SILICON LANDSCAPES

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High-technology industries and the future of employment

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How should high-technology be defined?
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what is its effect on other employment sectors?
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play in the overall employment process?

Discussions of deliberate government policy to subsidize and encourage the growth of high-technology industry confront three sets of problems: first, how to define high-technology industry; second, how to determine the goals and distributional impacts of an economic development programme; third, deciding upon the appropriate means for implementing such a programme.

What is a High-Technology Industry?

In previous policy debates, there has been a modest amount of disagreement and a great deal of confusion over just what precisely are the 'high-technology industries'. How does 'high technology' differ from 'low' and 'medium' technologies? Is the 'high technology' utilized in the production process or is it contained in the final product? Is it connected with manufacturing or distribution, goods or services? Must it be a relatively new invention or innovation, or can it be of less recent vintage?

'High-tech' definitions vary widely at the margin, but almost all include computers and microelectronic components (integrated circuits). While it is true that recent advances in information processing, combined with developments in electronic communications, are bringing dramatic changes to our everyday life, the reason why the above industries are singled out in a policy sense is primarily economic: they have been 'growing' while other parts of the economy have been stagnating. Growing in what way? In output and gross sales revenue, particularly as major export commodities. Thus, they have been important in helping alleviate the US balance of trade deficit. But the largest US export industry is agricultural products, which has also been growing quite rapidly in the past decade. Agriculture, however, is not considered to be high tech because while it uses considerable high technology in the production process, the export product itself is raw food. Oil and gas drilling equipment and aerospace and military equipment are also leading and growing US export items. These would seem to involve high technology in both production and product, yet they too are frequently excluded from lists of high-technology industry.

One reason why the latter two might be excluded is because their 1970–80 growth in employment has been small compared to the absolute and percentage employment growth in computers and electronic components. And yet recombinant DNA bioengineering is also included on many lists of high tech, even though it has brought no significant employment thus far, nor is it expected to bring much employment for quite some years. In fact, the biotech 'industry' is not an industry at all, but a technology that could potentially be used in a number of different production processes to produce a variety of products. Most of the production is likely to be done under the auspices of major pharmaceutical companies, which would seem to be pretty high tech in any case, and certainly have been growing in employment and exports. Yet, drugs are another industry generally left off most high-tech lists.

Despite the focus on manufactured goods, many high-tech lists include the computer software industry, which is a service. The reason for this inclusion is because the growth of software and 'hardware' in computers is so closely tied together and interdependent. But, medical services are also growing very fast in employment, and are highly interdependent with the rapidly accelerating manufacture of advanced technological medical equipment. Despite these similarities, the health industry is also generally not considered to be part of the high-tech category.

The methodological problems seem endless. One definition stands out as having logical consistency in measurement and application. This definition, which is being used increasingly in academic and policy studies, is that a high-technology industry (which may or may not have a US Department of Commerce Standard Industrial Classification) is defined by an above average percentage of its labour force engaged in engineering, scientific, professional, and technical work. For example, one grouping of high-technology industries for California averaged 25 per cent of the labour force in these categories, whereas the proportion in the total California workforce is 5 per cent.

Such a definition, while having the virtue of modest precision, also leads to policy problems, which I will discuss in the sections below.

Another definition, less measurable but perhaps more precise, is that the industries on the various lists for government policy purposes are chosen on the basis of political criteria. At the federal level, the key criteria seems to be that the high-tech industries are now manufacturing industries which have grown rapidly in economic power and importance in the past two decades, but have not as yet (with the exception of IBM) organized sufficiently to lobby for their special needs with Congress and federal agencies. This, more than anything else, is what distinguishes them from older and well-organized industries like oil and gas, aerospace, medical, pharmaceutical, etc. At the state and local level, the fact that information technology production has been a source of growth in substantial numbers of small businesses and also in significant expansion of branch plants by fast-growing corporations in the past decade means that states and localities are now discussing the adoption of policies specifically to attract new small firms or branch plants or larger firms in these particular industries. Whatever relatively new industry these governments hope to attract automatically becomes high tech. Newer fields with no record of significant employment growth also get included on various lists in the hope that a state or locality can duplicate an 'agglomeration' strategy similar to that in Silicon Valley in California or Route 128 in Massachusetts. Thus, the newer the technology (robotics, photovoltaics, bioengineering), the more potential for 'getting in on the ground floor'. In its most fundamental sense, then, high-technology industry generally means new technology goods-producing industries (and related services) which are still a long way from market saturation and over-production, or if they are beginning to face the problem of global competition, are now organizing to make demands for government assistance to preserve the gains in market share of the previous decade.

