A core idea unifying this strand of work is the centrality of theoretical knowledge as a source of innovation (Bell 1973). With some stretching, the new growth theory in economics (Romer 1986, 1990) could be included here as this work stresses the importance of knowledge in economic growth, noting that discoveries differ from other inputs because they are nonrivalrous and fuel further innovation.

There has been a good deal of debate in the economics field over whether particular industries are especially knowledge-intensive. Much effort has gone into analyzing how much these sectors contribute to growth in productivity (Brynjolfsson & Hitt 2000, Gordon 2000). Because the expansion of knowledge-intensive industries and the accompanying productivity increase occurred in the context of unusual macroeconomic and financial-market developments in the 1990s, a good deal of popular literature asserted that the knowledge economy operated differently from the past in some fundamental way. Although few scholars now accept such claims, much recent research in sociology and labor economics has focused on whether new kinds of jobs and novel forms of work organization have emerged in recent years. The degree to which new modes of work are particularly tethered to the knowledge economy is not altogether clear, and just how different these work arrangements are from older ones is the subject of much debate (Kochan & Barley 1999).

A third strand of work is much more narrow and managerial in orientation, focusing on the role of learning and continuous innovation inside firms (Drucker 1993, Nonaka & Takeuchi 1995, Prusak 1997). Some organizations appear to be particularly good at knowledge production and transfer, and researchers are interested in understanding why and whether these practices can be replicated. Such inquiry is potentially widely applicable, but the core concern of this line of work has been more applied. The broader sociological and economic implications concerning whether knowledge is codified or tacit, and what kinds of social arrangements enhance or impede knowledge generation and transmission have recently begun to attract attention (Cowan et al. 2000). Still, systematic empirical research on this topic is scarce and has not dealt with its implications for employment practices.

We define the knowledge economy as production and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence. The key components of a knowledge economy include a greater reliance on intellectual capabilities than on physical inputs or natural resources, combined with efforts to integrate improvements in every stage of the production process, from the R&D lab to the factory floor to the interface with customers. These changes are reflected in the increasing relative share of the gross domestic product that is attributable to “intangible” capital (Abramovitz & David 1996). Of course, many alternative labels and definitions are more expansive than ours, but we choose to keep the focus on the production of novel ideas that subsequently lead to new or improved goods and services and organizational practices.

We begin with a review of the evidence in support of the argument that key sectors of the economy are more reliant on knowledge generation and dissemination today than they were in the past. We then turn to the debate regarding whether recent technological advances have, in fact, raised productivity. We note that many of the most far-reaching effects of any new general purpose technology are not fully realized unless accompanied by related organizational and social adaptations (Rosenberg 1982, Bresnahan & Trajtenberg 1995, Helpman 1998). We examine the evidence as to whether new forms of more flexible work practices that embody technological change are becoming prevalent. We note that employment and work are becoming disaggregated, as more tasks are performed outside of the formal boundaries of a firm. We then consider distributional consequences of a knowledge-based economy, in terms of wages, unemployment, and jobs.

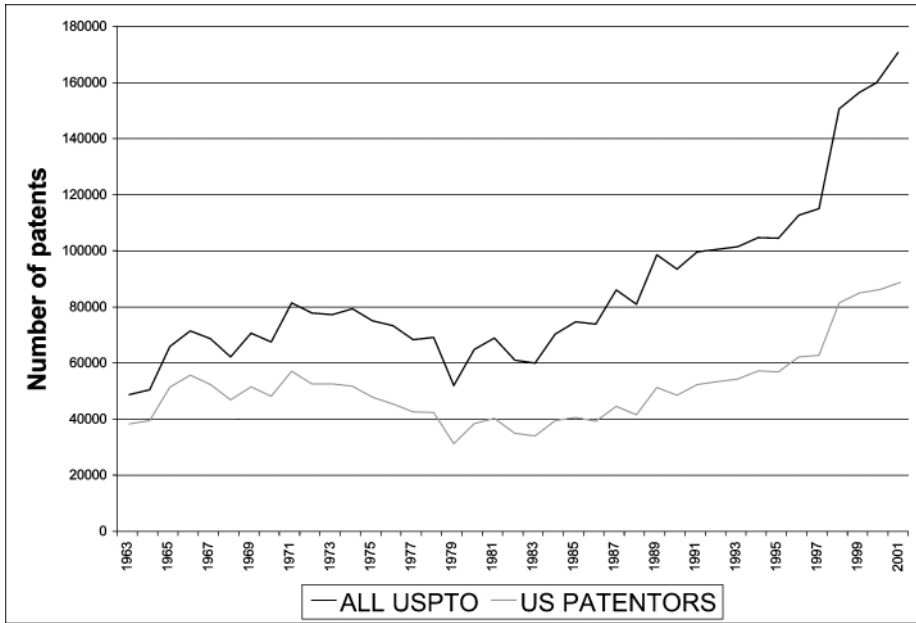
## THE ACCELERATION IN KNOWLEDGE PRODUCTION

