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Technology, Structural Change and Manufacturing Employment

Rothwell, R.

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TECHNOLOGY, STRUCTURAL CHANGE AND MANUFACTURING EMPLOYMENT

Roy Rothwell

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

This paper presents a revised version of Roy Rothwell's contribution to the IIASA Task Force Meeing on "Innovation and Industrial Strategy" in June 1980. It shows the heavy impact of technical change on employment both from the side of processes and products. Discussing the economic mechanisms of long waves the author mentions "...The fact that Menschs' inventions are rather more spread over time than his bunches of innovations, certainly suggests that other factors play a part in forcing their commercialization." Those factors are the self-reinforcing pressures of capital accumulation, which result in higher capital intensity and lower profitability until capital investment peaks out and begins to decline. Roy Rothwell comes to some conclusions for the policy to be applied. In his opinion governments, via market economies, might help to accelerate the formation of new industries through the process of innovative procurement in the public sector.

Heinz-Dieter Haustein,
Innovation Task Group,
Management and Technology,
November, 1980

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Technology, Structural Change and Manufacturing Employment.

1. Introduction.

Following the so-called energy crisis of 1974, unemployment increased significantly in most of the mature industrialised market economies. Moreover, the recovery of the world economy from the 1974-75 recession did not lead to a rapid fall in unemployment, which had been the pattern of all previous post-war recoveries (Rothwell and Zegveld, 1979). On the contrary, throughout Europe levels of unemployment have remained high by post-war standards, and in some countries rose even higher between 1976 and 1978. In the U.K. levels of unemployment are fluctuating but on an apparently rising trend. In the United States, although overall unemployment has remained higher than in the 1960s, there was nevertheless some reduction between 1976 and 1978, even though the labour force did increase fairly rapidly during this period. This was the result of active employment and expansionary economic policies through which a great many new jobs were generated primarily in the public sector.
Unemployment levels during the 1970s for a number of countries are shown in Table 1.

During the 1950s unemployment in the United States was high relative to Europe, and there was considerable concern in American Trade Unions about the effects of automation and computerisation on levels of employment. During the 1960s U.S. policy became more expansionary and U.S. growth rates were significantly higher than in the 1950s. Unemployment fell and there was a widespread feeling that the 'automation score' had been a false alarm. It had proved possible to generate new jobs in sufficient numbers to offset any labour displacement involved in the adoption of new technology. It was thus concluded in the 1960s that the unemployment problem in the USA was overwhelmingly one of demand rather than one of structural or technical change, and it is probably true to say that today emphasis in the U.S. is primarily on the role of aggregate demand.

In Europe, on the other hand, there is greater interest in problems of structural and technical change, and it is increasingly being suggested that new features in the world economic situation and in world technology mean that the employment problems of the 1980s will differ significantly from those encountered in the 1960s; that the high unemployment of the 1970s cannot be written off as due to a period of demand efficiency - a purely temporary aberration from a steady long-term growth pattern - but must be regarded as marking a transition to a rather different relationship between output and employment.

Table 1.
LEVELS OF UNEMPLOYMENT (1) (Percentage of labour force)

	1962-73 (Average)	1974	1975	1976	1977	1978 (2)
Canada	5.3	5.4	7.1	7.2	8.1	8.4
USA	4.9	5.6	8.5	7.7	7.0	6.0
Japan	1.3	1.4	1.9	2.0	2.0	2.2
Australia	1.6	2.3	4.4	4.4	5.6	6.4
Belgium	2.1	2.8	4.5	5.8	6.6	7.1
Denmark		2.5	6.0	6.1	7.7	8.5
Finland	2.4	1.7	2.2	4.0	6.1	6.7
France	1.8	2.3	4.0	4.2	4.8	4.8
German F.R	1.3	2.7	4.8	4.7	4.6	4.3
Italy	3.8	2.9	3.3	3.7	7.2 (3)	6.9
Netherlands	1.4	3.3	4.7	5.1	4.9	5.0
Norway	0.9	0.6	1.2	1.1	0.9	1.0
Spain		2.2	3.8	4.9	5.7	7.0
Sweden	2.1	2.0	1.6	1.8	1.8	2.2
UK	2.4	2.5	3.9	5.4	5.7	5.7
Ireland		7.9	12.2	12.3	11.9	11.8

Source: OECD "Economic Outlook" and "Selected Economic Indicators"

(1) National definitions, not adjusted for international comparability.
(2) 1978: latest 3 months available (usually second quarter)
(3) New survey definitions, not comparable with previous years.

This paper will present an argument for a 'structuralist' interpretation of the contemporary unemployment problem. It will argue that while aggregate demand is extremely important to maintaining employment, by itself it cannot explain current trends and that the rate and direction of technical change is one of the central issues involved. A detailed discussion of the issue of the relationship between technical change and employment is provided in Rothwell and Zegveld (1979).

2. Shifts in Post War Patterns of Employment.

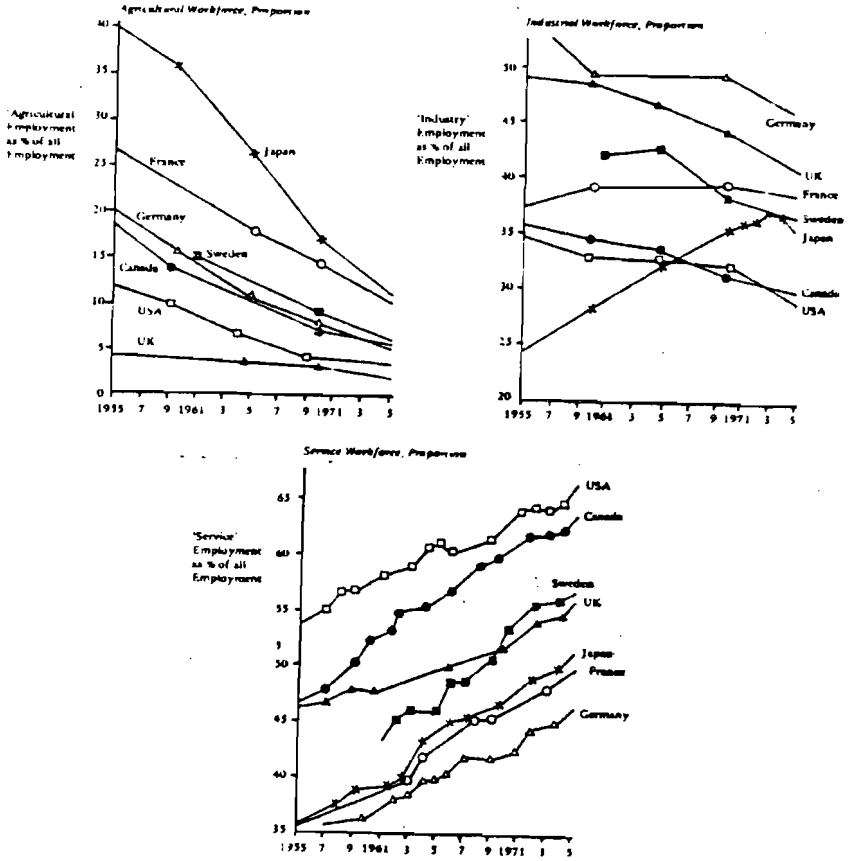
During the post war era there have been a number of marked inter-sectoral shifts in labour in all the mature industrialised economies, and a number of common trends are clearly discernible (see Figure 1). It is an established fact that there has been a steady decline of employment in the primary sectors (agriculture and mining) between 1948 and 1975. The decline in agricultural employment has, moreover, been accompanied by a marked rise in agricultural output, and it is an important fact that a pattern of 'jobless g growth' of output has been well established in a major economic sector for a long time.

The pattern of employment change in manufacturing is not so clear cut or so consistent as in the primary sector. There are variations between countries and there are peculiarities in the direction and rate of change of employment growth over time. Nevertheless, one generalisation can be made, and that is the rate of increase in manufacturing employment had already slowed down markedly in almost all mature industrialised countries well before 1973, which raises the question of whether the phenomenon of jobless growth has now become established in the secondary sector in the advanced economies.

A feature common to all the advanced Western economies is the steady post-war growth in employment in the tertiary sector, both public and private, and for most, if not all, of the countries shown in Figure 1, the tertiary sector now employs more than either the primary or the secondary sectors. Two notable characteristics of the tertiary sector are that labour productivity and capital intensity are both relatively low. Now, while it is generally recognised that the marked shift of employment to the service sector is related to the increase in demand for commercial and public services by consumers and businesses, nevertheless, the slow growth of labour productivity in this sector contributed to this shift. As Gershuny (1979) puts it:

> "One condition for maintenance of full employment in an economy (holding relative wages constant) must be that the total product rises at the same rate as does the manpower productivity across the economy. Over the past two decades, throughout OECD, manpower productivity in manufacturing industry has risen faster than GNP (Figure 2). Employment can only be maintained under such conditions by passing labour into the relatively low productivity, low productivity growth, service sector".