Employment the Key: How Much, What Type, Who Gets, and Where?

Despite the disparity in definitional criteria, clearly the most important single element from the standpoint of public policy goals is employment. All the high-tech industries on any list are there either for their actual record of rapid job growth in recent years or for their presumed long-run potential for significant job growth. The problem is that even assuming fantastic growth levels, these industries cannot possibly absorb all the surplus labour from other sectors nor accommodate all the new entries into the labour force each year. If every level of government everywhere pursues high-tech development strategies, most of them will surely be doomed to failure. In California, which is a national leader in high-tech employment (20 per cent of the US total according to one study), these industries still employ less than 5 per cent of the total state workforce. The business services sector is nearly as large, and the medical services sector employs more people than high technology (Center for the Continuing Study of the California Economy, 1982).

New technology producers go through product and profit cycles just like any other industry or sector, and some areas of electronics production are already facing world overcapacity with employment stagnating or even declining. Further, in addition to layoffs and cutbacks due to competition and excess capacity, many firms which are still experiencing growth in output and sales are reducing the size of their labour force due to automation.

Cutbacks in employment due to competition and automation mean that strategies of pursuing and subsidizing high-tech firms on the basis of past performance in employment growth and/or future potential for expansion of output may be self-defeating, unless the people in the jurisdiction will benefit from other employment linkages, derived demand employment effects, or from taxing the gross revenues and net income related to future expansion. For example, Feldman and O'Malley (1982) estimate that, at best, gene-splicing in California will employ only 14,000 people by 1990, or 0.01 per cent of the state's total labour force at the time. However, there may be substantial indirect positive employment impacts, and state and local governments might be able to tax the revenues accruing to these highly capital-intensive gene-splicing firms, either or both of which would help justify a public policy of support for the infant industry, despite its very modest short-term potential for direct job creation.

Direct vs. Indirect Jobs: Net Gain or Net Loss?

The issue of direct versus indirect job creation is crucial with relation to the growth and development of high-technology industries. The case of small direct job growth but large indirect job growth (which is hypothetical in the case of bioengineering) is very untypical. The much more common case is that of modest to substantial direct job growth, but massive indirect job loss. The production of new information-processing, communication, and other technologies is leading to a virtual revolution in the organization of work and society.

Such changes involve a vast retooling and restructuring of all forms of employment (as well as consumption) in terms of both geographic location/organization and social division of labour. *Business Week* (1981) predicts that 25 million current jobs will be eliminated in the next two decades due to the introduction of new technologies. Government policies that encourage the faster development, production, and utilization of new technologies in order to promote direct job creation in specific high-tech industries may be losing sight of the larger picture. The net job loss, the disruption to workers' lives and livelihoods and to the well being of communities may be devastating. Government economic strategies for private sector job creation that involve commitment of public resources through various subsidy programmes must take into account the total employment and community welfare impacts of an 'economic development' policy. While major technological changes can have beneficial long-term productivity and income effects, depending on the structure of ownership and control and the distribution of wealth and income, public policy planning for employment must be designed to enhance the continuity and stability of job opportunities and standards of living, so as not to accelerate the pace of social disruption and lost human potential brought about by job displacement, high unemployment, community disinvestment, and income loss. In other words, a high-tech employment strategy can only be considered as part of a much broader set of overall policies for job preservation and creation. Without such larger considerations, high-tech policy may be wasteful, misguided, and even counterproductive.

