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**The Micro-Electronic Revolution and its  
Impact on Labour and Employment**

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## **1. Introduction**

The relationship between technological change and employment has received increasing attention in the most recent period of time when fears of renewed inflationary pressures, intensive international competition and budgetary constraints have limited the scope for macro-economic demand management on the one side and when the rise in structural unemployment since the mid 1970s has been more or less dramatic in most industrialised countries on the other (see Fischer and Nijkamp 1987). Great concern has been expressed that job displacing types of technological change might outstrip the creation of new job opportunities over a fairly long period of time, involving much higher levels of structural unemployment in the 1980s and 1990s than in the past. These fears have been accentuated by the emergence of a new cluster of new technologies associated with the combination of micro-electronics, telecommunications and information technologies (see Soete and Freeman 1985) which may be loosely termed micro-electronics based technologies.

This new technological system satisfies all the requirements for a Schumpeterian revolution in the economic system. The revolutionary nature manifests itself in several features. First, it is pervasive in generating a whole range of new applications over a wide range of sectors. There is virtually no field in manufacturing and service industries which can fail to be influenced. Micro-electronics is regarded still being only in the beginning of wide ranging developments. The OECD (1987), for example, suggests that some 80 per cent of today's and medium term future technological advances are micro-electronics based. Second, the technological changes induced already were rather dramatic and sudden and of sufficient magnitude and consequence up to now. There has been never such a powerful cluster of new technologies advanced so rapidly in such a short period of time. Not only the capabilities and the performance of the microprocessor have increased significantly, but also the costs have been reduced remarkably. Third, micro-electronics based technologies provide a large potential for productivity increase in relation to all factor inputs, ranging from labour, capital, materials and energy to other more intangible factor inputs such as stock control, organisation, quality control, management and marketing; and, moreover, large potentials for flexibility in manufacturing and services as well as for more interactive decision

making and organisation. All these characteristics point to the radical change potential associated with the adoption of micro-electronics based technologies.

This new technological system seems to affect every branch of the economy, both in terms of its present and future employment and skill requirements and its labour market prospects. There is a wide range of studies in various OECD countries by a variety of research groups in industry and academic life which have attempted to assess and forecast the impacts of the new technologies on employment and occupations.

This paper discusses some of the labour and employment implications the micro-electronic revolution is likely to have. It draws largely on findings of a series of case studies in different countries. In order to provide a better understanding of how labour and jobs are changed we first describe the nature of these micro-electronics based technologies (see section 2.). It is not a straightforward task to identify and measure the employment effects of new technologies. There are different types of employment effects and serious methodological problems involved in this task. This issue is discussed in section 3 in some more detail. One of the key questions concerning the employment implications of technological change is whether the initial impact in terms of job displacement may be compensated for by endogenous and exogeneous factors which tend to increase employment in other ways at the macro-economic level. A discussion of this question is followed by a consideration of present and projected employment effects in manufacturing and service industries (see section 4). Regardless of whether these new technologies have a net positive or negative effect on aggregate employment they will affect job tasks, job skills and the work environment. Such changes in the quality of labour will be described in section 5. Finally some policy implications for labour market adjustments are considered.

## **2. The Nature of Micro-Electronics Based Technologies**

There is no established definition of micro-electronics based technologies (METs). METs may be roughly defined as comprising all those new technologies which use microprocessors or their electronic equivalents (such as custom or semi-custom integrated circuits), normally with large-scale or very large-scale integration circuitry, either in the form of single integrated circuit devices or in small groups of linked devices. The major distinguishing feature between microprocessors and custom integrated circuits refers to the fact that microprocessors can be programmed by the user for different applications while the programs of custom integrated circuits are fixed at the time of manufacture. Thus, custom integrated circuits are much less flexible, but might be considerably cheaper for large volume applications than the use of microprocessors. Semi-custom integrated circuits are a compromise between these two alternatives and offer varying degrees of user flexibility and cost savings for middle volume applications.