Figure 1. Sectoral Employment in the Seven Economies[1]



Source: J. Gershuny, SPRU.

Thus, an important question to ask here is "are there developments in technology which are liable to cause a dramatic increase in labour productivity in the service sector, with its consequences for employment growth in this sector?" The current debate concerning microelectronics very much revolves around this question. This issue will not, however, be discussed further in this paper which will deal solely with manufacturing equipment.

Figure 2 Gap Between Manufacturing Productivity Growth and GNP Growth, 1960-1974

	1 GNP Growth	2 Manufacturing Productivity Growth	3 1-2
Canada	3.6	3.7	-0.1
U.S.A.	2.5	3.6	-1.1
France	4.4	4.8	-0.4
Germany	3.5	4.9	-1.4
Sweden	3.3	5.9	-2.6
U.K.	2.2	3.6	-1.4

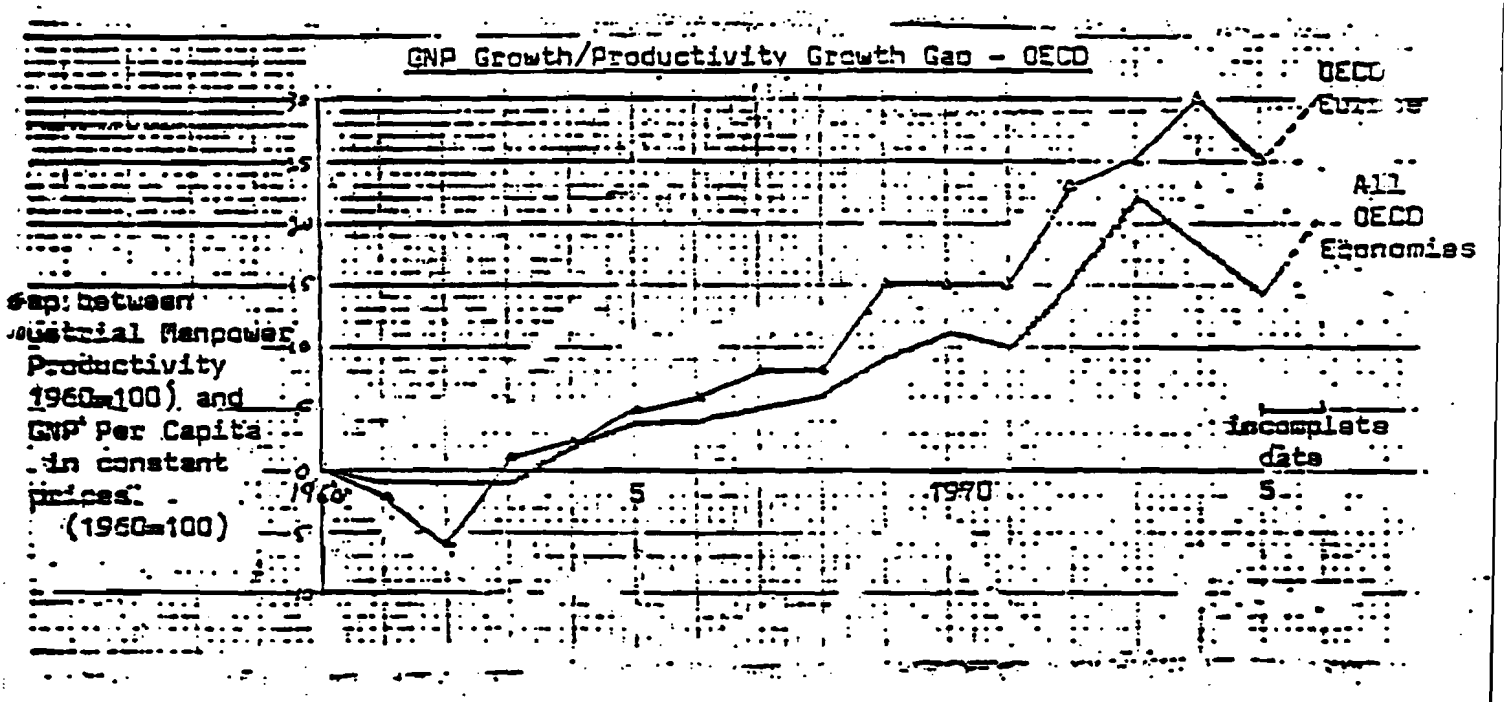


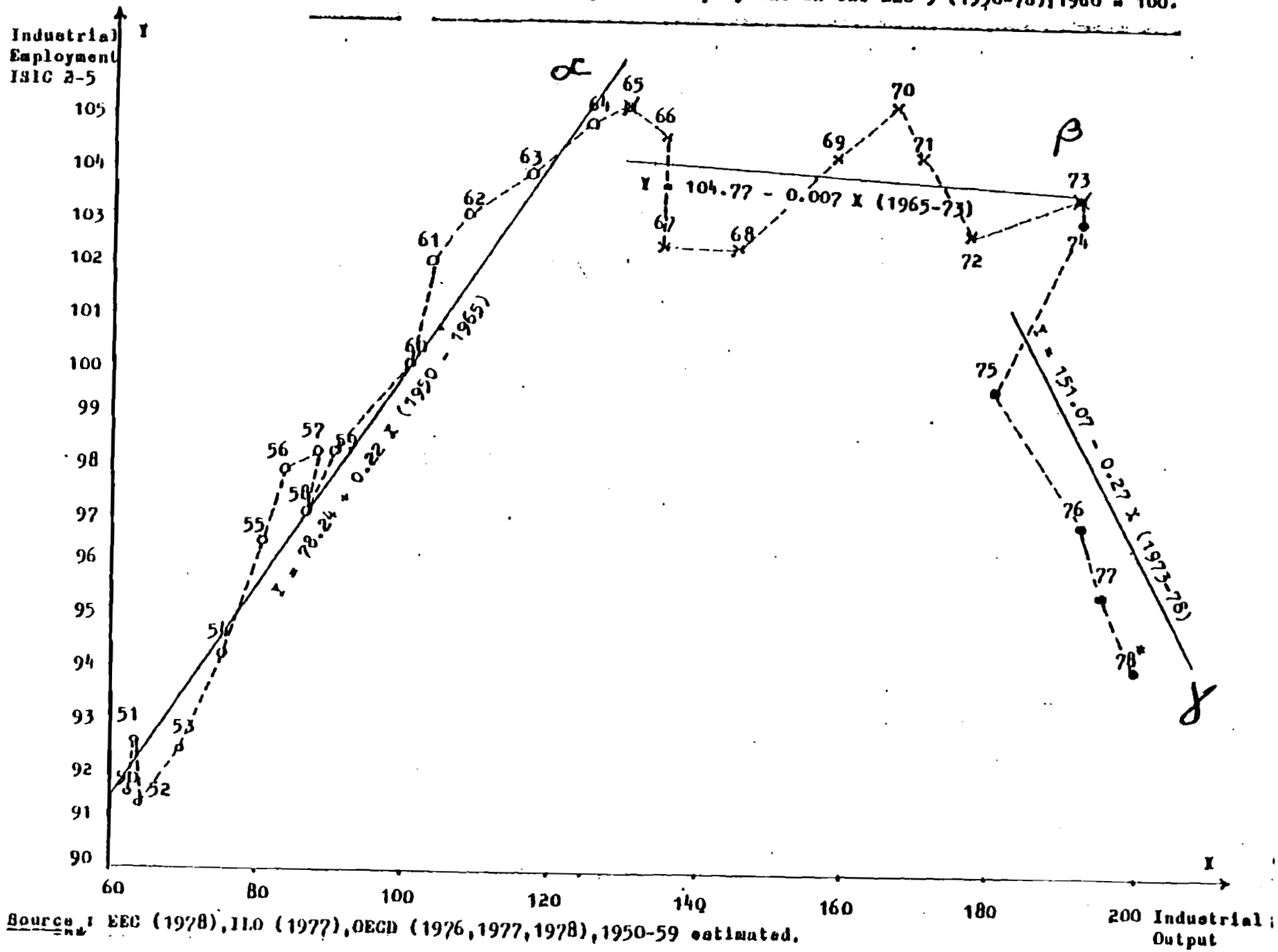
Table 2 : Production and Employment in Manufacturing Industry 1973 - 1978 (OECD) (1973 = 100).