Since the 1970s, many researchers have noted the transition that has occurred in advanced industrial nations from a manufacturing-based to services-driven economy. This change often goes by the labels postindustrial or post-Fordist (Bell 1973, Hirschorn 1984, Block 1990). Such a stark view of economic transformation misses an even more profound change in which the distinction between manufacturing and services has been rendered moot. Consider the automobile, the icon of the “old” Fordist, manufacturing economy. A new car today is less and less the product of metal fabrication and more a smart machine that uses computer technology to integrate safety, emissions, entertainment, and performance. The computer games, produced on assembly lines in Asian factories, with which teenage boys are so addled are sophisticated information processing devices, with both speed and graphics capability that exceed the largest supercomputer of a decade ago. Amazon.com, with its innovative use of collaborative filtering that tells consumers what people with similar tastes are watching, listening to, and reading, depends simultaneously on a warehousing system out of the factory era and on an Internet-based retail operation. These varied illustrations point not only to the blurring of

the manufacturing-services distinction but also to the very considerable extent that knowledge can be embodied in both goods and services. Economists have noted that these changes in production are part of a broader shift from tangible goods to intangible or information goods (Shapiro & Varian 1999). The replacement of answering machines by voice mail and multivolume encyclopedias by CD-ROMS are but two illustrations of this transition.

A challenge for social science has been to find metrics to gauge the extent to which society has become more dependent on knowledge production. Although there is wide recognition of the importance of knowledge and intangible capital in fostering economic growth and social change, devising useful measures of these assets has been difficult. One focus has been on stocks of knowledge—human, organizational, and intellectual capital, while another focus has been on activities—R&D efforts, investments in information and communication technology and in education and training, and organizational reforms. Perhaps the most developed line of research has focused on patent-based measures to quantify both R&D activity and stocks of knowledge. Patents have become a widely used indicator of intellectual capital (Grindley & Teece 1997) and economically valuable knowledge (Pakes & Griliches 1980, Griliches 1990). Thanks to the considerable efforts of Hall, Jaffe, Trajtenberg and colleagues (Hall et al. 2001, Jaffe & Trajtenberg 2002), the nearly three million U.S. patents granted between January 1963 and December 1999 are readily available on CD-ROM and on the National Bureau of Economic Research Web site, and more recent information can be obtained from the U.S. Patent and Trademark Office (USPTO). Thus, patents have become an easily accessible measure of inventive output, offering insight into the contribution of knowledge-intensive activities to economic growth. Figure 1 plots patenting activity in the United States over the period 1963–2001. The top line represents all U.S.-granted patents, whereas the lower line tracks patents granted to those inventors who are U.S. residents. The 20-year period between 1963 and 1983 evinces no strong trend. There is a rise in the late 1960s, but a decline in the 1970s that eventually drops below 1963 levels in 1979. Around 1983, the volume of patenting picks up and increases steadily until the late 1990s, when the pace takes off even more sharply. Over this 20-year period, the number of patents issued to U.S. inventors more than doubles, while all patents issued in the United States climb from less than 47,642 to more than 168,040. Clearly, patent trends suggest a recent marked acceleration in the production of new knowledge.

The benefits of innovation are realized in several ways. One aspect is cost reduction for goods in widespread use. A second, more dramatic consequence of innovation is the development of entirely new goods and services. We examine the patent data according to the industrial classification of the patents to see if novel ideas are occurring more frequently in new rather than established fields. A focus on the most prolific patenting sectors offers considerable support for the idea that the upsurge in patenting has been driven by new sectors of the economy. Table 1 shows a ranking of the leading U.S. patent classes over the period 1963–2001. In 1963, patenting activity was dominated by patents for organic compounds, synthetic resins, measuring and testing, and fluid handling. Resins and organic



**Figure 1** Number of patents granted by USPTO, 1963–2001.

compounds remained important over a long period (note the number of years these classes were among the top three classes), but measuring and testing and fluid handling declined in significance. In the 1970s and early 1980s, metal working increased in importance, as did pharmaceutical-based drugs. Molecular biology and semiconductors are well down on the list. By the end of the period, however, molecular biology and semiconductors had become the most prolific categories, along with pharmaceutical-based drugs. Molecular biology is the foundation for the new biotechnology industry, and semiconductor devices are the basis for the computer, electronics, and telecommunications fields. The upsurge in overall patenting activity is driven by the emergence of new industries, highly fertile in terms of the generation of novel ideas and new products. In tandem, there is a decline in traditional sectors.