Potential applications of METs are innumerable in manufacturing, but METs are also applied increasingly in the service sector. METs can be integrated into products leading to product innovations and can be part of production processes implying process innovations. Of course, one's firm new product may be another's firm new process. Technical development in the products of many engineering firms represent process innovations for their customers. Despite of this fact, the distinction between product and process innovations is a useful one. For the employment effects of product innovations are quite different from those of process innovations.

In principle, the above mentioned devices can be used in almost any product where something is to measure, monitor or control. In particular, the opportunities for including micro-electronic components in engineering products (such as automobiles, computers, consumer electronics, household appliances etc.) is vast. These components often replace mechanical and/or electro-mechanical components. Typical examples of product innovations range from consumer goods (such as digital watches, electronic calculators, microprocessor controlled household appliances, robotic toys, emergency and security systems) over manufacturing machinery (such as presses, spot welders, sewing machines, fabric cutting machines, machine tool controls) , office equipment (such as text and data processors, executive work stations, automatic cash dispensers, electronic mail), vehicle and transport equipment (such as air conditioning units, air navigation equipment, train controls, aero engine controls, automatic pilots) to medical equipment (such as infusion pumps, haematology analyses) and defense equipment (such as guidance systems, radar). Micro-electronic based circuits can replace a large variety of assembled devices utilized throughout the economy, such as for example, measurement, monitoring and control devices using any mix of mechanical, electromechanical, electric, discrete or integrated circuit technology. Product applications, however, are less common than process applications up to now, partly because they tend to be more difficult to develop and need more technical expertise, longer development time and higher development costs.

The micro-electronic revolution is not only creating new goods and services, but also altering how they are produced. In the last fifteen years developments in micro-electronics based technologies have opened prospects for the rapid evolution of equipment used in performing a wide variety of tasks that involve receiving, processing, transmitting and acting upon information. In the service sector process applications cover the use of electronic data processing in production processes accompanied by electronically enhanced equipment and its application. In manufacturing microprocessors gradually penetrated into all aspects of the production process, especially in the engineering industries which have been in the forefront of developments of automation relevant to industrial manufacturing. Applications cover the use of micro-electronics based equipment in the design, fabrication, assembly, handling, quality control and testing or other operations on site necessary to make a product ready for sale. Typical process and production applications include the use of computer-aided design (CAD) equipment, computer-aided manufacturing (CAM) systems and computerized tools and strategies for manufacturing management (such as management

information systems (MIS) and computer-aided planning (CAP)). CAD encompasses the use of a microcomputer based interactive graphics system in product design, production analysis and other engineering analysis.

CAM is concerned with the application of programmable automation technologies into the production process. Programmable in this context means that these technologies can easily be switched from one task to another by changing the computerized instructions. The term automation refers to the fact that these technologies perform a significant part of their functions without direct human intervention. They tend to provide flexibility in contrast to special-purpose automated machines because they are reprogrammable. Flexibility means that these technologies are suitable for small, medium and large volume production. Flexibility also allows to incorporate product changes if necessary (see OTA 1984a). Prominent examples of CAM technologies are numerically controlled (NC) machines, computerized numerically controlled (CNC) tools, robots and flexible manufacturing systems which will be briefly described in turn.

Numerically controlled (NC) metal cutting and forming machine tools - developed already in the period 1948-53 under the sponsorship of the US Air Force to help to produce complex parts for aircraft - are devices which cut a piece of metal according to programmed instructions about the desired dimensions of a part and the steps for the machining process. Numerical controls were first offered commercially in 1955. They characteristically consist of a machine tool, which is equipped with motors to guide the cutting process, and a controller which receives numerical control commands (OTA 1984a). This technology effectively achieves a drastic reduction in the setting-up of machine tools which is mainly the result of the ability to program off the machine and the ability to store a suite of tapes or programs from which a number of repeat items or variations of these can easily be made if necessary.