OECD-countries	Industrial Output						Employment in Industry					
	1973	1974	1975	1976	1977	1978+	1973	1974	1975	1976	1977	1978+
Canada	100	103.2	98.2	103.2	106.6	107.8	100	103.0	97.3	98.6	97.3	97.4
U.S.A.	100	99.6	90.8	100.0	105.6	110.9	100	99.9	91.4	94.5	97.4	100.8
Japan	100	96.2	86.0	95.5	99.5	104.9	100	99.4	94.1	91.6	90.0	87.5
Australia	100	102.6	94.8	100.0	98.3	100.0	100	100.5	92.9	94.5	88.9	86.6
Austria	100	105.0	98.5	104.7	108.3	110.4	100	99.6	94.5	93.0	93.8	92.6
Belgium	100	103.4	94.0	101.7	100.9	102.6	100	101.1	85.6	85.6	80.0	77.8
Danmark	100	95.7	89.6	100.0	100.9	107.8	100	95.6	85.4	86.3	84.4	81.9
Finland	100	105.0	100.8	101.7	98.3	102.5	100	105.0	104.3	100.5	99.0	96.7
France	100	102.5	95.0	103.3	105.0	105.8	100	100.8	98.2	97.1	96.4	92.5
Germany	100	98.6	93.0	99.8	102.8	102.7	100	97.3	90.8	88.6	88.8	88.3
Italy	100	103.9	94.8	105.8	105.8	108.4	100	104.0	104.2	103.0	97.0	95.5
The Netherlands	100	105.0	100.0	105.9	106.7	105.9	100	98.9	95.7	91.4	89.2	NA
Norway	100	104.3	111.3	119.1	120.0	101.7	100	100.8	105.7	106.9	105.1	100.8
Sweden	100	105.4	103.6	102.7	100.0	95.5	100	105.4	107.1	103.9	104.3	96.5
Switzerland	100	100.9	88.2	89.1	93.6	93.6	100	99.8	90.7	84.3	84.1	84.8
United Kingdom	100	98.2	92.8	93.7	95.5	97.3	100	100.5	95.7	92.6	93.9	93.7
Greece	100	98.4	102.7	113.6	115.9	123.1	100	100.9	101.7	108.5	112.8	113.7
Ireland	100	102.5	95.8	105.0	113.4	121.8	100	100.9	93.9	93.7	96.4	96.6
Spain	100	109.5	102.2	108.8	121.9	127.7	100	103.5	103.8	104.4	NA	NA
Yugoslavia	100	112.0	117.6	121.6	133.6	144.0	100	105.5	108.5	112.1	117.3	120.5

Source : OECD (1976,1978),UN (1978).

+ First six months only.

Figure 3 : Industrial Output and Employment in the EEC-9 (1950-78), 1960 = 100.



Source : EEC (1978), ILO (1977), OECD (1976, 1977, 1978), 1950-59 estimated.

3. Theories of Manufacturing Employment/Unemployment.

(i) Aggregate demand theory.

Table 2 shows production and employment in the manufacturing industries of 20 OECD member countries between 1973 and 1978 (Soete, 1978). It shows that, with the exception of the USA, the industrial recovery from the 1975 depression has not been accompanied in any of the "rich" OECD countries by a similar recovery in employment. On the contrary - again with the exception of the USA - in all the rich OECD countries employment has declined during the 1975-78 period, despite some growth in industrial output. These figures question the ability of the Western economies to solve their employment problems using purely neo-classical or Keynsian demand stimulation measures.

Figure 3 plots industrial output and employment in the nine EEC member countries during the period 1950-78. It shows three very distinct periods in the relationship between output and employment (Soete, 1978):

- the period 1950-1965, which is characterised by high growth in industrial output (7% annual average rate) accompanied by an important creation of employment (1% annual average growth rate);

- the period 1965-1973, which is characterised by high growth in industrial output (6% annual average rate) and employment stagnation;

- the period 1973-1978, characterised by low and stagnant growth in industrial output (1% annual averate rate) accompanied by "deployment" (- 1.8% annual average rate).

Between 1950 and 1978 the relationship between output and employment has clearly altered. Underlying structural change in this relationship appears to have become established during the mid to late 1960's, and has intensified following the so-called energy crisis of 1974. Thus, while the aggregate demand theory of industrial employment would appear to have been valid between 1950 and 1965, its validity for the period 1965-1978 is highly questionable, at least for the nine members of the EEC. Under these circumstances demand stimulation measures aimed at generating employment through growth in industrial output would seem to stand little chance of more than only limited success. This is not to suggest that levels of aggregate demand are unimportant, but rather that prescriptions and explanations couched solely in terms of aggregate demand are insufficient. What Table 2 and Figure 3 do suggest is that the phenomenon of jobless growth is now firmly established in the manufacturing sector of a number of advanced Western economies.

But what about the situation in the USA, where industrial employment did increase consistently between 1975 and 1978 as industrial output increased? The answer might lie, at least in part, in differences in the structure of U.S. industry compared to industries in Western Europe.

A recent report commissioned by the Anglo German Foundation showed that new technology based firms have played a major role in the U.S. economy, while their role in the U.K. and West Germany has been only small (A.D. Little Ltd., 1977). (There are several thousand NTBFs in the U.S. employing in excess of two million. In the Silicon Valley area alone, in 1974 there were 800 NTBFs with annual sales of $2.5 billion. In the U.K. the number of NTBFs currently in existence is only about 200 with total sales of £200 million. In West Germany the number of NTBFs is even less.) Although the regenerative capacity of small and medium-sized firms in Europe may be higher than in the U.S.A. Trade Statistics also show that U.S. Exports

are more technolcgy intensive than those from other major OECD exporters (Kelly, 1978). Now, it is well-known that the U.S. led the world in the production of semiconductors and semiconductor devices. A similar pattern is being established in the production of microelectronic circuits and devices. In both instances, initially small, but fast growing high technology firms played a major role in the production of these new technologies and devices. It might, therefore, be that the recent development of microelectronics in the U.S. has played an important role in the generation of new jobs via the creation of many new, fast growing high technology firms. (Between 1963 and 1973, the growth of the U.S. semiconductor industry was five times that of the U.S. GNP; growth of the integrated circuit segment was about 80 times that of the U.S. GNP).

The results of a recent study by the U.S. Department of Commerce would appear to lend some support to this "new small firm" argument (1978). The study looked at six "mature" corporations (including General Motors and Bethlehem Steel), five "innovative" companies (including Polaroid and IBM) and five young "high technology" firms (such as Marion Labs. and Digital Equipment). The mature firms, which had combined annual sales of $36 billion, added only 25,000 workers between 1973 and 1978; the innovative companies, with combined annual sales of $21 billion, added 106,000 workers; the high technology companies, with total sales of 857 million, created 35,000 new jobs. In terms of workers created/$million of turnover, this yields the figures: mature corporations 0.7, innovative companies 5, young high technology companies 41. In the "50's" and "60's" the semiconductor and computer hardware industries were generating a lot of new employment. In the "70's" the main growth in employment has not derived from the hardware side, but from the software side, e.g. computer bureaux, information services, where small new firms have proliferated.*

In contrast to the U.S., semiconductors in Europe were developed and exploited by existing large electronics firms. It seems reasonable to suppose that a similar pattern is occurring with the development and exploitation of microelectronics. This could mean that while the information technology has generated many new jobs in the U.S., this may not be true in Europe.

Thus, it might be that in an economy whose industry is characterised to a significant extent by the rapid growth of many new firms based on the emergence of new technological opportunities, the relationship between output and employment is positive. In an economy based more on mature industries and in which existing large firms largely exploit the same new technologies, the relationship between output and employment is much weaker.

(ii) International division of labour theory.

According to the international division of labour theory, structural unemployment in the advanced economies is due primarily to shifts in stagnant, labour-intensive industries from high labour cost developed countries to less developed countries where labour costs are much lower. At the same time labour in the developed world shifts to capital-intensive sectors having potential for growth. The final result of this process is one of national specialisation in relative factor abundant industries or products, and all countries end up being better off. According to this interpretation, unemployment in the developed world is only temporary and is due more often to past unwillingness to adjust under trade liberalisation.

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* The role of small firms in employment is discussed later in this chapter.

If a significant percentage of employment in the labour-intensive industries in the Western economies has moved to the less developed, low wage cost countries (LDCs), then this might be expected to be reflected in a significant level of imports from LDCs to the developed nations. Further, if this factor has grown in importance, and is making a major contribution to recent high levels of unemployment, then the percentage of imports from the LDCs would be expected to be significantly higher today, than, say, twenty or so years ago. Thus, by separating imports originating from LDCs from those originating from the advanced economies, it should be possible to separate international competition based largely on comparative advantage (i.e. low wage competition) and competition based largely on non-price factors (i.e. technical change).

Soete (1978) has produced data which show that international competition from developed countries is a more significant factor of domestic consumption - 4.31% (1959-1960) to 7.35% (1973-74) - than international competition from LDCs (less than 2% of domestic consumption in the Western World). Further, the evolution over time indicates that developed country competition has grown more rapidly than low-wage competition. Other data broken down for 11 broad industry groups showed that:

-in most industries foreign penetration of Western domestic markets is relatively high, and in the first place the result of competition from developed countries;

-in terms of "low wage" competition, market penetration is weak in all industrial sectors, except in Clothing, Petroleum products and Ferrous and Non-ferrous metal products (two natural resource intensive industries). Only in the Food industry, Textiles but also Chemicals, LDCs imports represent more than 1% of domestic apparent consumption.