We also see this shift in the sources of ideas and the creation of new products when we look at a smaller country, such as Finland, with a narrower set of leading industries. In the 1960s, Finland's economy was largely based on forestry and paper production. Today, that country's most prominent corporation is the ubiquitous Nokia, a global leader in mobile and wireless communications. Patent counts for Finland capture this transformation, with telecommunications patents replacing paper and pulp patents as the leading patenting sector. From the early 1960s until 1993, paper making was the leading class of patents granted by the USPTO to Finnish patentees. In 1994, telecommunications and multiplex communications surpassed paper making as the top patent class. The growth of telecommunications

**TABLE 1** Ranking of top three patent classes, U.S. patentors, 1963–2001

Class title	Ranking					Time period in top 3	Number of years in top 3
	1963	1973	1983	1993	2001		
Chemistry: molecular biology and microbiology	162	99	32	4	2	1996–2001	6
Drug, bioaffecting and body treating compositions	11	8	3	1	1	1975–2001	27
Fluid handling	4	3	21	20	41	1969–1971, 1973	4
Measuring and testing	3	5	5	9	23	1963–1968	6
Metal working	6	4	6	10	27	1974	1
Organic compounds	1	1	2	3	6	1963–1995, 1997	34
Semiconductor device manufacturing	195	91	33	12	3	2000–2001	2
Stock material or miscellaneous articles	16	6	4	5	7	1972	1
Surgery	90	30	13	6	5	1998	1
Synthetic resins or natural rubbers	2	2	1	2	4	1963–1996, 1999	25

Source: U.S. Patent and Trademark Office

patenting in Finland has been remarkable. While patents in paper making more than doubled from 1994 to 2001, there was a fivefold increase in telecom patents. Data from the European Patent Office show a similar trend for European-issued patents. In 1990, only 8.9% of all Finnish patent applications to the European Patent Office were high-tech patents. By 1995, the share of high-tech patent applications had increased to 30.3% and in 2000 to 51.6% (Zoppè 2002).

Research universities have been major contributors to the growth in U.S. patenting. University patenting has grown much more rapidly than patenting by private firms, suggesting a growing importance of basic science to economic growth. University patents are regarded as more fertile, in terms of subsequent uses, and more likely to reflect novel scientific findings (Trajtenberg et al. 2002). Owen-Smith (2003) documents a more than eightfold increase in university patenting over the period 1976–1998, an increase that is the product of research efforts at a relatively small number of research universities. As with patenting trends in the private sector, the academic upsurge was led by research in biomedical and information technologies.

Critics have argued that although considerable technological change is afoot, the upsurge in patenting is due to changes in the legal and regulatory environment that have increased the propensity of organizations to patent inventions (Heller & Eisenberg 1998, Lessig 2001, McSherry 2001). One of the landmarks in the shifting

institutional environment is the 1982 establishment of the Court of Appeals of the Federal Circuit (CAFS), a specialized appeals court for patent cases. The general view of CAFS is pro patent. Accordingly, its establishment has helped foster an environment where more inventors opt to protect their inventions by patenting. Drawing on U.S. and international data on patent applications and issued patents, Kortum & Lerner (1997) investigated the diverse causes behind the increase in U.S. patenting and conclude that institutional changes in the legal environment did not account for the upsurge. Instead, the jump in patenting reflects an increase in innovation, driven by improvements in the management of innovation processes. Nevertheless, there clearly is a feedback process in which greater patenting raises the odds that inventors think in proprietary terms and make intellectual property claims. U.S. patent policy has been strengthened in terms of protection and breadth, expanding to include computer algorithms, and business methods and processes. Just how much the patenting upsurge reflects technical advance or technology strategy is ripe for study (Bessen & Hunt 2003).

Whereas patents signal one form of growth in intangible knowledge capital, increases in the size of the science and engineering workforce offer an indicator of growth in human capital. Nonacademic science and engineering (S&E) jobs grew at more than four times the rate of the total U.S. labor force between 1980 and 2000. S&E employment increased by 159% between 1980 and 2000, an average annual growth rate of 4.9%, in comparison to 1.1% for the entire labor force. In 1999, more than 13 million people in the United States either had a S&E education or were working in occupations labeled as scientists or engineers (National Science Board 2002).

An important aspect of the expansion of the knowledge-based workforce is the development of occupational communities that consist of individuals, often working for different, sometimes rival organizations, who are in the forefront of producing and distributing novel ideas. One sign of the importance of these communities, such as the open software movement, is reflected in how many conventional organizations, such as IBM, value linkages to them, and build multibillion dollar business on the Linux platform (Moon & Sproull 2000, O'Mahony 2001, Raymond 1999). Perhaps more consequential is the extent to which these user communities maintain critical infrastructures, such as Internet standards. Similarly, R&D collaborations among ostensibly competing organizations have grown much more consequential in such fields as IT, nanotechnology, and biotechnology, where knowledge is developing rapidly and the sources of knowledge are widely dispersed (Powell et al. 1996, Merrill & Cooper 1999, Mowery 1999).

These forms of collaboration across institutional sectors are greatly assisted by fundamental changes in the technologies of knowledge and information production. The crossnational collaborations among the multiple organizations involved in the mapping of the human genome were rendered possible by computing advances and by the Internet, which enabled extraordinary volumes of information to be analyzed and accessed from distant sites (Lambright 2002). Many analysts have commented on the huge volume of information that is now widely accessible by the Internet (Castells 2001). The amount of information now available

enables a large number of people to access all kinds of literature in a timely manner (such access is stratified, however; see DiMaggio et al 2001). In addition, new communication technologies increase the ability to exchange knowledge across organizational boundaries, making cooperation among sophisticated technical communities vastly easier. Consequently, the growth in the number of jobs that are information-intensive is not confined only to high-tech sectors. This sea change in activity raises key questions about whether work is more productive under this new regime, and whether accompanying organizational changes privilege some employees at the expense of others. We take up these issues in turn.

