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High technology and international labour markets

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We are in the midst of a high technology revolution which has profound implications for production processes and employment throughout the world. Innovations in micro-electronics and computers have sharply reduced the cost of processing information. They have made possible the automation of a host of operations in such services as banking, insurance, and wholesale and retail trade. Micro-electronic innovations have also created commercially viable robotics, and as robots become less expensive they are bound to replace labour in a number of production tasks.

This technological revolution is not only creating new goods and services but also altering how and where they are produced. International trade and the division of labour are being significantly transformed.

It is also clear that the new technology is different from that which resulted in lowering the cost of manufactured goods in the nineteenth and early twentieth centuries. The earlier technology was developed for specific applications. With few exceptions, machines had to be built for each task. Much of the new technology, however, uses durable capital equipment that is programmable and therefore adaptable to multiple tasks – as products change, the same hardware can be used for the new products with a simple change of programme. Unlike technological innovation a century ago, the new technology appears to require less labour to develop and manufacture it than the labour it replaces (on robotics, for example, see Howell, 1984; Hunt and Hunt, 1983). Further, because of its multiple applications, because of the common physical principles underlying variations of the technology, and because of better communications among innovators, the technology is spreading at a faster pace than did the previous generation of innovations.

High technology, then, will influence all countries' economic growth, employment and wages in two principal ways: by rapidly diffusing throughout the world, it will change the conditions of industrial development and eventually, with advances in biotechnology, of agricultural development; and

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by rapidly improving telecommunications and informatics, it will accelerate the integration of every society into the world economy.

In this article we are concerned with understanding the impact of "high-tech" industries[1] on labour markets, the division of labour and the organisation of work, and the policy options open to societies for dealing with the effects. An analysis of these can be divided into two parts: *(a)* the characteristics of high-tech industries and their implications for labour markets in those industries; and *(b)* the implications of high-tech information systems, office automation and robotics for employment and the division of labour in other industries.

The characteristics of high-tech industries

The micro-electronics industry – the largest by far of the high-tech sectors – developed swiftly after the invention of integrated circuits in 1959. There were several phases in the growth of micro-electronics and the related computer industry. In the 1950s semiconductors were still expensive and computers were large and relatively slow: the cost of information processing was so high that there were doubts about the commercial viability of computers (Katz and Phillips, 1982).[2] But by the early 1970s the cost had dropped dramatically, opening up tremendous commercial possibilities and setting off the high-tech explosion.

In 1954 the cost of a silicon transistor was $23.95; in 1972 it was $0.27; and since then it has fallen even further. Integrated circuit prices fell from the $17-30 range in 1964 to $1 in 1972 (Soete, 1985, table 1.1). In addition, the "quality" of transistors and integrated circuits has increased greatly. Each of these units could perform a much larger number of tasks in 1972 than it could a decade earlier. So the price decline per unit underestimates the fall in cost per unit of quality.

The principal input in high-tech products is highly educated scientific and engineering staff. It is this characteristic that distinguishes high-tech industry from traditional manufacturing and services. In the latter the factors governing location are access to raw materials, distance to markets, and availability of skilled production and clerical workers. But most high-tech products neither require inputs nor produce outputs that are expensive to ship. The most important factor in high technology is skilled technicians who can develop new products, lower the production cost of a firm's output by developing new processes, or improve the reliability and quality control of existing products. The new technology is "embodied" in engineers and technicians who move from universities, where government contracts subsidise research, to industry, where the knowledge they have acquired can be turned into profit-making technology.

High-tech industries in the United States have therefore generally been located near universities with strong programmes in micro-electronics; firms choose locations where well-trained engineers are easily recruited and where they will, besides, have ready access to new ideas.

The largest concentration of micro-electronics, biotechnology and laser technology firms in the world is in Silicon Valley in Santa Clara County, California, near Stanford University. One of the great attractions of Silicon Valley, despite the high salaries that have to be paid there because of exorbitant housing costs and competition from other firms, is the very existence of so many engineers and their technological knowledge. The rapid diffusion of technology has been one of the most important factors in the growth of high-tech industry, both in its early developmental stage and in the recent "Schumpeterian" entrepreneurial phase, which owes more to venture capital than to government contracts (Rogers and Larsen, 1984).