-in terms of growth, import competition has increased in all industrial sectors, especially in Clothing (mainly low-wage competition), but also in Textiles, Rubber, Transport Equipment and Machinery.

The natural conclusion to draw from these figures is that, contrary to "pure" trade theory, and the concept of the international division of labour, low-wage cost foreign competition has, directly, played only a minor role in the structural employment crisis in the Western economies. However, it might be that competition from low wage cost countries has accelerated the scrapping of old vintages, and also resulted in some product and process innovation, thereby having an indirect effect on structural change.

(iii) Technical Change Theory.

There are two aspects to the technical change theory of unemployment. In the first place, jobs can be lost because of lack of competitiveness in the face of technically advanced imports. In the second place, jobs are lost through rationalisation by the home industry in attempting to increase its production efficiency to match that in major competitor countries, as well as attempting to overcome the price advantage enjoyed by traditional goods produced in the LDCs.

In order to provide a rigorous verification of the importance of technical change on the export performance in manufactured goods of OECD member countries (Iceland and New Zealand being excluded), Soete investigated the relationship between patents granted to those countries by the US patents office between 1963 and 1976 in 40 industrial sectors with, for these same

countries, the 1974 exports of the 40 industries. It was assumed in this analysis that the United States is the leading inventive activity country and market, and will thus attract most of the important patents from other OECD countries. The results of this analysis are:

- for most capital goods industries, significant results are obtained;

- for most consumer goods (just as intermediate goods and materials where technical change is weak) where technical change is more based on the diffusion of innovations that have occurred in the capital goods sector, non-significant results were obtained.

In interpreting his results, Soete assumed that most technical change in capital goods is of the cost-reducing, continuous type. He therefore concluded that while technical change per se is important to competitiveness, cost-reducing technical change in particular is the crucial factor in international competition in capital goods; as a result, in the Western economies between 1963 and 1976, competition mainly from other developed countries has been the crucial factor in inducing industries into, in the first instance, job-displacing, labour-saving technical change.

While much technical change is undoubtedly of the cost-reduction type, nevertheless a number of detailed studies of specific industry sectors, have highlighted the importance of "product performance" technical change in international competitiveness. Examples are agricultural machinery (Rothwell, 1979) and Portable Power Tools (Walker, 1978). Several studies have also emphasised this aspect of competitiveness over a wide range of industrial products (NEDO, 1977, Corfield, 1979). Two studies of machine building industrie have explicitly linked job loss in the U.K. to lack of performance-orientated technical change. The first of these (Rothwell, 1980) showed that during the post-war period the position of the U.K.textile machinery industry has been one of decline and that this decline was primarily the result of the failure of many U.K. firms to undertake programmes of technical development. As a result the U.K.'s share of world trade in textile machinery declined from 30% in 1954 to 11% in 1975. At the same time, employment in the industry dropped from 75,000 in 1951 to 35,000 in 1973. This fall in level of employment was the result mainly of loss of market share due to a decline in "product performance" international competitiveness rather than the rationalisation of manufacturing processes. According to the second of these studies (Swords-Isherwood and Senker, 1978):

> "There has been a trend towards reduction in employment in the British engineering industry. Automation has played some part in causing this. But is has been the result to a greater extent of the failure of British management to invest sufficiently in research and development and production facilities to make products which would be more competitive on international markets. If management in the British engineering industry fails to remedy these deficiencies, the consequences in terms of job loss could be considerable because of the impact of overseas competition. If the industry does modernise, this could result in pressure to continue to reduce job opportunities. But the industry would be creating resources which collective bargaining can ensure are used to alleviate these effects by securing benefits such as shorter working weeks and better working conditions."

So, there exists eivdence to suggest that both rationalisation and international competitiveness technical change have resulted in the loss of significant numbers of jobs in some Western economies especially, in the

case of the U.K., the latter. Now, while steps can be taken to reverse lack of international competitiveness through vigorous programmes of product development, jobs lost through rationalisation can only be recouped via the growth of new businesses or through significant business expansion. The recent development of microprocessor controlled production systems however, makes it likely that many firms can significantly expand output with the same, or even reduced, manpower, which would place the burden of new job creation on the growth of new manufacturing firms and on the service sector of the economy.

Finally, Cox (1978) has looked in some detail at the relationship between employment costs, sales receipts and rationalisation and has presented extremely convincing data from the United Kingdom and West German mechanical engineering industries to show that where there is a mismatch between sales receipts and employment costs, firms shed labour and rationalisation investment replaces growth or replacement investment. The process of employment loss through wage cost inflation is illustrated in Table 3.

Table 3. The relationship between costs per employee, sales and employment in the U.K. and West German mechanical engineering industries.

	Percentage increase per year		Actual change in employment
	Costs per employee	Sales	
	%	%	
UNITED KINGDOM			
1958 to 1963	3	6	+ 56,000
1963 to 1967	7	9	+ 33,000
1967 to 1971	12	14	+ 54,000
1971 to 1975	23	19	- 77,000
WEST GERMANY			
1967 to 1971	15	16	+143,900
1971 to 1975	9	7	- 96,100

Cox concludes:

".... in current output technological development is responsible for maintaining and increasing sales and, potentially, the numbers employed. If however unions negociate an average cost per employee that is out of line with increase in sales receipts, then technical development comes to play an additional role - that of substituting machine effort for human effort, which has become too expensive." Thus, wage- and social security-push have reduced employment and favoured rationalisation investment.

The above explanations are not, of course, mutually exclusive and can act concurrently to reduce levels of employment in the advanced economies. This is illustrated in Table 4 for the U.K., which shows the reasons for jobs lost in the 24 industries most affected by U.K. competition between 1970 and 1975. It can be seen that 12.3% of jobs lost were due to falling demand at home (aggregate demand) 50% were due to rising productivity at home (rationalisation technical change), 26% because of trade with non-third world countries (technical change competitiveness) and 9% as a result of trade with third world countries (low cost competitiveness). In the area of textiles, in which third world countries probably enjoy their greatest success in trade in manufactured goods, only 25% of U.K. imports derived from these countries.

This suggests that current demands for stringent controls on U.K. textile imports from the LDC's are largely mis-directed.

Table 4 Reasons for jobs lost in 24 industries most affected by Third World competition in the U.K. between 1970 and 1975.

Reasons	Number	Percentage
Falling home demand	52,800	12.3
Rising productivity at home	214,300	50.0
Trade with non-third world counties	113,400	26.4
Trade with third world countries	47,800	9.0
	428,300	10.0

Source: Sunday Times, 10th February 1980

4. Structural Changes in the Relationship Between Manufacturing Output and Employment

Figure 3 presented data which strongly suggest that, within the nine countries of the E.E.C., the relationship between manufacturing output and manufacturing employment has undergone a number of marked structural changes during the post-war era. Figure 4 presents similar data for three E.E.C. countries separately, and for Japan and the U.S. (Mensch 1979).* It shows that the general pattern indicated in Figure 3 generally holds true for the five countries separately - although there are obvious differences of detail and timing - which suggests that the phenomenon of structural change in the output/employment relationship is common to all the major advanced market economics.

In interpreting these results, Mensch points to changing patterns of investment in industry (Mensch, 1980). Utilizing data from West Germany, he has shown that the relationship between expansionary investment (E) and rationalisation investment (R) has altered during the post war era. During the 1950's and early 1960's, investment aimed at expansion was sufficiently high in relation to that aimed towards rationalization that job generation was greater than job displacement. In the mid-1960's the productivity effects pf rationalization investment began to dominate and increased industrial output could be attained with no increase in employment. A period of jobless growth was thus established. From the beginning o fthe 1970's rationalization investment effects swamped expansionary

* Mensch has, for convenience, substituted imput data (capital) for output in these figures. He found a consistently high correlation (better than 90%) between the two quantities.

investment effects, and increased output was achieved with a reduced labour force. The pattern of change in the E/R ratio for West German industry is shown in Figure 5, which indicates that from the late 1960's on E/R dropped rapidly and reached a fairly stable 'low' in about 1975/76.

On the basis of these data, Mensch suggests a 'threshold theory' for the structural changes in the output/employment relationship. Thus, when E/R fell to a particular level (Mensch calculates this at approximately 0.5 for West Germany - point α on Figure 3) the output/employment relationship switched from a net 'job-expansion' phase into an 'employment neutral' phase in which it continued until E/R reached a second threshold (approximately 0.25 - point β on Figure 3) when labour substitution effects became dominent. E/R then fell to a fairly stable value (approximately 0.23) when a lower level 'underemployment' equilibrium was reached*. According to Mensch, only when E/R increases to a certain threshold (point γ on Figure 3), the value of which is unspecified, will employment in manufacturing once again increase as output increases.