## TECHNOLOGY AND PRODUCTIVITY

Much of the macroeconomic research on the knowledge economy has focused on the linkage between technology and labor productivity, defined as the amount of output given a unit of labor input. Early studies of the relationship between information technology and labor productivity were prompted by the massive growth in computer investments and the concurrent productivity slowdown in the American economy in the late 1970s and throughout the 1980s (Roach 1987). After two decades of steady growth, labor productivity had come to a standstill in the early 1970s and showed little sign of revival, despite a subsequent surge in computer investments. The economists were puzzled by this. Paradoxically, the greatest increase in computer investment occurred in the service sector, which was also experiencing the most severe slowdown in productivity. Roach (1987) showed that during the 1970–1985 period, the service sector increased its share of computer spending of overall capital stock from 6.4% to 15.5%. Yet, the productivity of white-collar information workers was not even keeping up with that of production workers.

Loveman (1994) examined the productivity of large manufacturing firms between 1978 and 1984 and found that the returns on investment in information technology were actually negative. Similarly, in a series of studies on manufacturing industries, Morrison & Berndt found that the gross marginal product of technology investment was less than the costs associated with them (Morrison & Berndt 1990, Berndt & Morrison 1995). The lack of evidence of a positive relationship between technology investment and productivity measures was termed the “productivity paradox.” The findings of the early studies were captured by economist Robert Solow’s (1987, p. 36) widely repeated quip: “You can see the computer age everywhere except in the productivity statistics.”

Measuring the gains from the growing use of computers has proved difficult. None of the standard measures consider convenience, for example, or more rapid access to information. Nor does the speed or breadth of information dissemination register in standard productivity accounting (Brynjolfsson 1993). Nevertheless, by the late 1990s, a number of studies reported evidence of a strong positive relationship between technology investment and labor productivity growth (Jorgenson & Stiroh 2000, Oliner & Sichel 2000). During the mid 1990s, labor productivity



growth in the United States started to show signs of resurgence, fueling the discussion of a purported “new” economy. Nordhaus (2001) analyzed the 1996–1998 period and found that the sectors that contributed most to the rebound were industrial machinery and electronic machinery, which are the sectors that include computers and semiconductors, respectively. Together, these two sectors represented fewer than 4% of nominal GDP, but made up 0.60 percentage points of the 2.39 annual productivity growth over the 1996–1998 period. Stiroh (2002a) examined the relationship between information and communications technology (ICT) capital intensity and labor-productivity growth across U.S. manufacturing industries between 1973 and 1999 and found a positive relationship between information-technology investment and productivity growth. Those manufacturing industries that invested most heavily in information technology in the late 1980s and early 1990s enjoyed productivity gains in the late 1990s. To be sure, there are still skeptics, such as Gordon (2000), who argues that the Internet and information technology in general have had a less significant effect on the economy than earlier inventions such as electricity. By and large, however, there seems to be a general consensus that investments in information and communication technologies have fostered productivity growth. Much of the contradiction between the more recent findings and much earlier studies has been attributed to the use of more appropriate and comprehensive data (Hitt et al. 1999). Studies using macrolevel data tend to fail to find a linkage between technology and productivity, whereas studies relying on more fine-grained, firm-level data have captured much more of an effect of technology on productivity. This pattern of results suggests the difficulty of measuring aggregate output. Consider, for example, the difficulty of capturing the efficiencies realized by being able to check on the Web for the balance in your checking account.

Conventional economic theory views economic growth as a result of two factors—labor productivity growth and labor supply growth (Solow 1957, 1987). Labor productivity growth depends on growth in productive inputs such as capital intensity and labor quality. The part of economic growth that is not explained by increases in inputs is referred to as multifactor productivity, or the Solow residual. Growth in multifactor productivity results from technical progress and improved efficiency. Alongside growth in labor productivity in the late 1990s, the U.S. economy enjoyed a revival in multifactor productivity. Many of the enthusiasts of the knowledge economy quickly claimed that investments in technology were driving the growth by creating broader productivity gains in the form of economywide spillovers [Organisation for Economic Co-operation and Development (OECD) 2000]. The empirical evidence of spillover effects has been mixed, however. Whereas Griliches & Siegel (1992) found a relationship between computer investments in U.S. manufacturing industries and multifactor productivity growth, Stiroh (2002a,b) found no correlation between ICT investments and multifactor productivity growth in U.S. manufacturing industries.