It can be argued that the development of Silicon Valley had more to do with the vision of Frederick Terman, Stanford's Vice-President in the late 1940s and 1950s, in developing Stanford's vast landholdings into a source of revenue for the university than with specific decisions by early high-tech industries themselves (Rogers and Larsen). But Stanford did, too, have the electrical engineering department and basic research that could attract and support such enterprises. In 1984, of the 1,090 Californian firms that were members of the American Electronic Association (AEA), 450 were in Santa Clara County. The second largest concentration of high-tech firms (110 AEA members) was in the Boston area around the Massachusetts Institute of Technology. Other concentrations are located close to the Universities of Texas, North Carolina, Colorado and Minnesota.

Highly educated labour is employed primarily in research and development (R and D) and in the marketing of high-tech products. It is less prominent on the production side. Assembly lines generally are not long, and quality control is as important as the actual assembling of the products. Much of the production is subcontracted to other firms, many of them in other countries (for example, the IBM personal computer is manufactured largely in Asia; final assembly is done in the United States). The assembly operations in the United States are performed primarily by semi-skilled, low-paid women workers who are employed under exacting conditions and do the repetitive work of placing electronic elements into integrated circuits, assembling final products, and inspecting devices for faults at various stages of assembly.

Production in high-tech manufacturing in the industrial countries is increasingly susceptible to automation, as robots and complex (programmable) machines are developed that can assemble circuit boards and final products more rapidly and more accurately than human beings. The Apple plant that produces the Macintosh microcomputer in Fremont, California, is a good example of an automated high-tech factory.

At the same time, because the transport of assembled inputs and final products to markets accounts for a relatively small share of total costs, the industry is highly mobile geographically. A number of American companies have moved their entire production facilities to Asia. Whereas R and D units tend to stay near universities and other high-tech industries, larger companies are not averse to opening divisions in new locations that have the necessary conditions for attracting highly educated labour from other areas.[3] The advantages that high-tech industries bring to communities also enable firms to extract considerable concessions from local and state governments in return for locating in a particular area (*High Technology*, 1985).

All of these features of high-tech industry have shaped the nature of its labour force. The structure of employment in electronics is significantly different from that in traditional manufacturing or in commerce and services (Gordon and Kimball, 1985a; 1985b). In Santa Clara County 24 per cent of the labour force in 1980 were employed in electronics manufacturing, and another 15 per cent in defence and traditional manufacturing (Carnoy, 1985a). The labour force in both traditional and defence manufacturing was overwhelmingly male (72 per cent and 75 per cent, respectively). In electronics manufacturing, however, only 58 per cent of the labour force were male, and of the remaining 42 per cent almost one-third belonged to Hispanic and Asian minorities.

The electronics industry is more skill-intensive than traditional manufacturing or the labour force as a whole. In Santa Clara County, with its large R and D component, about 34 per cent of the labour force employed in electronics have completed university or attended graduate school, compared with fewer than 20 per cent in traditional manufacturing and about 27 per cent in the county's labour force as a whole.

Both men and women in electronics have fairly high earnings (about the same as in traditional manufacturing for all but those with the highest levels of education, Anglo[4] males in this category being paid more in electronics) because they – especially women – tend to work longer hours than workers in other sectors of the economy (Carnoy, 1985a). But the labour force in electronics is highly stratified by sex, much more so than the rest of the county's labour force or in traditional manufacturing, with Anglo males occupying the professional and managerial positions, and women – Anglos, Hispanics and Asians – filling the assembly-line and clerical jobs. In 1980 more than 55 per cent of the Anglo females working in electronics had only a high school education (12 years) or less, as compared with 22 per cent of Anglo males. The corresponding figures for all sectors of the county were 50 per cent for females and 38 per cent for males, and those for traditional manufacturing 57 per cent for females and 50 per cent for males. At the other end of the spectrum, 49 per cent of the Anglo males in electronics had completed four years of college or more, compared with fewer than 13 per cent of the Anglo females. In the county's labour force as a whole, 35 and 22 per cent of Anglo males and females had completed university or attended graduate school, and in traditional manufacturing 22 and 18 per cent.