It is interesting to compare Figure 5 with the West German data in Figure 4. As E/R dropped rapidly in 1965, so did employment; when E/R increased rapidly after 1967,so employment increased also. In this case, however, the fall in E/R was the result of a rapid cutback in 'E' - associated with government action during a period of relatively high inflation in West Germany - rather than witha large and sudden, increase in 'R'**. Indeed, as Figure 4 indicates, between 1965 and 1967, West German industrial output remained more or less constant, and even declined slightly in 1967. Similarly, the rapid fall in E/R between 1973 and 1975 was the result of 'E' declining rather than 'R' increasing significantly***.

Clark (1979) has investigated the relationship between annual changes in manufacturing employment and annual investment in U.K. manufacturing. He found that the ratio DE/I, which is the annual change of employment per unit of investment has varied in a cyclical manner during the past 60 years or so. Clark interprets these data (see figure 6) as suggesting that changes in the relationship between expansionary investment and rationalization investment vary in a cyclical manner also.

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* Mensch investment data are based on an IFO survey of 6,000 West Germany manufacturing companies only. Given the difficulties in accurately specifying the amount of investment aimed purly at expansion and that aimed purely at rationalization, the validity of quantifying the 'turning points' must be seriously questioned. Nevertheless, the concept is an interesting one.

** Between 1965 and 1967 'R' remained more or less constant, while 'E' fell by nearly 40%.

*** Between 1973 and 1975, 'R' remained almost constant, while 'E' fell by about 50%.

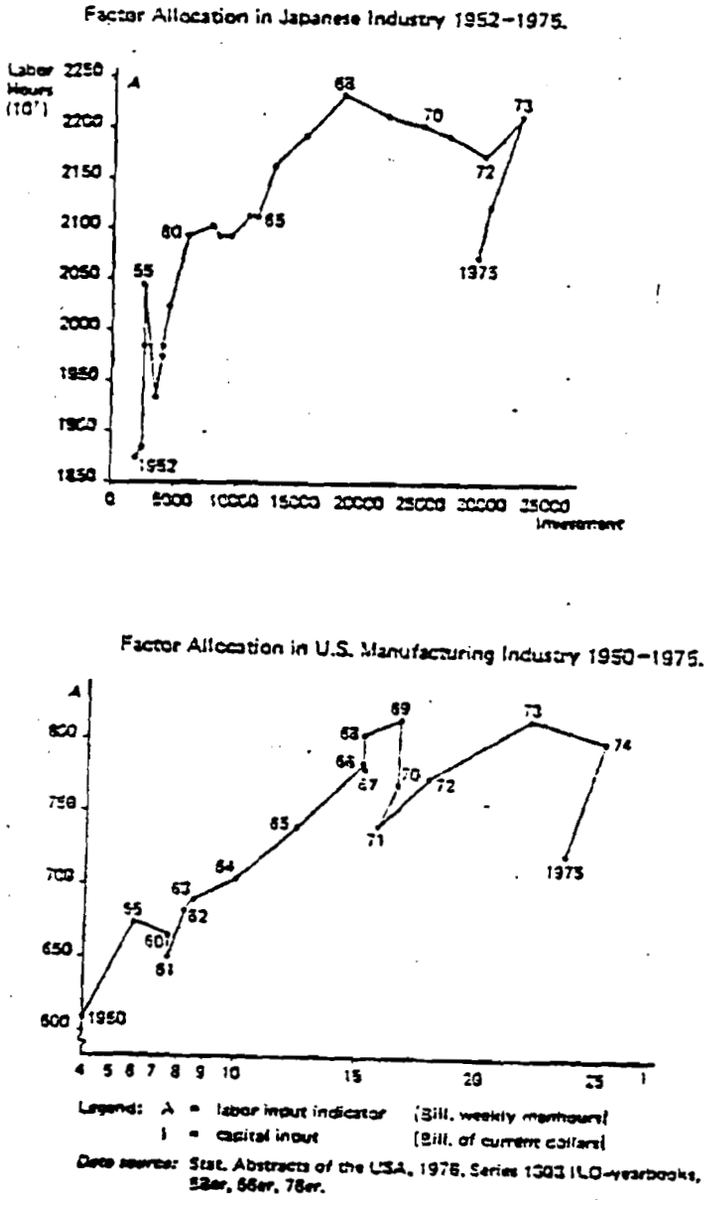
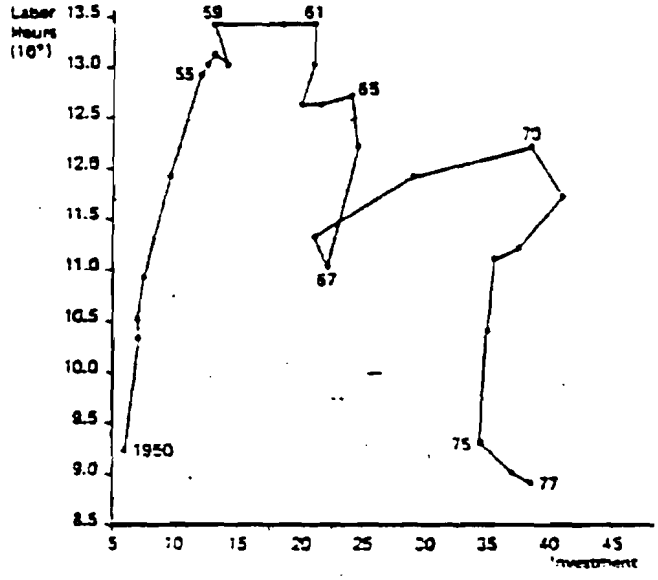


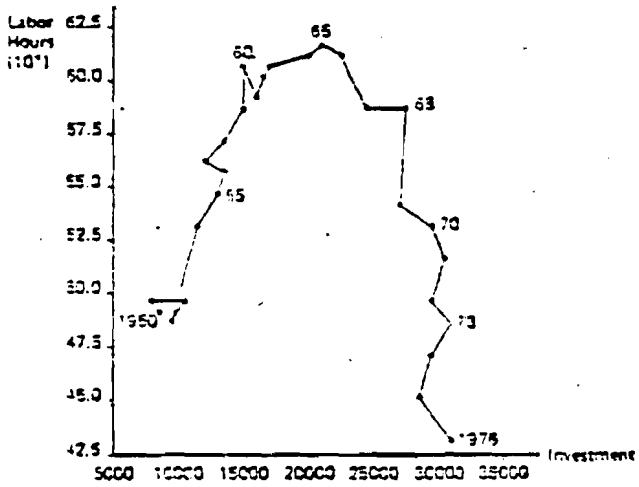
FIG. 4. Investment and Employment in West Germany, Netherlands, United Kingdom, Japan and the U.S.A., 1950-1975

Source: Mensch 1979

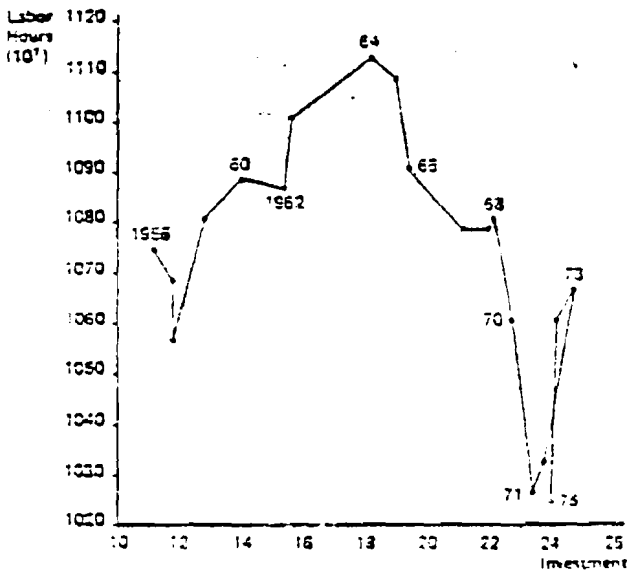
Factor Allocation in West German Industry 1950–1977.

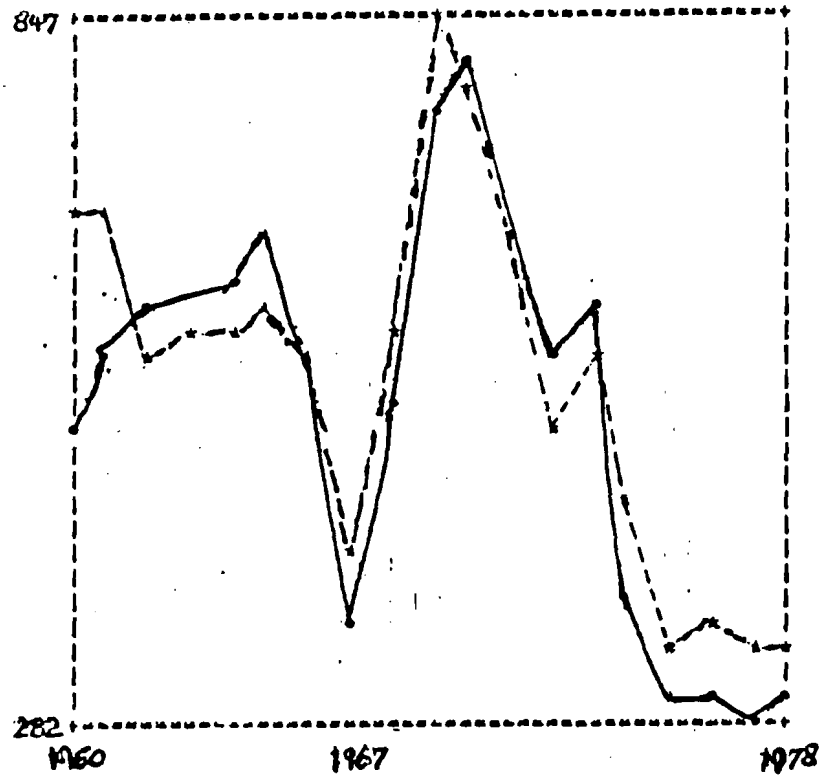


Factor Allocation in Dutch Industry 1950–1976.