The Dual Labour Force and the Vanishing Middle

As mentioned above, one prominent characteristic of high-tech sectors is the substantial proportion of the labour force in the scientific, professional and technical category. These are jobs which generally require at least an undergraduate college degree, and very often advanced graduate training. They are well-paid jobs with relatively decent working conditions and they are overwhelmingly filled at present by white males less than forty-five years old.

Another characteristic of the high-tech labour force is that a substantial proportion consists of low-paid assembly and clerical work. In addition to poor pay and benefits, these jobs often do not provide very satisfactory working conditions, particularly in the unskilled assembly work. Those hired to perform such jobs are overwhelmingly female and very large percentage from ethnic minorities.

Most high-tech firms are also distinguished by being entirely non-union, that is, none of their workers are organized and represented by trade unions for the purpose of collective bargaining with the owners and managers. Certainly the lack of any union organization and representation is one reason why clerical and assembly workers' wages and working conditions have not significantly improved during a decade of high profits and rapid expansion in these industries. The lack of unions for professional and technical workers is more problematic, though it might be argued that high-tech managers' fear of unionization (as well as of employee turnover) by their white-collar workforce has led to more beneficial conditions of employment than might otherwise be the case. It could also be argued that a major reason for innovative labour policies at the high end of the employment scale has to do with a demand-supply imbalance in favour of workers with certain technical skills, which may be one reason why many employers are insisting that universities should vastly increase the supply of engineers and scientists, whereas the various engineering and scientific associations are less enthusiastic about such an undertaking.

Since the growth of direct high-tech employment is often pointed to as a possible solution for the problems of employment decline and plant closings in other sectors of US manufacturing industry, we can readily see that the structure of the high-tech labour force poses major difficulties for solving the employment problems of 'blue-collar' decline. Since the highest single proportion and fastest-growing segment of high-tech jobs is in the scientific, professional, and technical categories, skilled manufacturing workers displaced from other industries are, at present, totally unqualified for the bulk of these professional and technical jobs. In most cases, a displaced manufacturing worker would have to undergo anywhere from two to ten years of education and training to be qualified for these positions, during which time he or she could not possibly be earning more than a fraction of his or her previous full-time pay and benefits.

While former crafts or factory workers might be qualified to perform clerical or assembly work in high-tech industries with only one year or less of education and training (or perhaps none at all), they would probably be facing a 50–80 per cent pay cut, plus a loss of a great deal of control over the work environment that they had previously attained through trade union organization. However, even in cases where displaced workers do apply for high-tech jobs that do not require significant college-level education and training, they generally are not hired by high-tech employers because many employers feel these workers are more likely to express dissatisfaction with their wages and working conditions and be more likely to support efforts to organize their workers into trade unions (Bluestone and Harrison, 1982).

Not only is an important segment of the 'middle' of the US job structure vanishing, in the sense of relatively well-paid, stable, skilled manufacturing-related employment, but the new types of low-paid high-tech assembly work that have grown so rapidly in the past decade are also beginning to disappear. Some of this work has been shifted overseas to countries where average wage levels are significantly lower, corporate and governmental discipline more repressive, and unions virtually non-existent. In addition, many of the large numbers of assembly jobs that still remain in the United States will be automated out of existence within the next two decades. Clerical jobs will still grow, but perhaps at a less rapid rate, as certain categories of clerical employment are also being automated through the new technologies of the 'electronic office'.

Where jobs in high tech are not being eliminated outright, in many instances a process of 'deskilling' is taking place where previously growing professional, technical, and clerical fields become more capital-intensive, less skilled, and much lower paid. This process is taking place not only within high tech, but throughout the productive economy as a result of the development and introduction of new technologies into production (and service) processes. Even in such a seemingly labour-intensive field as the writing of computer software, a great deal of automation and deskilling is taking place which will eliminate many of the now attractive jobs at the less-than-PhD-degree level. Further, the process of creating such a wide gap between the two main categories of employment (top professionals versus unskilled labour) means that the notion of a career ladder, which has traditionally been very important in terms of skill and pay upgrading within the labour force, may also be disappearing as a consequence of advancing high tech. For policy purposes, the question of what kind of jobs and career opportunities is as important as the simple raw numbers of projected available employment.