Thus, labour in high-tech industries is more highly educated but also more sexually stratified than either labour in traditional manufacturing or the labour force as a whole. Though fewer jobs are available for women in traditional manufacturing than in electronics, the wage differential by sex is smaller, at least in Silicon Valley (Carnoy, 1985a). This is probably due in part to the absence of unions in electronics firms. Some attempts have been made to unionise, but have failed. There is intense anti-union activity by management; indeed the AEA even holds training courses for management on how to prevent unions from getting into their companies. These seminars preach that a preventive approach to unions is most effective (Rogers and Larsen, 1984, p. 190; Siegel and Markoff, 1985). Thus, many firms attempt to follow what has come to be known as the Hewlett-Packard model (see below), treating their employees to generous benefits and giving their workers more responsibility (*Business Week*, 1985).

Equally dissuasive is the threat of moving production abroad. Lack of unionisation and firms' geographical mobility imply lack of job security for both production and technical workers. Even before the current national downturn in the electronics industry, due partly to foreign competition in semiconductors and partly to market saturation in microcomputers, job loss had become an accepted part of working in high-tech production (*Mercury News*, 1985).

Nevertheless, high technology has been touted by many as the saviour of manufacturing in the United States and as the way out of the world economic crisis. The entrepreneurship associated with it has stimulated new faith in American enterprise. It is claimed that high technology has the same potential as the automobile industry had in the 1920s, and will eventually create massive new employment opportunities directly in electronics manufacturing and indirectly in related industries.

Depending on how they are defined,[1] high tech industries employed 2.5 million, 5.7 million or 12.4 million Americans in 1982, out of a total of 92 million employees (Rumberger and Levin, 1984, table 3); and the projected increase in high-tech employment between 1982 and 1995 ranges from 34 to 36 per cent. Employment in all industries is expected to increase by 25 per cent during the same period, so that new employment in high-tech industries will account for anywhere from 3.4 per cent to 16.5 per cent of all new employment between 1982 and 1995. However, if we take only the high-tech occupations listed in note 1 as the basis of the projection, they employed a mere 3.2 per cent of all civilian workers in 1982, and even with a projected growth rate of 47 per cent between 1982 and 1995 (compared with a rate of 25 per cent for total employment) they will account for only 6 per cent of all new jobs – 1.5 million in absolute terms (Rumberger and Levin).

The small absolute number of high-tech jobs has significant implications for what most Americans will be doing in 1995. Whereas eight out of ten of the most rapidly growing occupations in percentage terms are high-tech occupations, those eight will only produce 935,000 jobs during the 1982-95 period. The nine fastest-growing jobs in *absolute* terms are all service jobs, such as janitor, office clerk and secretary. Those fastest-growing jobs are projected to increase by 6 million during the same period. Moreover, seven of the nine require a high school education or less, whereas six of the eight fast-growing high-tech jobs require at least some university education (Rumberger and Levin, table 4). And the high absolute growth occupations have mean earnings that are 30 per cent lower than the average for the country as a whole, whereas the fast-growing high-tech occupations have earnings that are about 30 per cent *higher* than the average.

These figures suggest that high-tech industries and high-tech occupations will create a significant but not massive number of new jobs over the next decade, certainly not the number claimed by the high technology lobby. Even the most optimistic projection of jobs in high-tech industries indicates that most of them will not be in professional work but in production and clerical work. This is consistent with the job structure in Santa Clara County's electronic industry where fewer than 45 per cent of electronics jobs in 1980 were professional-technical or administrative-managerial jobs. And this proportion is found in a high-tech location with a larger R and D component than most. For the country as a whole, the professional-administrative percentage in electronics tends to be lower (Gordon and Kimball, 1985b).

The growth of high-tech industries will therefore have an appreciable impact on employment in certain regions and in the manufacturing sector, but not on employment in the country as a whole. The labour force will continue to expand largely in trade and services – the rate depending primarily on the overall growth of the economy – and jobs in these sectors will continue to be relatively low skilled and low paying, according to projections by the Bureau of Labor Statistics (BLS). Real average weekly earnings in the United States declined by about 16 per cent between 1973 and 1983, and this trend – although it has levelled off over the past two years – has not been reversed. At the same time high salaries have risen rapidly since 1982, contributing to the growing inequality in national income distribution observed between 1980 and 1984 (Carnoy and Castells, 1984). The Rumberger-Levin data suggest that the future pattern of job growth could exacerbate that trend, in part because of the polarised nature of the labour force in high-tech industries.