More careful empirical research at the firm level has shown that the contribution of information technology investments to productivity growth exceeds the

contribution of other investments—but only when coupled with significant organizational changes. In a series of studies, Brynjolfsson & Hitt (1995, 1996, 2000) and Black & Lynch (2000, 2001) show that technology enables complementary organizational investments, which, in turn, reduce costs and improve output quality and thus lead to long-term productivity increases. Black & Lynch (2000) found that manufacturing plants with a greater proportion of nonmanagerial workers using computers were more productive. Brynjolfsson & Hitt (1995, 1996) analyzed data for 367 firms between 1988–1992 and found a clear positive relationship between information technology investment and firm output, but also wide variation among firms. Moreover, in a study of 600 of the *Fortune* 1000 firms, Brynjolfsson & Hitt (2000) illustrate that although computers contribute to output growth in the short term, the returns to computers are two to eight times greater when measured after three to seven years. In a cross-sectional survey of organizational practices in 400 large U.S. firms, Bresnahan et al. (2002) find an interaction effect between the value of information technology investments and both increased worker autonomy and labor force skills. Similarly, drawing on a survey of 4100 U.S. firms, Black & Lynch (2001) found that productivity gains from technology investments were often associated with workplace changes, such as profit-sharing plans and employee participation in decision making.

One group of economists that has taken a broad view of the relationship between the economy and society argues that information technology is best described as a general purpose technology, similar to the telegraph, steam engine, and the electric motor (Bresnahan & Trajtenberg 1995; Rosenberg 1976, 1982). The true value of a general purpose technology comes from a series of complementary innovations rather than directly from the original technology. Thus, the gains from a general purpose technology are limited more by managers' ability to invent new organizational processes and structures than by technological capacity (David 1990, Brynjolfsson & Hitt 2000). Indeed, introducing a novel technology without appropriate organizational changes can lead to significant productivity losses, as any benefits of the new technology are offset by negative interactions with existing organizational practices. For example, Brynjolfsson et al. (1997) describe how the introduction of computer-based manufacturing equipment failed because workers continued to work according to time-tested practices. The disjuncture between old and new sets of work practices made the transition impossible and resulted in productivity losses. Similarly, Baily & Gordon (1988) describe how venerable paper-based procedures still remained in an office after computers were introduced. Similar kinds of mismatches between a new technology and preexisting organizational practices and structures have characterized many of the shifts to earlier general purpose technologies. The introduction of the electric dynamo (David 1990) and the steam engine (von Tunzelmann 1978) required matching between the innovative technology and existing and new practices. Seen in the light of historical research on the adoption of technology, the long-expected gains in productivity from investments in information technology are not fully realized until complementary institutional arrangements are developed.

The large twentieth century corporation was designed to meet the goals of increased output and lower unit costs. As Alfred Chandler (1962, 1977) detailed in his magisterial studies of the rise first of a functional hierarchy and then of a multidivisional structure, the expansion of mass production necessitated a detailed division of labor and the delegation of administrative tasks. The role of a manager in the large bureaucratic firm “evolved as guardian of the organization’s centralized knowledge base” (Zuboff 1995, p. 202). The technological changes made possible by steep gains in computing power were initially harnessed to reinforce hierarchical, centrally controlled organizational structures—to watch, control, detect, and duplicate. Managers struggled to hold on to the information on which their authority rested, even as new information technologies opened up possibilities for the broad distribution of information. Such distributed knowledge can erode the old basis of managerial control, however. The coevolutionary process by which technologies and institutions adapt to one another entails experimentation and learning; therefore, it takes time for novel technologies to be debugged, to be diffused widely, and to become productive. Thus, the long-expected gains in productivity from information technology may not be realized until older, centralized organizational arrangements are abandoned and alternative ways of organizing are developed. Whether this transformation takes place depends as much on politics and struggles inside organizations over the exercise of authority as it does on the availability of new tools. We next consider evidence as to whether the workplace has been altered, introducing more autonomy and flexibility, as a result of changes in technology.

## WORKPLACE ORGANIZATION: FLEXIBILITY FOR WHOM?

Numerous studies have noted the shift from the Fordist mass-production system that characterized U.S. manufacturing industries during the postwar period to a more flexible way of organizing work, but debate has raged as to whether this transformation represents a move to more intensive forms of control or more autonomous and discretionary work (Appelbaum & Batt 1994, Osterman 1994, Smith 2000, Vallas & Beck 1996). Since the late 1970s, different organizational innovations and staffing practices, such as quality circles, job rotation, use of teams, and broad job definitions, have become increasingly common (MacDuffie 1995, Cappelli et al. 1997, Lawler et al. 1998). Osterman (1994) surveyed 694 U.S. manufacturing firms and found that 35% of firms with 50 or more employees had adopted 2 or more of these flexible work practices. The key link between workplace reform and the knowledge economy is that new flexible practices are most commonly found in firms that compete in international product markets, emphasize quality, or have a technology that requires highly skilled workers.

Although there is evidence that much workplace reorganization is afoot, there is strong debate as to the consequences of these changes. What some interpret

as a trend toward more empowered workers, flatter hierarchies, and increased responsibility, others see as a “wolf in sheep’s clothing” that managers can use to exploit and control labor. Whereas some emphasize technological change and a push for efficiency as the driving forces behind the changes in work organization, others argue that high performance work systems are management fads that exist more in rhetoric than in practice (Appelbaum & Batt 1994, Gordon 1996). Yet even fads can have impact. Cole (1999) has shown that many practices for enhancing quality were adopted in an imitative fashion but subsequently persisted and have been combined in innovative ways to create effective workplaces.