Factor Allocation in British Industry 1955–1975.





0———0 S from official statistics

------- estimates: S=bE/R

S = number of 'open' position in industry

E = Expansionary investment

R = Rationalization investment

FIGURE 5

Source: Mensch et al, 1980.

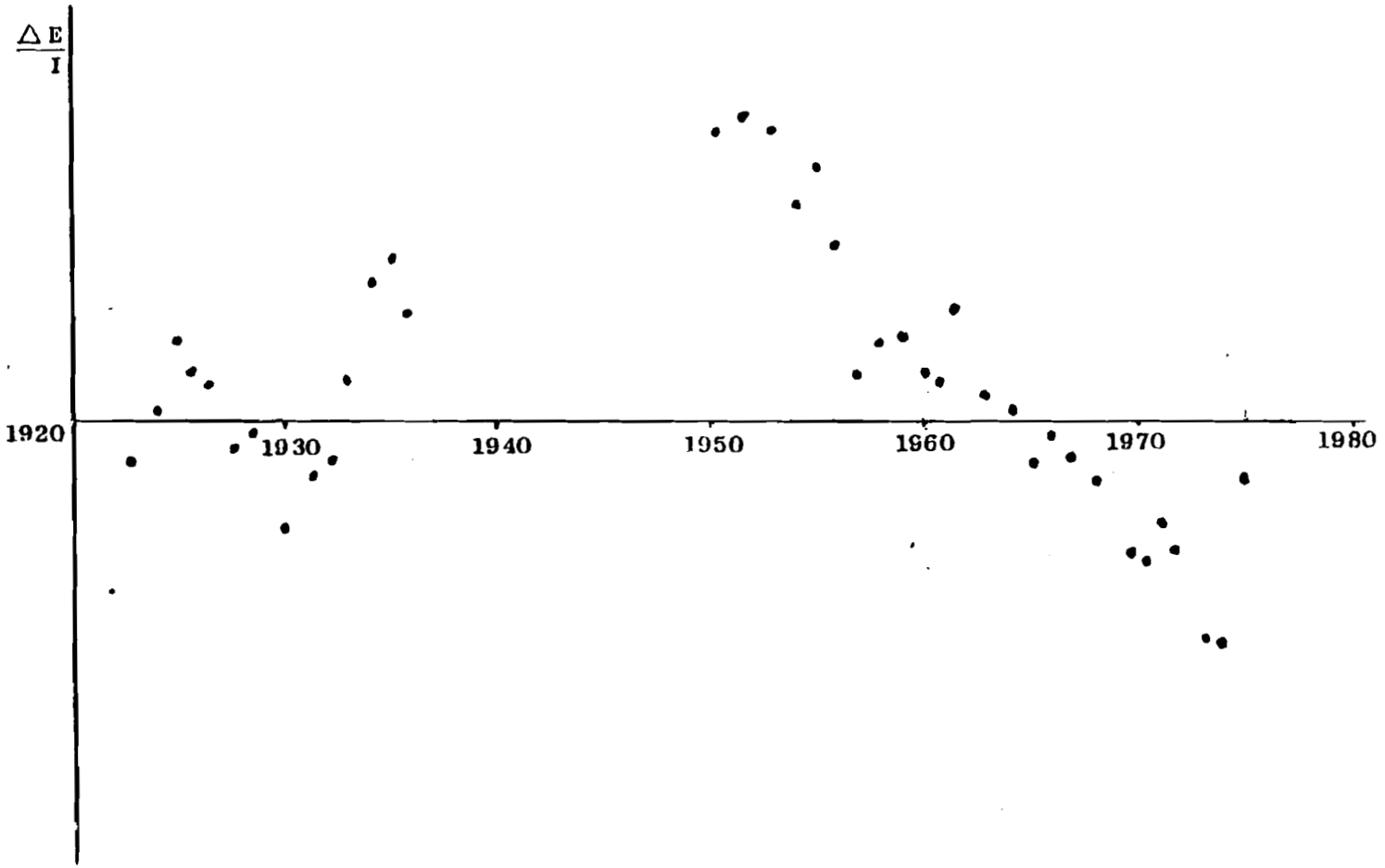


Fig. 6 Employment change per unit of investment (smoothed), UK manufacturing.

SOURCE: CLARK 1979

Before discussing the role technical change plays in causing these structural changes, a brief description will be given of the theory of long-waves in world economic development and their relationship to technical change. According to this theory, the world is currently in the latter phases of the fourth industrial revolution.

5. Technology and Structural Change in the World Economy.

While it is generally accepted that the shock to the world economy of the fourfold increase in the price of OPEC oil in 1974 contributed to the current world recession, it is increasingly being mooted that this simply accelerated an already established trend; that the current world economic crisis is the result of fundamental structural changes taking place in the world economy in which technical change plays a central role; that the fourth quarter of the twentieth century will be rather more similar to the second rather than to the third quarter of this century.

These conjectures have led to a resurgence of interest in the possibility of long waves occurring in the development of the world economy. Probably the earliest detailed formulation of long-wave theory was that of a Russian economist Kondratiev who, in the 1920s, analysed the development of long-term trends in selected economic indicators. He discovered a number of long waves in the world economy of between 50 and 60 years duration. While Kondratiev did not explicitly include the role of technical change in long-wave formation, he did suggest that when a major wave of expansion was under way, inventions that had remained dormant would find application.

The notion of long waves was later taken up by Schumpeter (1939), who ascribed a central role to technical change in long-wave formation. He introduced the idea of technological revolutions as the driving force of the Kondratiev cycles, and pointed in particular to the role of steam power in the first Kondratiev (1818-1842), railroads in the second (1843-1897) and of electric power and the automboile in the third (1898 to about 1949).* Schumpeter related these major changes primarily to bursts of innovative activity by entrepreneurs.

* The period of prosperity associated with the fourth Kondratiev is approximately 1949-1968.

Kuznets(1954) later pointed out that there appears to be no special reason to expect that the intensity of entrepreneurial innovative activity will vary in long cycles, although he did accept the possibility of a bunching of innovations associated with new technologies and of investment activities associated with these bunches of innovations. Such innovations would need to be such, however, that their effects would permeate throughout the economic system and be far reaching.

Freeman (1979) while basically supporting the Schumpeterian interpretation, has pointed to a number of snags - for example to the very different development in time of the automobile industries in America, Europe and Japan. He also pointed to the need for 'basic science' coupled to 'technical exploitation' followed by 'imaginative leaps' - all preceding the Kondratiev upswing. As Ray (1980) puts it:

"Schumpeter himself emphasised the view that whilst there is a relationship between innovation and economic development, it is a very complex one. One innovation is followed by another and the long chain eventually produces new products or processes which are again further developed and/or replaced. If the new product or process is important enough, it generates activity in many allied areas and cascades through the whole fabric of economic and social life."

Work on long-wave formation to-day falls basically into two camps, the first emphasising factors of demand, the second emphasising factors of supply. It is probably true to say that researchers in the U.S. generally fall into the former category and are looking at indicators of aggregate demand, notably demand for capital goods, while workers in Europe are focussing largely on the supply side, i.e. on the role of innovative push.

Perhaps the most rigorous work in the U.S. is being done by the Systems Dynamics Group at M.I.T. and Graham and Senge (1979) have summarised the M.I.T. hypothesis of long-wave behaviour as follows:

> " Economies move through long waves of approximately 50 years duration, arising from over- and underexpansion of the capital-producing sector.
>
> The upturn of a long wave, which lasts about 30 years, is characterised by self-reinforcing pressures to acquire more

physical capital to meet rising demand for capital, increase capital intensity of production, and to take advantage of high returns on investment.

Productivity per man increases during the upswing of the long wave, due at least in part to increasing physical capital per person.

When the accumulation of physical capital has run its course, adding more capital is no longer more attractive than adding labour. Capital investment peaks out and shows signs of declining, and the economy enters the peak period of the long wave, which can last for a decade or so.