High-tech growth and Third World economies: Some speculations

Some Third World economies, particularly several Asian newly industrialising countries (NICs), have participated actively in the high-tech boom of the past ten years as production centres for American, Japanese and European companies, supplying components and even finished products for industrial country markets.

High-tech growth has contributed to the rapid economic development of the NICs. For example, Hong Kong, Singapore and the Republic of Korea, with their low labour costs and reputation for reliability, have profited from the farming out of repetitive manual assembly operations. In addition, service industries, such as insurance companies, are contracting out data preparation (one American insurance company has its key punching done in China and the data sent by satellite to the United States).

This is not the only type of high-tech production in the Third World. In countries such as Mexico and the Asian NICs, final assembly operations take place for local consumption or for export to less developed countries of the region. Software development geared to imported products or Japanese or American products manufactured locally is also found in a number of Third World countries, although on a limited scale.

Finally, some countries are imitating the French model and protecting the development of a local high-tech industry through import controls on high-tech products. This implies the development of a "total" industry and possibly new products, i.e. the *creation* of technology for local markets, including software, and means that the State will have to provide support for the industry similar to that provided in France, Japan, Sweden, the United Kingdom and the United States – in short, wherever there is an indigenous high-tech sector. In Brazil, a country which has a large business market for such products, as well as its own military production and a large civil service and education sector, there is sufficient domestic demand to sustain an indigenous industry.

The development of both final goods production for import substitution and the "total" industry model is made easier by the rapid diffusion of technology inherent in high-tech industries. New products and production methods spread quickly and are usually easily copied (the Apple computer copies springing up in Hong Kong are a good example). The economic rent period of a new product or process of production – the time an enterprise has to establish itself as an industry leader – is as short as six months or even 60 days (Rogers and Larsen, 1984).

The implications of these different models for labour markets in the Third World are not difficult to imagine. Like many assembly industries for re-export, electronics manufacturing employs almost entirely unskilled and semi-skilled, low-paid (female) workers. Thus, any developing country that can attract high-tech assembly plants can increase industrial output, but the result for employment will generally be to bring new female workers into the labour force rather than take up the slack of unemployed or underemployed males. In the case of import-substitution production of high-tech goods by subsidiaries of American or Japanese manufacturers, the effects on the labour force will be similar, except that more people will be employed owing to the manufacture of components through subcontractors, and more of the employees will be clerical staff. Some sales and management personnel will be required, trained by the home office. But the large number of engineers and technicians associated with the R and D centre of the firm will be needed only in the indigenous production model.

Could import-substitution high-tech production eventually lead to a labour force structure in that sector similar to the American or Japanese structure? Conceivably, if the use of high-tech goods in the developing country – especially microcomputers – produces a generation of engineers and programmers oriented towards creating new high-tech products for local uses. But that very interest may lead the most creative of them to take graduate degrees and work overseas rather than at home, leaving local industries to be production/sales appendages of home offices in the industrial economies, and the labour forces largely semi-skilled operatives and quality-control inspectors. The principal bottleneck for higher orders of import-substitution ("total" high-tech development) is, as in industrial countries, the shortage of well-trained engineers and technicians, and this is not something that can be remedied overnight.

For this reason, it seems probable that most developing countries will be relegated to assembling pieces of high-tech equipment largely for consumption in industrial countries. The NICs will be more closely integrated into world-wide high-tech production; some indeed are already manufacturing high-tech products from start to finish because of their lower labour costs. Robotisation in the industrial countries may impede the shift of production to the NICs, but robotisation itself will also be introduced in the cheaper wage labour markets, reducing the employment impact of high-tech production even in the NICs.

The effect of high technology on labour in other industries

Although there is much debate about the contribution that high-tech industries will make to the expansion of world employment and about who will get the jobs, the most controversial and speculative discussion focuses on the implications of informatics and robotics for employment in other industries.

The optimists contend that high technology will not only create many new jobs itself but will, as its products are adopted in other industries, raise productivity, thereby raising profits or lowering costs, so that new demand will be created and hence new jobs (see, for example, Lawrence, 1984).