The idealized view of new work practices presented in the business press stresses greater job discretion and worker autonomy. Flexible work arrangements facilitate worker involvement and allow workers to draw on their specialized knowledge to solve problems (Adler 1992, Heckscher 1994). The managerial literature on the knowledge economy argues that flexible work arrangements are not only appropriate but essential in an economy based on knowledge production (Kelly 1998, Atkinson & Court 1998). A recent OECD policy report recommends that governments encourage the reorganization of work, because “firms that introduce new practices such as employee involvement, flatter management structures and team work tend to enjoy higher productivity gains than other firms” (OECD 2000). A number of empirical studies show that implementing such work practices does, indeed, improve productivity when implemented on a large scale (Levine & Tyson 1990, Kalleberg & Moody 1994, Kalleberg & Marsden 1995). MacDuffie (1995) reports a strong positive relationship between employee involvement and productivity and quality. In a study of apparel firms, Dunlop & Weil (1996) report that team-oriented work practices increase productivity when combined with changes in the distribution system. Other studies have pointed out that implementing only one or two of the practices associated with flexible work arrangements may have little or even negative effects on productivity (Levine 1995, Ichniowski et al. 1997). In a survey of 627 U.S. establishments, Black & Lynch (2001) found that introducing high-performance workplace practices was not sufficient to increase productivity. When coupled with increased employee voice or profit-sharing practices, however, the introduction of workplace reforms had a positive effect on productivity. This finding goes to the core of the debate: Are these new practices intended to remake the organization of work to produce shared gains, or to increase productivity by increasing work output while the associated gains are skimmed off by those at the top of the (flatter) hierarchy?

Critics of workplace “reform” argue that such changes are cosmetic and often serve as a means of concealing traditional control and authority relations (Pollert 1988, Barker 1993, Harrison 1994, Graham 1995). In this view, flexible work practices have not altered hierarchical control structures. Just the opposite trend is reported: Flexible work practices reinforce managerial control, erode informal work cultures, and reduce the existing power of labor unions (Grenier 1988, Fantasia et al. 1988, Dudley 1994). Increased autonomy shifts responsibilities from supervisors to workers and results in more intensive and demanding work. The

expansion of jobs creates another set of pressures for workers. As traditional job classifications blur, responsibilities of individual workers may grow without any commensurate increases in rewards. Job intensification does not constitute the re-making of work, according to critics. The purported system of work reform is just hyper-Fordism, obscured behind participatory language (Pollert 1988, Kenney & Florida 1993, Sayer & Walker 1992).

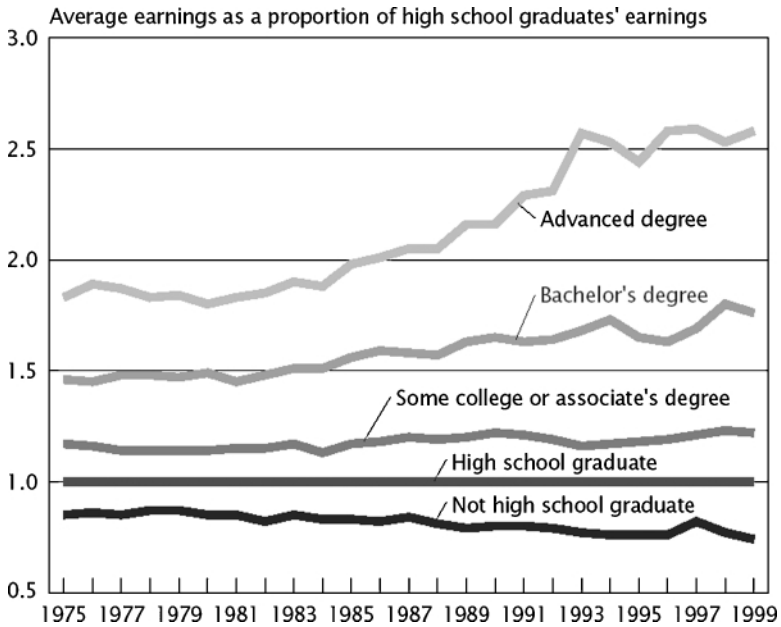
The answers to these questions involve a complex mixture of considerations: Do new forms of organizing simultaneously generate greater participation and more monitoring? Is scientific and professional knowledge becoming central to the conduct of work, or are we seeing the emergence of a class of privileged workers? When flexible practices are combined with technological change, is the eventual product or service intended for sophisticated consumer markets or for mass consumption? The initial claims made by flexible specialization theorists (Piore & Sabel 1984), who argued that a shift from Fordist mass production to technologically sophisticated flexible production would result in a democratization of the workplace, were clearly too sweeping. Just the same, arguments that all reforms only increase managerial hegemony have not been borne out either. Detailed nuanced empirical studies find that when organizational and technological innovations are introduced, the results are often an unexpected mix of autonomy and constraint (Attewell 1987). For example, research on just-in-time inventory systems and quality management practices finds increased worker participation, but it also finds that these technologies facilitate management monitoring and control. In their study of paper and pulp manufacturing plants, Vallas & Beck (1996) found that introduction of programmable control systems and new process technologies undercut the experience of veteran manual workers and older managers, while strengthening the power of well-educated engineers. Scott et al. (2000) describe the introduction of sophisticated information technology in insurance companies as a process of “delaying,” in which expert systems lead to cutting several layers of middle and lower management and greatly upgrading and expanding the role of claims adjusters. In tandem with their expanded scope of work and increased pay, these adjusters’ work was intensively monitored by new computer and information technology. These careful ethnographic studies illustrate that workplace changes that involve informational and technological upgrading seldom have uniform effects but instead generate differential returns that are often based on the skills and political clout of different classes of workers. We take up this issue of inequality in the next section.