Capital investment eventually falls off dramatically; the economy needs much less new investment to replace depreciation than it did to expand its capital plant. The capital-producing industries collapse and many of the people in them become unemployed.

During the depression, physical capital begins to deteriorate and obsolesce. Eventually, there is a need to replace it, and demand for capital rises. Again the process of capital accumulation is begun in the upswing of the next long wave."

Thus, the MIT researchers focus very clearly on the role of demand for physical capital in the formation of long-waves. The work that emphasizes most strongly the role of technology-push is that of Mensch in West Germany, who talks about a push of basic innovations opening up new investment opportunities and providing the basis for the growth of whole new industries. According to Mensch there are, over the past 200 years or so, distinct periods

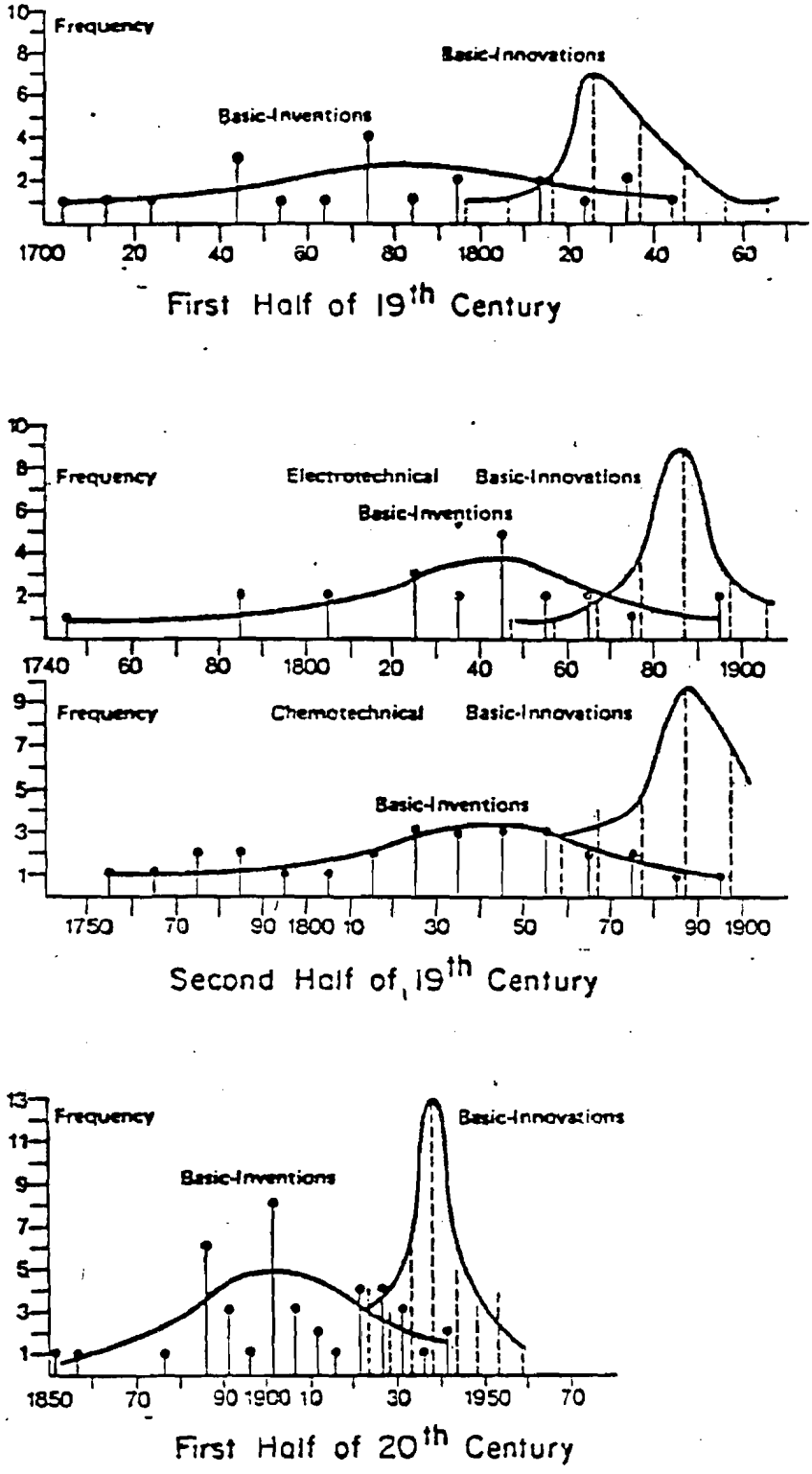


Figure 7 Frequency of Basic Inventions and Basic Innovations
Source: Mensch 1979 p. 146-148

in history which uniquely favour basic innovations. His data are shown in Figure 7 which plots the frequency of basic innovations, and the inventions which preceded them, as a time series. It is interesting that Mensch's innovation peaks preceed the Kondratiev depressions by about 20 years, which suggests that the seeds of the new upswing were already being sown during the previous downswing.

Graham and Senge have taken up Mensch's data and suggest that their long-wave accumulation of physical capital affects the process of innovation as follows:

> " Eventually, during an upswing and at the peak of a long wave, the economy's physical, technological and managerial infrastructure is committed to older technologies. There are numerous opportunities for improvement innovations, and large markets for them. Little if any of the current infrastructure is able to support basic innovations, and there are few economic incentives to turn away from the established technologies.
>
> During the downturn of the long wave, very little new investment occurs, and there is little market for technological innovations.
>
> During the late upswing, peak, downturn, and trough, scientific and technical progress continues, even though most of the basic inventions do not yet become commercialised basic innovations.
>
> As a long-wave downturn gives way to a new upswing, old capital plant has depreciated, so substantial amounts of new investment need to be made. This economic climate permits investors to develop the new technologies that may have gone untapped for decades.
>
> The cluster of basic innovations near the trough and in the early upswing of a long wave moulds the technological character of later investments, and the cycle of basic innovations repeats itself."

Thus, the boom created by the rapid re-equipment by industry in turn creates the right climate for the exploitation of dormant basic innovations which results in the growth of new industries, with subsequent further increases in demand for physical capital, often of a new kind. The fact that Mensch's inventions are rather more spread over time than his 'bunches' of innovations certainly suggests that other factors play a part in forcing their

commercialisation. A relatively rapid increase in the rate of expenditure on capital goods would certainly contribute towards creating a climate of confidence and optimism for entreprneurs to operate in, but it is difficult to see how this would have had a sufficiently large impact to, for example, have caused the railway boom in the U.K. in the mid-nineteenth century.

Railways were developed in Britain at a time when she enjoyed a very large share of world trade and was opening up new and captive markets in the countries of an expanding Empire. Industrialisation was proceeding apace, and much wealth was being generated. There was a pressing and growing need for an efficient and rapid transport system to carry raw materials from various parts of the country and from the sea ports to the centres of production, and back to the ports as finished goods. The need for rapid personal mobility of businessmen was also growing. The basic innovations necessary for the development of the railways (the steam engine, Stephenson's first locomotive in 1814) were in being. Cheap and mobile labour was available in Ireland in large quantities. There was thus a 'confluence' of factors - technological, economic, sociological and demographic - which, together, formed the basis of the second Kondratiev.

Similarly, the economic and political situation in Europe during the 1930s and in particular the 1939-1945 war, forced the rapid transformation of scientific and technological knowledge and inventions into practical innovations and spawned the modern industries - synthetic materials, petro-chemicals, pharmaceuticals, composite materials and electronics - during a relatively short period. This involved massive capital expenditure, mainly on the part of governments, and the concentration of scientific and technical manpower resources. The bunching of new industries formed the basis of the fourth Kondratiev. Again, the influence of a number of factors, - including, centrally, new technological capabilities - was necessary before the economic upswing could take place.

Thus, it seems that while technology has played a central role in forcing the world economy out of its major periods of recession, it needs to be coupled with a great and widely diffused need(s) the availability of large volumes of capital - along with favourable social and political conditions - before commercialisation and rapid business development occurs on a sufficiently large scale.

If this Schumpeterian model of world economic development is indeed valid, and if the world economy is in a Kondratiev recession/depression phase,

then this clearly has implications for both government and innovation policies.

6. The Role of Technical Change in the Economic Crisis.

The question to ask now is, what role does technical change play in creating the structural crisis that results first in recession and then in depression? In order to attempt to provide an answer to this question, it is necessary to look at the nature, rather than the rate of technical change in existing industries, as well as at changing patterns of investment and rates of growth in demand! It has been suggested, notably by Utterback and Abernathy, (1975), that as industries mature, the underlying nature of innovation changes essentially form a focus on new product development, to one of process optimalisation and cost reduction *. At the same time productivity increases dramatically and, in the final stages of maturity, increased automaticity results in some unmeployment. Parallel with these changes in technology, the pattern of investment changes from a net 'expansionary' mode into a net 'rationalisation' mode.