The pessimists, on the contrary, argue that high-tech jobs will account for only a small proportion of total employment for many years to come, and that high technology in the form of office automation and robotics may actually eliminate jobs in other industries more rapidly than higher productivity can create new jobs (Benson and Lloyd, 1983).

The pessimists' argument that the use of high-tech products will produce a levelling off of employment through office automation and robotisation is not supported by the past performance of the American economy or by the BLS projections up to 1995, although these data show certain industries and occupations as being affected negatively (Rumberger, 1984). But the argument that high technology will produce more jobs through increases in productivity is not supported by any concrete evidence either. The United States productivity curve remained flat between 1973 and 1982, even though this was a period of rapid adoption of high technology. Productivity growth in manufacturing industries even slowed down sharply despite increases in capital per worker (Carnoy et al., 1983). Productivity increased in 1983-85, but this increase could be attributed as much to traditional business cycle factors as to a new, secular trend. Both the 1973-82 and 1983-85 periods were marked by overall increases in employment.

Productivity growth appears to be associated as much with general macro-economic growth as with technology *per se*, and there is apparently no systematic relationship between rising productivity and employment in American industry.

> In some cases rising productivity is associated with declining employment, while in others it is associated with rising employment. . . . The inability to determine the net employment impact of technology also makes it difficult to determine the effect of technology on unemployment (Rumberger, 1984, pp. 6-7).

Yet unemployment in the United States has increased steadily over the past three decades: the unemployment rate averaged 4.5 per cent in the 1950s, 4.8 per cent in the 1960s, 6.2 per cent in the 1970s, 8.2 per cent in 1980-85, and no less than 7.2 per cent at the height of the 1983-84 recovery. Similarly, unemployment rates in Europe during the 1980s have remained high even with moderate growth rates. All this suggests that it is increasingly difficult to employ everyone who wants to work. Rumberger (1984) shows that in 1960 every job in the American economy required $11,000 of sales and $8,000 of capital, and in 1980 (in constant dollars) $14,600 of sales and $12,300 of capital. This trend will continue. If the costs of labour increase, and the costs of capital, especially computers, continue to decrease, capital will continue to be substituted for labour in producing goods. Because of the particularly rapid decline in high-tech capital costs, real earnings in the United States would have to decline even more sharply than the 16 per cent drop recorded in the 1973-82 period to slow down the capital-labour substitution process. The current decline in (high-tech) capital costs might level off in future, however, and then, as in the period 1947-73, wage rates could again increase substantially.

The BLS projections of an increase of 25 million jobs between 1982 and 1995 indicate that the effect of capital-labour substitution will be amply offset by the effect of overall economic growth. But some employment projections show very different results: Leontief and Duchin (1984) predict that increased technical innovations and their diffusion throughout the American economy will lead to a net reduction in aggregate employment. They argue that rapid diffusion of robots, word processors and other computer-based technologies throughout the economy could eliminate 20 million jobs by the year 2000, or 12 per cent of all the jobs that would exist in the absence of further technological diffusion beyond 1982.

We have mentioned two ways in which high-tech industries in industrial countries can remain competitive: by moving part of their production to countries where labour costs are lower and by robotising and automating at home. Other manufacturing industries are doing the same, and the effects of robotisation on employment are already being felt. While there were fewer than 3,000 robots in the United States in 1983, their number could rise to 100,000 by 1990. They will form part of flexible manufacturing systems, where programmed machine tools produce the parts, robots handle the materials, and computers control the entire production system.

These systems allow small quantities of goods to be produced inexpensively and permit rapid change-over to the production of other products. While such factories may keep American manufacturing in the US, they are unlikely to produce many new jobs: a show-case Japanese plant employs only one-tenth the workforce of a conventional factory it replaces; a new General Electric plant will produce one locomotive frame a day entirely by machine when it formerly took 70 skilled machine operators 16 days to produce it (Rumberger, 1984, p. 20; see also Bylinsky, 1983, pp. 57 and 60).