## DISTRIBUTIONAL CONSEQUENCES

A growing body of social science literature on the knowledge economy has focused on the implications for workers in terms of employment, job security, and wage inequality. There is some consensus that a mismatch exists between certain workers’ skills and the types of jobs that typify a knowledge economy. Technological change is often painted as one of the culprits for the growing wage inequality

and increasing educational wage differentials in the U.S. labor market (Levy & Murnane 1992, Morris & Western 1999). Researchers generally agree that technological change has increased the demand for highly skilled labor relative to the demand for low-skilled labor. Some studies attribute this trend to computer-labor substitution, suggesting that technology can substitute for low-skilled labor and thus reduce demand for less-educated workers. The skills mismatch hypothesis suggests that technological change contributes more to the productivity of highly educated workers than to the productivity of less-educated workers, i.e., technology is complementary with a certain set of skills (Berman et al. 1994). Productivity gains in turn lead to an increase in the demand for highly educated workers.

The fear of a jobless future has persisted for decades, going back to debates concerning automation in the early 1960s. More recently, the displacement of workers has regained attention owing to the upsurge in information technology (Rifkin 1995). Indeed, along with a large-scale technological transformation and a boom in productivity, the U.S. economy in the 1990s was characterized by a markedly turbulent labor market. On the one hand, almost 22 million new jobs were created during the decade, and unemployment dropped as low as 4%, the lowest rate since World War II. On the other hand, the decade witnessed massive layoffs and the disappearance of many well-paid, permanent jobs. Farber (2001) examined job loss in the United States between 1981 and 1999 and showed that when accounting for business cycles, the overall job loss increased through the 1993–1995 period despite economic expansion. Some critics attribute the changes in the job market to the introduction of new technologies (Aronowitz & DiFazio 1994). They argue that with new technology, firms are able to produce the same amount of output with a fewer number of workers, thus reducing the amount of workers needed. Empirical evidence on the relationship between new technology and employment is ambiguous, however. Schultze (2000) argues that the downsizing problem might have been overstated, as much of the media reporting on the subject focused on dramatic cases involving large established manufacturing firms. Using data from the *Fortune* Industrial 500 companies, he showed that on average, the 50 firms that had over 50,000 employees in 1987 that still existed in 1997 had reduced their work force by 20%. This results in a decrease from an average of 126,000 employees per firm in 1987 to 102,000 in 1997. During the same period, however, similar size large firms outside of manufacturing added employment. Moreover, most of the 21 million new jobs outside of manufacturing industries were created by smaller firms. Similarly, studies at the country level offer little support for the argued relationship between technology and overall employment. A comparison of unemployment levels in the OECD countries reveals sharply divergent trends. Although in most countries the unemployment rate has declined during the 1990s, countries such as Finland, France, and Germany struggled with record-high unemployment rates (OECD 2002). Carnoy (2000) compared different measures of technological diffusion in 1994, such as spending on information technology per worker, the percentage of households with PCs, etc., with rates of unemployment in 1995 and found no relationship between any of the technology diffusion indicators and unemployment.



**Figure 2** Average earnings of full-time, year-round workers as a proportion of the average earnings of high school graduates by educational attainment: 1975 to 1999. Source: U.S. Census Bureau, Current Population Surveys, March 1976–2000.

There is a growing research suggesting that some of the new jobs that have been created over the past two decades are fundamentally different from the ones that have been lost (Morris & Western 1999). The new jobs tend to favor educated workers over those with less education and skills. Data on returns to education suggest a very divergent pattern of reward for those with educational credentials and those without. Over the period 1975–1999, earnings differences increased markedly among workers with different levels of educational attainment (Cheeseman Day & Newburger 2002). More education translates into higher earnings, but this payoff is most pronounced at the highest educational levels. Figure 2 shows that differences in wages and educational attainment were fairly constant between 1975 and 1985, but the average earnings for those holding advanced degrees grew markedly from 1985 to 1993 and then remained constant, whereas less-educated workers have seen their wages either decline or stagnate.

