Chapter 6
Innovation, Productivity, and Employment

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Introduction

Innovation, the continual generation of new technological ideas and products and services based on those ideas, is a prime requisite for a healthy industry in a high technology field. Congress and the executive branch have been particularly concerned about possible economic and regulatory incentives to innovation. The Congressional Research Service (CRS) identified 30 separate bills concerned with stimulating innovation that were considered by the 96th Congress.[1] A major executive branch study coordinated by the Secretary of Commerce culminated, in October 1979, in a Presidential message to Congress on industrial innovation, in which a number of measures were proposed.[2]

Information technology is central to these concerns. Computer and communication technologies are moving ahead so rapidly that products can become obsolete within a few years. Thus, although the United States holds a substantial positive balance of trade in certain areas of computer technology, the maintenance of this balance depends on continued research and development (R&D). Because of aggressive import competition from Europe, Japan, and Canada, even domestic markets are vulnerable to any faltering in the technological lead. A parallel OTA study is examining U.S. industrial competitiveness in the international electronics and computer markets.[3]

[1] Congressional Research Service, "Industrial Innovation," issue brief No. IB 80005; updated 10/24/80.

[2] U.S. Congress, House of Representatives, "Industrial Innovation message from the President of the United States transmitting proposals for Fostering Industrial Innovation," Oct. 31, 1979, Washington, D.C. (96th Cong., 1st sess., House, Dec. 96-214).

[3] U.S. Congress, Office of Technology Assessment, *Asessmen t of Impact of Technology on Competitiveness of U.S. Electronics Industry,* in progress.

Research and Development

The structure of innovation and product development in the computer industry is unusual, even for a high technology field. Basic research in computer science, which is largely carried out in universities, is based on the technology rather than on physical laws.[4] Thus, the leadtime between a fundamental theoretical advance in computer science and a practical application is, in general, relatively short, a few years or less.

Because of this close connection between technology and research, the vitality of the computer industry is in part dependent on the vitality of academic computer science. However, university departments of computer science are experiencing problems.[5] Rapidly growing departments face competition with private industry for the talented faculty needed to do the research and to train new experts. This situation is particularly critical in systems design and soft-

[4] Bruce Arden (cd.), *What Can Be Automated?* report of the Computer Science and Engineering Research Study (Cambridge, Mass.: Massachusetts Institute of Technology Press, 1980).

[5] National Science Foundation, *Science and Engineering Education for the 1980's and Beyond: A Report to the President,* October 1980.

ware engineering. The departments also need to invest in the facilities necessary for R&D and in experimental* computer science.

Several U.S. corporations in the information industry, realizing that their success depends on continued innovation, have established their own large research centers. Bell Laboratories in the United States and IBM both here and overseas are notable examples. These centers produce outstanding basic and applied research, and are also important links between the basic research carried out in the universities and the needs of industry.

*Experimental computer science tries to develop new concepts of computer architecture and programing by working directly with the machines rather than through theoretical analysis. Many vital areas of computer science cannot yet be addressed through theory. They are approached through the experience of developing programs to do particular tasks.

Another aspect of innovation in the information industry is the role played by small entrepreneurial firms in new product development. Many specialized areas at the leading edge of information technology are dominated by relatively small new companies (see ch. 14). Indeed, some experts in the industry suggest that one important pattern for innovation in information technology involves an entrepreneur who develops a new product and then forms a company to produce and sell it. If successful, the new company's need for capital expands. Frequently in the last decade, the only choice for the small company to meet this capital need was to be acquired by a larger firm. This is still the predominant goal of most high technology, high growth companies, although a few have been able to reach the public market.

Productivity

In the 1970's, the rate of productivity growth in the United States fell far below historical trends, causing concern in Government and industry. In addition to providing the basis for an increased standard of living, productivity growth is a major defense against inflationary pressures, especially those caused by cost increases for externally provided resources such as oil. (Electronics and agriculture, two sectors that have experienced very high productivity growth rates, have supplied the principal exports offsetting the large international trade imbalance due to oil imports.) Productivity growth also provides the leeway to meet certain societal goals, such as a more equitable distribution of basic goods and services like food, medical care, and education.

Although not all economists agree on the causes of the productivity lag, four main factors in the last decade have commonly been noted by various experts:

- growth of the service sector of the economy,
- entry into the job market of a large number of young and inexperienced workers,
- decline in the rate of technical innovation and investments in R&D, and
- growing Federal intervention in the form of regulation and tax policies that discourage innovation.