Office automation equipment (microcomputers that perform word processing, financial analysis and filing functions), automatic tellers in banks, computer-aided design and laser scanners are all highly labour-saving innovations. But they also open up possibilities for new kinds of services, and are said to increase profits so that existing services can be expanded and new jobs created.

This suggests that the adoption of new technology in itself may not cause a net decline in employment in industrial countries, but that it will tend to put more, not less, pressure on overall economic growth to continue at a rapid rate if employment is to increase. Macro-economic policy will be an even more crucial factor in the future than in the past in producing growth with increased employment and low inflation.

What effects will office automation and robotics have on the skills required in industry and the service and trade sectors? According to the optimists, not only will many new jobs and new kinds of jobs be created by the growth of high technology, but increased skills will be required, there will be less skill polarisation, and there will be greater opportunities for developing countries *(a)* to expand employment in industries and services supplying the rapidly growing industrial countries; and *(b)* to increase the efficiency of other domestic industries. According to the pessimists, not only will the net growth of employment be slowed by the new technology, but *(a)* real wages will have to fall in the industrial countries and remain low in the developing countries in order to combat substitution by (ever cheaper) high-tech capital; *(b)* new technology will result in a general deskilling even though a small percentage of jobs will require higher skills; and *(c)* all this will lead to an increasing polarisation of the labour force, nationally and internationally.

As for the effects of robotics, a number of studies suggest that semi-skilled production jobs – operatives, assemblers, welders and painters – will be replaced by semi-skilled maintenance and clerical jobs – robot technicians, secretaries and clerks (Howell, 1984, tables 7 and 8, cited in Rumberger, 1984). If this is true, robotics will eliminate more jobs than it creates, but will not change the general skill level of those remaining.

As regards office automation, a recent study of the insurance industry suggests that the introduction of high technology eliminates the lowest-skilled jobs, upgrades some semi-skilled clerical and secretarial jobs connected with the operation of the equipment, and also tends to eliminate many lower- and middle-management jobs (Baran, 1985) – precisely those that hitherto provided upward mobility in the industry for women. One of the effects of office automation, then, may be to steer women into relatively high-skilled but dead-end and relatively low-paying clerical and secretarial work.

Taken in conjunction with the overall projections of future job growth discussed earlier, these trends indicate that the number of low-skilled jobs produced by a continued growth of the service and trade sectors in the United States will be much greater than the number of high-skilled jobs produced by the growth of high technology. Even the expansion of high-tech industry itself, though much more skill-intensive than traditional manufacturing or trade and services, will create somewhat more jobs for semi-skilled workers than for professionals and technicians.

Implications of automation and robotics for employment in the developing countries

Robotics and automation will increase employment in developing countries directly since the production of computers, microcomputers, programmable machines and robots will undoubtedly take place partly in those countries because of their lower labour costs. At the same time, however, automation and robotics may cost the developing world jobs. Labour-saving technology may eventually become so intensively used as to make labour a very small component of the total cost of manufactured goods whose production is gradually being transferred to the low-labour-cost economies. The manufacture of steel, heavy equipment, machines and even textiles could become viable and competitive again in industrial countries (for an ambivalent view on this issue, see Kaplinsky, 1982).

In those conditions comparative advantage might be due more to marketing and management than to the wage rate. This could be a setback for the industrial development of low-income economies, and would certainly affect the structure of employment and wages there: net employment might expand, but there would be fewer of the high-wage jobs associated with traditional medium and heavy manufacturing. Instead, employment would tend to expand in lower-wage jobs and perhaps more for women than for men.

Although manufacturing and services might tend increasingly to stay in the industrial countries, they would not be as employment-intensive as in the past. And as computers and robots became cheaper, the net effect of the new technology would be to reduce the amount of new employment created by each increment of national product, not only in the industrial countries but in the low-wage countries as well, *even if wages did not rise there.*

The expansion and decreasing price of communications will make it easier to locate production anywhere in the world but will also make it cheaper to supply world markets from a centralised industrial country location. This is particularly true for high-skill financial and other business services. Branches of American banks in the developing countries, for example, will be able, with a small staff and using high-speed computerised communications systems, to provide the same full range of services that is available to customers in New York.