The increase in the education premium has often been explained by skill-biased technological change. Many technological innovations require workers with complementary skills and knowledge of that technology, which leads to an increase in demand for educated workers. At the same time, low-skilled positions are made redundant by technology, which decreases the need for less-educated workers. There seems to be a widespread belief that there has been a change in the skills

required for contemporary work. Surprisingly, there is relatively little research on what skills are needed in the knowledge economy. Most studies of skill-biased technological change have relied on survey data (Bound & Johnson 1992, Katz & Murphy 1992) or measures of job complexity from the *Dictionary of Occupational Titles* (Spenner 1990). The lack of direct measures of skill and technology are the major shortcomings of most survey studies (see Handel 2003 for a good survey of this line of research). Moreover, the role of management in organizational change cannot be overlooked. When technology is introduced to replace some tasks in an organization, managers are responsible for organizing the remaining tasks. How jobs are organized has important consequences for the skills demanded. Autor et al. (2002) studied the effects of the introduction of digital check imaging in two departments of a large bank. In one department, the tasks that were not computerized were divided into narrow jobs, while in the other department the tasks were combined into jobs involving greater complexity. In a longitudinal case study of the retooling of a food processing plant, Fernandez (2001) studied the impact of technological change on shifts in the overall wage distribution and on racial differences in wages for hourly production workers. He found that the retooling resulted in greater wage dispersion but, contrary to the skill-bias hypothesis, organizational and human resources factors strongly mediated the impact of the changing technology. Indeed, without these organizational responses, the impact on wage distribution would have been even more extreme.

In sum, although technological upgrading of work has favored the well-educated over those less-educated and younger workers over older, a skills-biased argument is too blunt an instrument to explain many of the core features of processes of work stratification. Recent decades have seen the narrowing of the gender gap in pay, and the persistence of a racial wage gap, neither of which is directly linked to skills-biased factors. More fine-grained studies like Fernandez (2001), Autor et al. (2002), and Black & Lynch (2001) are needed to better understand the linkage between technological upgrading, organizational changes, and employment.

Technological advance, like many aspects of economic and social life, is often characterized by a feedback process in which early success is heavily rewarded. Just as more educated workers are garnering the lion's share of gains from the knowledge economy, both specific institutions and regions that were "present at the founding" capture increasing returns from the knowledge economy. This process of accumulative advantage, famously described by Merton (1968, 1988) in the words of St. Matthew, "for whosoever has, to him shall be given, and he shall have more abundance," limits the opportunities for those organizations, regions, and nations that were not early participants in technical advance.

Consider U.S. research universities and their growing role in translating basic research into commercial application. Audretsch & Stepan (1996), Zucker et al. (1998) and Powell & Owen-Smith (2004) show that initial breakthrough discoveries at a small number of university labs lead to the founding of start-up biotechnology firms near these universities. Mowery et al. (2001) and Owen-Smith (2003) document that universities that were in the forefront of developing effective



policies for the transfer of intellectual property have a substantial advantage—in terms of licensing revenues and productive relations with companies, as well as federal grant support and basic science impact—over latecomers. Public science advantage translates into economic growth. Powell et al. (2002) observe that high-tech industries are remarkably spatially concentrated. For example, slightly more than half of the biotechnology firms in the United States are clustered in just three areas—Cambridge, Massachusetts, and San Diego County and the San Francisco Bay Area in California. This trend repeats itself on a global scale, as the founding of new firms occurs in a limited number of regions with access to leading research institutions, venture capital, and an abundant pool of educated labor (Owen-Smith et al. 2002). In the intensely competitive realms of basic science and technology transfer, positive feedback and increasing returns are enjoyed by early entrants, while institutions and regions that did not have a hand in the initial discoveries struggle to catch up.

## CONCLUSION

Numerous social scientists have documented the transition underway in advanced industrial nations from an economy based on natural resources and physical inputs to one based on intellectual assets. We document this transition with patent data that show marked growth in the stocks of knowledge, and show that this expansion is tied to the development of new industries, such as information and computer technology and biotechnology. The literature on the knowledge economy focuses heavily on knowledge production, however, and attends less to knowledge dissemination and impact. This neglect is unfortunate because a key insight of the productivity debate is that significant gains in productivity are achieved only when new technologies are married to complementary organizational practices. Information technology that facilitates the broad distribution of knowledge is not successfully tethered to a hierarchical system of control. Thus one cannot assume that there is a natural link between knowledge production and flexible work, as new information technologies open up novel possibilities for both discretion and control.

A focus on knowledge dissemination might also aid the analysis of the skills mismatch thesis. The argument that some classes of workers are highly disadvantaged by technical change is too simple, although clearly older, less-skilled, and minority workers have borne the brunt of the transition to an economy based on intellectual skills. But fine-grained studies of how some less-skilled workers acquired the necessary technical skills to work in new settings are rare, and would be valuable.

The debate over skills also reveals the relative lack of standard metrics in this area of research. Patents have become an appropriate measure of stocks of knowledge, but we lack any comparable indicators of skills, and too often researchers rely on occupational labels or categories. Yet such labels are easily changed by the

stroke of a pen. Consider the thousands of polytechnic schools worldwide that have changed their names to universities. Such “upgrading” is part of a movement to signal membership in a knowledge economy, but accurate substantive measurement of the knowledge economy remains far from resolved. The challenge for social science research is to connect the abundant quantitative indicators with qualitative studies of substantive changes in organizational practices and their outcomes.

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