Maier and Haustein (1980) have also discussed the way in which industries change structurally over time. They have extended Utterbach's work and developed a five-stage model of this ageing process (Figure 7). According to this model (as with Utterbach's) as an industry ages, so the underlying nature of technology changes from mainly new product development to mainly process change: at the same time the substitution of capital for labour increase progressively until the industry reaches a crisis stage when all typesof investment generally decrease.(According to Maier and Haustein it might be possible to avoid decline in the saturation stage, which results in crisis,if the industry adopts a vigorous policy of innovation, to regenerate demand in existing markets, as well as a policy of diversification into new market areas). The process of capital/labour substitution is thus closely associated with the underlying nature of innovation.

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*Mensch (1977) has analysed 342 major innovations in W.G. industry between 1952 and 1973, that were identified by an NSF Science Indicators Project. He showed that the ratio of 'expansionary' innovations to 'rationalisation' innovations changed from 53% for the period 1952-1959 to 28% for the period 1960-1973.

Thus, as a new industry grows, initially many new products are created which open up new markets, and business expands rapidly generating many new jobs. In order to meet the rapidly growing demand for its products, the industry invests more in physical capital and in increasing production efficiency and productivity. Eventually, markets become saturated, the rate of demand for existing products slackens and the possibilities for new product development become increasingly fewer. The industry reaches a stage of overproduction, - the rate of productivity growth outstrips the rate of growth in demand - and begins to shed labour. Business confidence wanes. If this happens concurrently in a number of major industry sectors, then a recessionary trend becomes established, and many jobs are lost.

The point is, there is evidence to suggest that a number of major industries have indeed reached a stage of market saturation (synthetic fibres, steel industry, petro-chemicals), and that in some areas in which post-war rates of growth have been very high, market expansion is small or nil, and markets are very much ones of replacement (automobiles, consumer electronics, consumer white goods).

According to this interpretation, the major industries need to look to the rapid development of new markets (in, for example, the third world) in order to expand output considerably, or for radical new developments to regenerate demand in existing markets. To some extent the electric light industry achieved a series of such partial reversals from a state of saturation with the introduction of the fluorescent lamp in 1938 and the halogen lamp in 1959. (Haustein, (1980).

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* The point is, it is not the rate of productivity growth per se that causes unemployment, but rather the mismatch between the rate of growth in demand and growth in productivity. Thus, between 1960 and 1973, when there was considerable expansion in world trade, the average annual percentage increase in manufacturing productivity for the countries Japan, France, Canada, Italy, Germany, USA and the U.K., taken together was 4.48: at the same time, unemployment in these countries was relatively low. Between 1973 and 1979, the average annual percentage increase in manufacturing productivity for the same countries was only 1.92, but this outstripped demand growth in a number of key areas: during this period, manufacturing unemployment in these countries became, and has remained, historically high by post war standards.

No.	Characteristic	Take-off	Rapid growth	Matura-tion	Saturation	Crisis
1.	Example	Solar energy	Micro-elec-tronics	Chem-istry	Synthetic fibre industry	Steel industry
2.	Predominant type of change in production units	New es-tablish-ments	Enlarge-ments	Total modern-ization	Rational-ization	Rational-ization
3.	Degree of techno-logy change: Pro-duct	very high	high	medium	low	very low
	Pro-cess	low	medium	high	low	low
4.	Techno-logical policy for growth mainly oriented towards	push	push & compen-sation	compen-sation	compensa-tion & continua-tion	compensa-tion & continua-tion
5.	Relative efficiency	low	very high	high	middle	very low
6.	Total benefits	nega-tive	low	very high	high	low or negative.
7.	Substitution of labour by capital	nega-tive	low (high demand for quali-fied person-nel)	high (high demand for less quali-fied personnel)	very high	low
8.	Firm strategy	Creative push	Offens-ive long-term oriented	Market-oriented	Defensive or pseudo-offensive	Defensive
9.	Management	Flexible risk-taking creative	Flexible risk-taking entrepre-neurship	Less flex-ible Rigid organiza-tion	Risk-avoiding Rigid organiza-tion	Preference of strong leader-ship

Figure 7. Stages in the development of industrial organizations, creating and adopting innovations.

Source: Maier and Haustein (1980)

A second - Schumpeterian - solution would be the generation of a whole new bunch of industries based on technologies currently in their infant stages. Possibilities already being mooted are biotechnology, energy-related technologies (e.g. techniques for the reprocessing of coal) and technologies for the exploitation of the ocean bed. These could open up new investment opportunities, generate new, and rapidly expanding markets, and create a climate in which entrepreneurial activity - both individual and corporate - could flourish, and drive the world economy into the fifth Kondratiev upswing.

Finally, while this paper emphasises the role of technological innovation in creating the current unemployment crisis in the advanced market economies, this must not be taken to suggest that other factors are unimportant. Non-technological (organisational) innovations, scale economies, industrial concentration, levels and rates of growth in demand, energy costs, generally high levels of inflation and levels of real disposable income - these all play their considerable part. What this paper does suggest is that technical change - both its pace and nature - has played the key role in the macro changes that have occurred in the world economy, and in particular in the structural changes that have occurred in the relationship between manufacturing output and manufacturing employment during the post war era.

7. Policy Implications.

To increase employment opportunities in mature industries, where the thrust of technical change is currently very much one of manufacturing process rationalisation, and in which productivity growth appears to be outstripping demand growth in stagnant markets, companies would need to adopt a policy of vigorous product diversification into new market areas, or one of significant market regeneration. An example of the latter would be the planned expenditure in the U.S. automobile industry of $70 billion over the next five years to produce a small, energy-efficient motor car. It is unlikely that this will be achieved without considerable government backing and, indeed, U.S. federal government regulations have played a significant part in forcing these changes. A second such area would be the development of more efficient public transport systems in which governmental regulations, financial backing and innovation-oriented procurement, could play a major role.

Mature industries could also look more to the capital-rich developing countries as sources of rapid market growth for existing products (although as Iran showed there can be major problems caused by political instability). In other developing countries, where capital shortages are acute, long-term, low-interest government credit might be offered to stimulate demand and to facilitate subsequent economic growth. This appears to be a major tool of the Comecon countries to aid exports to the third world. There also exists a great need in developing countries for the agricultural regeneration and reclamation of vast areas of marginal and non-productive land. This would appear to present potentially very large opportunities for Western companies involved in agricultural chemicals and soil-based biological products.

If, as Mensch suggests, a new push of 'basic' innovations is needed to form the basis of the next Kondratiev upswing, then governments might look increasingly towards the stimulation and support of radical innovations in promising areas (e.g. bio-technology, coal products). The government supported scientific and technological infrastructure could also play a key role in identifying and developing radical new technologies, and in transferring their results to industry.

Governments might help to accelerate the formation of new industries through the process of innovative procurement in the public sector. For example, the French government is sponsoring a number of 'wired' villages in order to stimulate the development and adoption of new microelectronics telecommunications systems, which is part of a strong French interest in the general area of 'telematique'.

Although the evidence is not conclusive, it is probably safe to say that new small firms do play a very significant role in the generation of new manufacturing employment opportunities* and, indeed, governments in most of the advanced market economies are currently taking steps to facilitate manufacturing start-ups. It seems, however, that the general climate - social, cultural and regulatory, as well as economic - is crucial to the stimulation of entrepreneurship and specific government measures. (reduced corporate tax, cash credits) appear to have met with only limited success in this respect.

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*See, for example, D. Birch, "The Job Generation Process", Research Report, MIT, Center for Policy Alternatives, 1979.

A number of recent initiatives in the U.K. have shown that it is possible to estab lish new small firms, and new branches of existing firms (in both services and manufacturing), in areas of high unemployment. For example, the community of St. Helen's Trust, established in St. Helen's, Lancashire, which was created on the initiative of Pilkington Bros. (the largest local employer), the local authorities, industry, Chamber of Commerce, unions and banks (and which has the support of the Department of Industry), has successfully attracted new firms and branch establishments into the area. A second example is BSC Industries, a company established by the British Steel Corporation to fill the gaps left by closing British Steel Works in company towns in Scotland, Wales and the North of England: it helped to create 3,000 jobs in 1978 and a further 6,000 in 1979.

In terms of future industrial competitiveness, upon which many jobs hinge, a number of governments are attempting to stimulate the production, and especially the widespread adoption into industrial use, of microelectronic components and devices. Schemes to this end exist in the U.K., West Germany, France and Japan.

Finally, since the design, use and maintenance of microelectronics systems and devices requires the application of specialist skills, governments have a key role to play in the areas of education and training. In particular, a great deal of effort needs to be put into the re-training of displaced workers. Already, some major companies are experiencing a severe shortage of microelectronics skills (Siemens, for example, has reported a shortage in this area of 2,500), and the situation is likely to be much worse in small and medium-sized firms: such shortages appear to be widespread in the U.K. Clearly, at a time when unemployment is increasing, these shortfalls in human capital are untenable, and vigorous governmental action is called for to greatly reduce this mismatch in skill supply and demand.

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