There is reason to believe that innovation in computer technology can help productivity growth in the United States. In addition to lower cost and/or better quality retail consumer products, the new technology also generates improved techniques and tools for making those products. Experts have noted the positive correlation between innovation rates and productivity in several industries.[6]

Based on anticipated advances in artificial intelligence, robotics, computer control, and input-output technology over the next few

[6]Edwin Mansfield! "Research and Development, Productivity, and Inflation, " Science, vol. 209, Sept. 5, 1980, pp. 1,091-1,093.

years, computer-based factory automation will make a substantial contribution to improving manufacturing productivity. Word processing and other forms of office automation are already responsible for improving clerical productivity and may have similar potential for managerial productivity. Intelligent cash registers and automated checkout are directly improving the productivity of retail clerks and indirectly the productivity of retail management (e.g., accounting, inventory control, procurement). Automated bank tellers (teller machines) are reducing the service loads on human tellers. The full impact is yet to be felt of these and other applications that are only now starting to be installed in the service sector. However, they are likely to help restore an upward trend in the Nation's productivity.

From a larger societal perspective, the increased productivity brought about by advances in computer technology may be reflected not only in greater output per employee, but perhaps also in terms of better product quality, improved work environment and job satisfaction, and longer term social benefits such as improved job safety and greater opportunities for on-the-job learning and career advancement.

Unemployment

It is self-evident that any innovation that creates new products and new industries will eliminate some jobs only to create others. Structural shifts in the economy will occur to the distress of the temporarily displaced.

An innovation that creates a demand for highly skilled programmers while eliminating the jobs of low-level clerical workers causes hardship through a short- to medium-term increase in unemployment. In certain industries, such as insurance, automation has caused a significant reduction in clerical staff.

Some believe that the nature of labor displacement should be examined in more detail since there are likely to be marked differences between the well-recorded experience of computing technology's first quarter of a century and the coming decades. Some of these differences are said to include:

- *Cheaper and readily available communication and computer technology,* which allows previously labor-intensive jobs—such as sales clerks, bank tellers, and secretaries—to be automated.
- *New research results* in fields such as process control, robotics, and the interface between humans and machines, which widen the applicability of computer automation. The "automated factory," a completely automated shop capable of manufacturing a wide variety of products on demand without human intervention, may become a reality in the next decade or two.

The assessment of the role of the U.S. Postal Service in electronic mail is the only study in OTA's examination of three national information systems to specifically look at employment impacts. Preliminary research results suggest that electronically transmitted mail would likely eliminate postal jobs as the volume of conventional mail decreases. However, it appears that the rate of such job displacement would be unlikely to exceed ordinary attrition. Further research is focusing on the rate of job displacement and possible geographical discrepancies, the need for job retraining, the impacts on levels and costs of service, and the broader implications for the future of the U.S. Postal Service. [7]

[7] U.S. Congress, Office of Technology Assessment, *Preliminary Assessment of the Role of the U. S. Postal Service in Electronic Message Services,* in progress.

Issues

Congress will be confronting a number of issues concerned with innovation in computer technology and its effects on productivity and employment.

R&D Support

For a number of years the vitality of U.S. science and technology has depended, in part, on Federal support. In times of low productivity gains, taxpayer resistance to increased governmental spending is understandable as pressure grows to trim programs, such as R&D, that do not satisfy immediate needs. There has been a similar tendency by some sectors in private industry to cut R&D budgets when money is tight. Industry also cites tax disincentives to R&D investment, particularly prior to the 1978 capital gains tax reduction.

Innovation in information technology improves the productivity of the information industry itself and also offers the tools for improving the productivity of many other sectors of the economy. Therefore, some believe Federal R&D support is a wise policy, particularly in light of international competition for the same markets.

Research in basic computer science is supported by the National Science Foundation (NSF), the Office of Naval Research, the Advanced Projects Research Agency, and to a lesser extent by a few other agencies. Applied R&D is supported by NSF and by mission agencies such as the National Aeronautics and Space Administration and the Department of Energy, although the major part of development support comes from the Department of Defense. One issue to consider is whether research in the applications of computer technology to problems in the private (civilian) sector—in such areas as education, health, transportation, environmental quality, and job safety—is receiving adequate Federal support, given the critical nature of computer technology to the Nation's well-being.

Computer Impact Research

The very applicability and power for change inherent in computer technology that makes it so promising as a means of solving many societal problems has raised concerns that it might also have negative effects. Many computer and social scientists, aware of these potential problems, have been developing a field of research on computer impacts. [a] Professional journals have been started, courses are being developed, and a few computer scientists are describing their principal professional interest to be "computer impacts." To date, however, it has been difficult to secure much Federal support for research because this subject does not comfortably fit into traditional scientific basic research programs, and because the products of early research tended to be of mixed quality.