Another issue in addition to job and income quality is the question of who gets the jobs. Here, the record to date in high-tech firms is fairly dismal. Strong affirmative action policies are required both in the educational system and in the hiring, promotion, and training policies of high-tech employers. Ignoring affirmative action means that women, minorities, and even older men will continue to be excluded from one of the most desirable areas of job growth in the coming decades: professional/technical/scientific occupations. But since everyone cannot be employed in these fields, regardless of who get hired, we also need strong policies for 'comparable worth' and pay equity, whereby job content and skill levels of all occupations are reanalysed, redefined, and restructured to reduce the wide disparity in compensation and working conditions between different categories of employment that are today highly segregated by sex, race, and age.

If current employment trends continue, then American society is facing the prospect of a major increase in the number of 'brain workers', both in absolute numbers and particularly as a percentage of total paid employment. This prospect brings with it considerable problems of adjustment for the existing adult population. On the other hand, it also holds out the possibility of a major increase of jobs in our educational institutions as well as the possibility of greater opportunities for creative work by a larger share of the US population. Whether very large absolute increases in the number of these jobs will occur as forecast, and whether equal access to these prospective job opportunities will be ensured through vigorous public and private action, remain vital and unanswered policy questions in 1984.

Small Business vs. Large Corporate Development

American public opinion and policy-makers have often looked with great favour on small business development as an alternative to the giant corporation, and the growth of high-tech industries is frequently extolled as a successful example of small decentralized entrepreneurship. Overall, however, the growth of these industries may end up being at least as concentrated as, if not more concentrated than, any other sector of the US economy.

First of all, in other sectors where three or four firms dominate the market, such as in steel, auto, chemicals, aircraft, pharmaceuticals, petroleum, electrical machinery, rubber, and glass, there are still thousands of smaller firms that produce parts, accessories, machine tools and dies, and perform a myriad of production and service-related activities, often on subcontract from one of the majors. These smaller companies generally experience greater instability in market demand. Larger firms rely upon these suppliers and subcontractors to bear the risks of seasonal production and of new product development, and to bear the resonsibility of recruiting and laying off workers with greater cyclical fluctuation. Dominant firms in an industry frequently point to the cost savings in lower overhead and greater efficiency of subcontracting or of purchasing supplies and services from smaller companies rather than engaging in 'in-house' production. Small businesses hold their own in highly-concentrated industries only by specializing in market niches where the demand for the goods or services is not sufficiently large-scale and stable enough for giant corporations to want to compete.

High-tech industries conform to the pattern just described. In the electronics industry, for example, production of mainframe computers is highly concentrated among a small number of firms (with IBM holding near monopoly status), and in production of mini and micro computers and semiconductors and other electronic components the four- and eight-firm concentration ratios are also quite high. While initially, with the development of a new product, there may have been a good deal of competition between many small firms, the pattern of merger, consolidation, and business failure has quickly led to rather concentrated market dominance. Small business, of course, will continue to grow side-by-side with big business for the reasons cited above; in fact, behind the fabled tales of electronics industry executives splitting off from the parent company to start their own small firms, we find that in many cases, top executives who remain with the parent company are some of the principal financial backers of the new venture.

Despite the proliferation of company names on the high-tech scene, we increasingly find a significant conglomeration of actual ownership. Not only, as cited above, are the concentration ratios high in most sectors of high-tech production, but many of these large high-tech firms are being bought up by even larger multi-national conglomerate corporations. Even the new small entrepreneurial high-tech enterprises are, in many cases, already owned by giant corporations. For example, the California case studies (see pages 35–48) showed that the newly-emerging pioneers in biotechnology, robotics, and photovoltaics were actually owned by major oil, drug, and other manufacturing corporations, even where the new venture retained a separate management identity. Thus, we find that the need for start-up capital and later for expansion capital, given the costliness of research and product development, marketing and other basic expenditures, means that many of the new high-tech entrepreneurs are really just managers or professional workers for one of the *Fortune* 500 firms. Even in computer software, which does not involve huge capital costs, the Hall/Markusen/Osborn/Wachsman study (1982) found a tendency toward large corporate ownership in certain categories, a pattern of concentration similar to the merger mania still accelerating in financial and business services.