High technology, work reorganisation and policy alternatives

There is little evidence, then, that high-tech industry will provide the number or quality of jobs that its most fervent proponents claim for it, and the impact of automation and robotics on employment in other industries may even prove to be negative. Skill polarisation in high-tech industries is great. Some of the polarisation in the industrial countries may be reduced by shifting the most manual and repetitive production jobs to the Third World while simultaneously robotising and automating production at home. Nor does it appear that high-tech growth and diffusion will offset the generally greater increase, in absolute terms, of low-skill, low-income service and commercial jobs in both industrial and developing countries over the next 15 years.

It seems certain that job growth in the future, at least in the industrial countries, will depend even more on general economic growth unless changes occur in the trend of labour/output and labour/capital ratios. In the 1970s much of the increase in employment in the United States was achieved as a result of declining real wages combined with economic growth and the absence of any significant productivity increase. It is difficult in a democratic society to go on reducing average wages or to keep them from rising, especially during periods of growth, without producing a political reaction. European producers have been particularly constrained historically in lowering industrial wages (see the extensive literature on employment problems in Europe, for example Jallade, 1981; and on the growth of the public sector, for example OECD, 1985). The Asian NICs have relied for their development on exports using low-wage labour and a high degree of quality control, but if wages rise in those countries they will have to find other ways of competing.

Job growth can only occur together with wage growth, then, if productivity rises and results in higher wages and not merely higher profits (average after-tax profits in the United States rose from 8.1 per cent in 1977-

80 to 17.8 per cent in 1985 – see Carnoy, 1985b). Some futurists, such as Toffler (1980), believe that the "electronic cottage", where workers will become "computer commuters" and self-employed computer service subcontractors, will provide the creative employment of the future. People will stay at home, doing "brain work" at their terminals and communicating with their supervisors and fellow workers, or with their clients, by electronic mail. The electronic cottage is already a reality for a few. But if it is ever to become a reality for the many, it will have to reach the same standards of efficiency as the automated office where management can use the computer to exact more work from clerical staff by keeping automatic tabs on performance (Rogers and Larsen, 1984, p. 256). In both cases, productivity may rise, but in one, high technology is "an ominous Big Brother to office workers", whereas in the other, it is a "liberating force". Which role technology plays depends on how it is used (Rogers and Larsen, p. 257).

Another source of higher productivity is the organisation of work. Firms such as Hewlett-Packard have developed a management style that produces intense worker loyalty. Hewlett-Packard features stock options, extensive employee benefits and personal relationships with employees. It has pioneered flexible schedules, and during the last two recessions its staff chose to work reduced hours rather than see some employees laid off while others worked full time. Many high-tech companies have followed the Hewlett-Packard model, both because it is good for productivity and because it helps to keep unions out (Rogers and Larsen). Yet even a company like Hewlett-Packard will hire fewer new workers per unit of output as production, clerical and management processes are automated.

As we noted at the outset, in the next decade almost every country of the world will have to come to grips with the domestic economic growth, employment and wage policy implications of the rapid diffusion of high technology and the increasing integration of the world economy which it has made possible.

The technology itself, as we have seen, will probably not create more jobs. And in one sense, the rapid adoption of high-tech inputs could also create significant social costs (to labour) as work becomes more disciplined but less stable, with much of it subject to automation, robotisation and even elimination. Enterprises will probably also have greater geographical mobility for their activities, and at a lower cost.

Yet the new technology also creates the potential to increase productivity through greater participation in decision-making at the level of the enterprise (Benson and Lloyd, 1983). The miniaturisation of the computer, the availability of "user friendly" software, and intra-enterprise computer communications could make accessible vast amounts of information about firm operations to most employees. With such increased information, employees would be able to help determine where efficiency could be improved, to communicate suggestions easily to higher management, and to participate intelligently in decision-making. Although the Hewlett-Packard model does not yet provide for employee participation to this extent, it does demonstrate that increased employee involvement in product development and manufacturing reaps high rewards in employee productivity. The new technology can therefore mean more economic democracy and, with it, new and effective management based on greater worker freedom and even job security. To achieve such objectives, however, firms must emphasise higher labour productivity through more creative management rather than the reduction of wage costs (see Carnoy et al., 1983).