Computer impact research is not pure computer science; neither is it classifiable as purely social or political science. It is also of no direct interest to the mission agencies, such as the Departments of Energy and Defense. However, the kinds of data and ideas that could be generated by long-term research in the societal impacts of computers could supply valuable input to the executive branch and to congressional agencies such as the General Accounting Office, CRS, and OTA. In addition, this research could help public officials and administrators gain a broader perspective of the social, economic, political, and institutional issues involved with managing information resources and technology in Government.[9]

'R. L. Kling, "Social Issues and Impacts of Computing: From Arena to Discipline," *Proceedings of the 2d Conference on Computers and Human Choice,* Vienna, Austria, June 1979.

'See Donald A. Marchand, "Are Public Administrators Failing To Do Their Computer Homework?" *Government Data Systems,* September/October 1980, p. 22 ff.

Employment

It is still uncertain whether the productivity increases brought about by computer technology will create or eliminate jobs. It would be helpful to know more about the long-term effects of automation. It is assumed that there will be some local structural impacts. Even if new jobs are created or old ones redefined, not all workers will find it easy or desirable to shift. This dislocation could result even when an official policy of no job loss has been established by a company, if employees are unwilling or unable to adapt themselves to the new technology or prove to be untrainable in the new procedures.

One OTA advisory panel member observed that, in periods of high demand and relatively full employment, labor displacement is unlikely to occur; however, when trying to pull out of a period of high unemployment there is greater incentive for firms to make productivity gains by investing in automation rather than increasing their labor force. Substituting machines for labor is easier when it can be done by not hiring when market demand for the product increases rather than having to fire.

On the other hand, it can be argued that the rising consumption of goods and services by the developing world will create a very large demand. Consequently, gains would be turned into increased production rather than decreased labor input.

Effects of Government Policy on Innovation

Innovation seems to be very sensitive to a variety of governmental policies. Thus, when exploring the potential impacts of new laws and regulations, Congress needs to be sensitive to possible unintended effects on the innovative process. For example:

- *Taxation.*. Industrial investment in innovation is very sensitive to tax policies, particularly those that encourage or discourage capital formation for new firms, for R&D expenditures, and for investments in new processes and equipment.
- *Antitrust:* The purpose of antitrust enforcement is presumably to encourage competition and, hence, innovation. Some experts hold, however, that major antitrust actions or threats of such actions against companies that are large principally because of a successful record of innovation may dampen their enthusiasm for further product development.
- *Regulation:* Regulation can encourage or discourage innovation depending on how it is applied. Regulators either try to direct innovation toward particular societal needs (as in the cases of automotive safety or environmental protection), or to control it for social protection (as in the cases of food and drug safety). The second order effects of this innovation can dampen innovation elsewhere as industrial investment must first respond to the regulatory demand. Only the remaining capital is available for investment.
- *International controls:* Multinational restrictions on the flow of data and computing hardware across national boundaries affect the design of communication-based information systems, and to some extent shape the nature of competition in the international marketplace.
- *Standards:* Federal standards, * voluntary or mandatory, directed at Government or private sector applications can also shape the nature of innovation and competition. On the one hand, for example, some argue that standards for data processing compatibility will encourage a competitive industry to develop around so-called "plug-compatible equipment" (independently manufactured devices that plug into computers

* For a detailed discussion of standards, see app. (' to U.S. Congress, Office of Technology Assessment, *Telecommunication Technology and Public Policy*, in press.

made by major firms such as IBM). On the other hand, the premature imposition of standards can freeze the technology at an early stage and inhibit the development of new products and ideas.

What the United States does on its own here may become moot in the longer term. International data standards are developing rapidly. In the United States, the National Bureau of Standards has coordinated the U.S. position. The objective of the International Standards Organization is to have, before the end of the 1980's, compatible protocols and interfaces to allow any one computer to "talk" to any other. Within the United States, pressure in this direction is being exercised through the mandatory Federal Information Processing Standards for Federal Government procurement.

The Federal Communications Commission is presently struggling with the problem of videotext. * Many broadcasters and manufacturers have repeatedly maintained that they cannot invest in developing hardware and services to support such service until they get a clear message on standards. Others argue that the technology is so new that standards at this time could inhibit new developments.[10] In short, the relationship between standards and innovation is not well understood, and could benefit from further study.

*Videotext and related services are systems for providing magazine-like information sources directly over the household television set.

[10]"'Upstart Television: Postponing a Threat," *Science* vol. 210, Nov. 7, 1980, pp. 611-615.