One reason for the level of concentration among the prime contractors (as opposed to the numerous subcontractors) in high-tech industries is that the US Department of Defense (DOD) is still the largest single purchaser of many of the products and services, and the largest single financier of many aspects of the research and development. The US military, which since the 1940s has played a key role in nurturing and spawning these new technologies and new private industries, still sees itself as responsible for subsidizing development of 'state-of-the-art' technologies in many key industries. The pattern of dependency of these private corporations on the Defense Department does not always receive the attention it deserves as a serious economic and public policy issue. Among other consequences of this relationship, however, is that the DOD preference for dealing primarily with very large established companies, a preference that has been reproduced by The Department of Energy in its approach to new energy-production technologies, encourages the trend toward ever higher levels of industries concentration.

Investing in People: Which People, Which Skills?

Many high-tech employment strategies focus on revamping the public role in education and research. The main thrust of these initiatives is to push for greater public and private funding of maths, science, and computer education in primary and secondary schools, and electrical engineering and computer science education in universities, including more and better technical equipment, more money for research grants and fellowships, and higher faculty salaries in certain fields. Both 'Atari Democrats' and Reagan Republicans argue that educating people for the new 'Information Age' of computers and telecommunications will meet the needs of an expanding labour force in these areas, lead to the development of new products, and expand the market for existing electronic products. Some politicians make analogies to the 'Sputnik Crisis' of 1957, which led to the passage of the National Defense Education Act (NDEA) in 1958 and major expansions in the federal military and space budgets, and which sparked a new generation of technological developments through publicly-funded research and education. In this view, the challenge of the 1980s is not to put a man on the moon, but to boost the US economic growth through the widespread development of new technologies.

It is questionable whether vigorous public promotion of the private high-tech sector even makes sense as an employment strategy, as I have indicated above. Investing in education makes sense, however, as an economic strategy, as if both creates jobs directly and acts as a crucial stimulus to indirect job creation. For example, the highly-skilled nature of the population in certain US metropolitan areas is frequently cited as a major factor in attracting and spawning new business investment and private sector employment.

The analogy to NDEA breaks down at this point, however, because in the 1960s, all forms of education and research expenditure grew at very rapid rates, whereas in the 1980s, sharp federal, state, and local budget cutbacks are the rule rather than the exception. In the context of fiscal austerity, high-tech education programmes are competing for shrinking public and private education dollars, in that funds are proposed to be shifted from other current educational programmes rather than added from increased revenues. At the same time as public policy-makers and corporate leaders are talking about the urgent need to increase faculty salaries in electrical engineering and computer science, overall educational expenditures in the United States, from kindergarten to post-doctorate, are facing severe budget reductions.

Placed in the context of the resource needs of the total education programme, these high-tech education initiatives by themselves make little sense as the main components of a long-term employment strategy. The most important characteristic of a highly-skilled workforce in an age when technology is constantly changing is the ability to think clearly, to learn quickly, and to adapt to an ever-changing workplace and consumer environment. The best way to achieve this is through strong, well-rounded basic education, of which technical knowledge and skills are just one aspect. For example, at one time, keypunch operators were needed in great quantities as a result of spreading computerization. New advances in technology will shortly turn keypunch operators into an endangered species. Narrow skill training leaves these operators unable to adapt well to other forms of data-processing employment, let alone to wider clerical or other employment fields. A good basic education in reading, verbal, and analytical skills (including maths and science), as well as 'hands-on' technical training, would be of greater benefit to these workers in their career lifespan and would be of greater benefit to prospective employers. Studies of clerical workers and productivity with new word processing and other information/communication technologies have confirmed the need for a good, broad, basic education. Such an economic policy goal can only be achieved by an overall expansion of educational resources, not by sharply cutting back in most areas in order to expand a few.