The new technology also creates new challenges for macro-economic policy. We have argued that as the new technology is adopted, it will be increasingly difficult for societies to achieve low rates of unemployment through growth alone. Yet that same technology will help to increase the productivity of those who do work. The main challenge for macro-economic policy in the future will be – as it has been in the past – how best to allocate this increased productivity.

One model, associated with "monetarism", attempts to harness the economic potential of the new technology by fostering growth and employment in the context of rapidly rising productivity but slowly rising wages. A relatively slow-growing money supply and an anti-union government stance favour returns to capital and aim at encouraging investment. In this model, the money supply is supposed to set the general price level, and economic growth to achieve (eventually) full employment and higher income levels. Monetary policy also seeks to keep exchange rates at levels that favour exports. Countries that adopt monetarist policies of this type will experience greater fluctuations in unemployment rates and will have to achieve higher growth rates than in the past in order to absorb the same amount of labour into wage employment while remaining competitive in the world economy.

As we have suggested, such a model may pose political problems in democratic societies. High unemployment rates and pressure to keep wages low produce a highly unequal distribution of income. The growth of high technology can even exacerbate this inequality. A small number of employees may profit handsomely from growth, whereas the large majority may not participate at all, or even sustain losses. The rapid change and considerable employee mobility and community disruption implicit in the new technology may not be politically acceptable either.

One alternative to the monetarist model – an "incomes policy" of the type applied in Sweden, Austria and Japan – attempts to avoid these political constraints. This model uses the new technology to raise productivity but allows wages to rise as productivity increases. Employment, profit and pricing objectives are set simultaneously under economic agreements between labour, management and government. An effort is made to equalise the distribution of income as productivity rises (in part by providing considerable job security) and to soften the disruptive effects of technological change.

This alternative, however, is open really only to societies where labour is reasonably well organised and labour, business and government are prepared to co-operate. Both the monetarist and the incomes policy alternatives can work, but only the latter can ensure that the economy remains internationally competitive with relatively full employment and rising wages. In the former, labour will have to pay the increasing cost of competing in the world economy and there will be less pressure on management and the government to come up with organisational innovations for raising productivity.

Thus, there are options. The new technology is not deterministic. It has created new conditions for enterprises and public policy, but it has also created new possibilities. Different macro-economic and organisational policies will produce different results for labour and management under the new conditions. Societies that understand the possibilities and exploit them in a way that is consistent with local circumstances will pay the lowest social costs and gain the greatest social rewards from what high technology has to offer. For those that fail to do so, high technology will be the tail that wags the dog.

Notes

[1] There are several definitions of high technology industries. The broadest definition includes industries where the proportion of workers employed in high-tech occupations (engineers, life and physical scientists, mathematical specialists, engineering and science technicians, and computer specialists) is at least 1.5 times the average for all industries. A narrower definition includes only those *manufacturing* industries in which the proportion of workers employed in high-tech occupations (those listed above) is equal to or greater than the average for all *manufacturing* industries. An even narrower definition includes only industries where the ratio of research and development expenditures to net sales is at least twice the average for all industries (see Rumberger and Levin, 1984, table 3). When I refer in this article to high-tech occupations, I mean those listed above.

[2] The United States Government played a crucial role in the first phase of development of high-tech industry in three fundamental ways: (1) by funding basic research, primarily in universities, but also in quasi-public companies such as ATT's Bell Laboratories (research sponsored by the Federal Government at the laboratories resulted in the "discovery" of the semiconductor in 1947) and by military contractors such as Lockheed and General Dynamics; (2) by indirectly financing engineering education through federally funded projects at universities; and (3) by being the largest consumer of high-tech products in the early stages of their development. A single decision by the Pentagon in the early 1960s – to place integrated circuits in all missiles – guaranteed a market for early integrated circuits and thus allowed leading manufacturers like Fairchild Semiconductor and Texas Instruments to devise more efficient ways of producing such circuits in large quantities (what Rosenberg (1982) calls "learning by doing").

[3] Engineers and technicians tend to be highly mobile and, given the right conditions, are often ready to move to the places where plants are located. The existence of suitable low-cost housing in pleasant surroundings (Colorado, for example) may figure in a firm's decision to select a particular site since this helps to keep down the salary costs of the highly educated labour required for R and D units.

[4] A term current in the south-west of the United States to denote people of European descent.

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