Basic education is not the only issue. Many of the high-tech education programmes are aimed at increasing certain forms of specialized training, particularly at the college level. These specializations are proposed to thrive at the expence of other academic fields, which might wither and die. Such an approach, as a long-term economic/employment policy, is quite mistaken, because the hallmark of the advancing technological revolution is the wide variety of cross-disciplinary skills and integrated knowledge necessary to design, produce, and disseminate new inventions and innovations. For example, one of the biggest bottlenecks in the spread of automated/

computerized manufacturing is that people trained in electrical engineering and computer science generally are ignorant of mechanical engineering, and vice versa. Mechanical engineering has been a dying field in the 'Information Age', and yet now we discover that its neglect has left a crucial gap. In the development of computer software, the lack of which is now the single most pressing bottleneck to the spread of computer hardware, a vast array of language, logic, and communication skills, as well as very specialized non-high-tech academic training, are vital to solving problems in this industry. Putting more education dollars into computer science and cutting back on English, history, classics, linguistics, French literature, African studies, etc. could be disastrous for the needs of the 'Information Age' and the very specific requirements of the computer software industry.

Recently, two major Japanese corporations acknowledged this problem by giving major educational and research grants to two very unusual institutions from a traditional high-tech perspective: Sony's grant went to the American Film Institute for a video production studio, and Mitsui's grant went to the UCLA College of Fine Arts, 'to study, among other things, the complex problems of processing and storing the explosion of scientific and commercial information produced by an increasingly technological society'. 'There are so many things that are involved', said a Mitsui executive, 'video, animation, cable, satellite, it's very complex.' He further pointed out that the ability to produce computer hardware at present far outstrips the ability to write programs to direct the machines or to develop forms of communication and utilization by which people can employ and interact with new technologies in their daily work and community lives (*Los Angeles Times*, 1982).

Who Will Control the Development and Uses of New Technologies?

Since the spread of this knowledge-based economy will be based to a significant extent on research, a major problem arises as to: (1) who will finance the research; (2) who will control the research; (3) who will control the uses of the research findings; (4) who will benefit or suffer from these uses? The issue of scholarly, free, scientific inquiry in university microbiology departments versus the commercialization of products utilizing recombinant DNA (gene splicing) has sparked major controversy among faculty and administrations at a number of leading universities and medical schools. The Regents of the University of California recently adopted stiff guidelines on commercialization of campus-based research. Their argument is that since the educational institution is publicly-supported, the emphasis should be on broad public benefit rather than narrow private gain. And yet University of California researchers, under contract from large agricultural firms, developed an automatic tomato harvester and a 'square tomato' capable of machine harvesting. Through this research, the University budget gained by receiving grants and by royalties from a licensing agreement; the agricultural corporations gained by lowering labour costs; consumers may have gained through lower tomato prices (though this is arguable), but probably lost in tomato taste.

One group definitely lost: human tomato harvesters, farm labourers, who lost a large number of jobs due to this academically-researched technological development. These farmworkers had no part in the decision-making process either of the privately-owned (but publicly-subsidized through numerous federal and state agricultural, trade, and water policies) agri-businesses or the publicly-owned and subsidized university. No explicit public policy decision was ever made to displace these workers, and yet a private decision was made and it was subsidized with public funds. And no provision was made for the fruits of this technological change to be shared with the farm workers who were made jobless. They did not receive any share of profits from their former employers, nor any share of royalties from the University. Perhaps both would have been feasible, enabling them to organize cooperative farms, or start their own businesses or get training and education to branch out into new careers.

Clearly we cannot devise a high-tech economic policy designed to enhance the employment and income prospects of the total US population, to minimize individual and community disruption, to build democratic consensus, and to preserve the positive aspects of our physical and social environment, without raising the issue of who *controls* the development and uses of new technology.

Workers and communities will need to develop tools for negotiating and enforcing 'collective bargains' with private employers and public institutions over the introduction of new technologies so that the benefits and costs are openly assessed and equitably distributed. This could mean slowing down *or* accelerating the pace of change – in fact it will probably mean both, depending on the circumstances. But it definitely means that all who are affected will have an opportunity to negotiate over what they are giving up, and strike a private or public contractual bargain over what they will get in return. In the absence of such a process, a government policy of investing heavily in high tech may bring economic chaos, not salvation.

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