Around 1975 machine tool manufacturers have begun to use microprocessors in the controller of NC machines, i.e. to construct NC tools with integrated computer control (so-called computerized numerically controlled or CNC machines). CNC can be used, like NC, with separate programmers and operators, but allows also the reintegration of operating and programming and facilitates moreover editing and programming on the machine. Both modes of CNC usage can be found in practice. CNC machines are substantially more reliable than ordinary NC machines. Moreover, they offer the operator more complex information about the status of the machining process and provide the ability of linking CNC machine tools with various other machines (see OTA 1984a). NC and CNC machine tools are far more efficient than conventional automation machinery. Of course, their efficiency in actual production work varies, depending on the type of machine and the degree of precision and difficulty of the work assigned to it. As regards the scale of production they are considered to be most efficient for the recurrent production of small and medium-sized batches. The advent of CNC also allowed another development, namely the simultaneously control of

a number of NC machines by a single computer (known as direct numerical control or DNC).

Robots, another example of CAM, may be roughly defined as reprogrammable manipulators designed to move workpieces or tools along various paths for the performance of a variety of tasks. Typically an industrial robot has three main parts: the controller consisting of the hardware and software (involving a microcomputer or microelectronic components) which guides the motion of the robot; the manipulator consisting of a base which is usually bolted to the floor; and the arm itself which can be configured in various ways to move through particular patterns. Robots with point-to-point controls for simple material handling tasks were first introduced commercially in 1959. The first robot with path control capability appeared in 1961. This type of robot was suitable for a number of purposes, such as spray painting, spot welding, arc welding and investment casting (see Ayres 1988).

Among users of robots, the car industry strongly dominates. Other important users include aerospace, electronics, foundries, machinery and miscellaneous light manufacturing (see OECD 1983, OTA 1984a). There is a significant difference between Japan and other countries with respect to the tasks that have been robotised. In Japan robots are concentrated in welding and painting while in the US and in Western Europe their use is spread over a wider range of tasks (including machine (un)loading and material handling) (Watanabe 1986). It is worthwhile to note that in Japan where a high level of automation had been attained already prior to the introduction of robots the labour-saving effects have been much more restricted than elsewhere.

The largest potential use of robots is in labour intensive mass production assembling and inspection of light industrial and consumer goods. But there are still many important technical problems to overcome. It is worthwhile to mention that the next generation of robots will be differentiated from previous generations by its sensory ability and capability to react to changes in the surrounding work environment. In particular visual and tactile sensing is necessary for the application to more complex assembly tasks.

Robots, NC and CNC machine tools with automated parts-handling can be used in a machining cell or so-called flexible manufacturing system (FMS). FMSs, which have evolved particularly, but not exclusively in the metal forming and mechanical engineering industries, are production units which enable to produce a range of discrete products with a minimum of manual intervention. The first attempts to combine NC machine tools with an automated materials-handling system under computer control appeared around 1967. Applications have focused on mid-volume batch production of moderately complex parts of volumes of 2 000 to 50 000 units/year. (Ayres 1988).

In more sophisticated modern flexible manufacturing systems the workpieces are processed at various programmable multipurpose machine tools and other workstations.

They typically consist of production equipment work stations (NC, CNC or other machine tools for fabrication, assembling or treatment) linked by a materials handling system to move parts from one workstation to another. It operates as an integrated system under the central control of a computer which maximizes work flow and minimizes in process queue. These systems may involve in built tool changing, component (un)loading, checks for wear and failure, product testing etc. (Wilson 1987) and allow small quantities of goods to be produced inexpensively and permit rapid change-over to the production of other products.

At the beginning of 1985 there were 46 FMSs in the US, 100 in Japan, 60 in the USSR and 36 in the FRG (see Ayres 1988). The reasons for the scarcity of application include the newness, the high costs and complexity of the systems. The high complexity implies the need for a high degree of technical expertise which manufacturers may not have to date. In addition, there are still serious reliability and versatility problems which need to be solved before a more widespread diffusion might be expected.

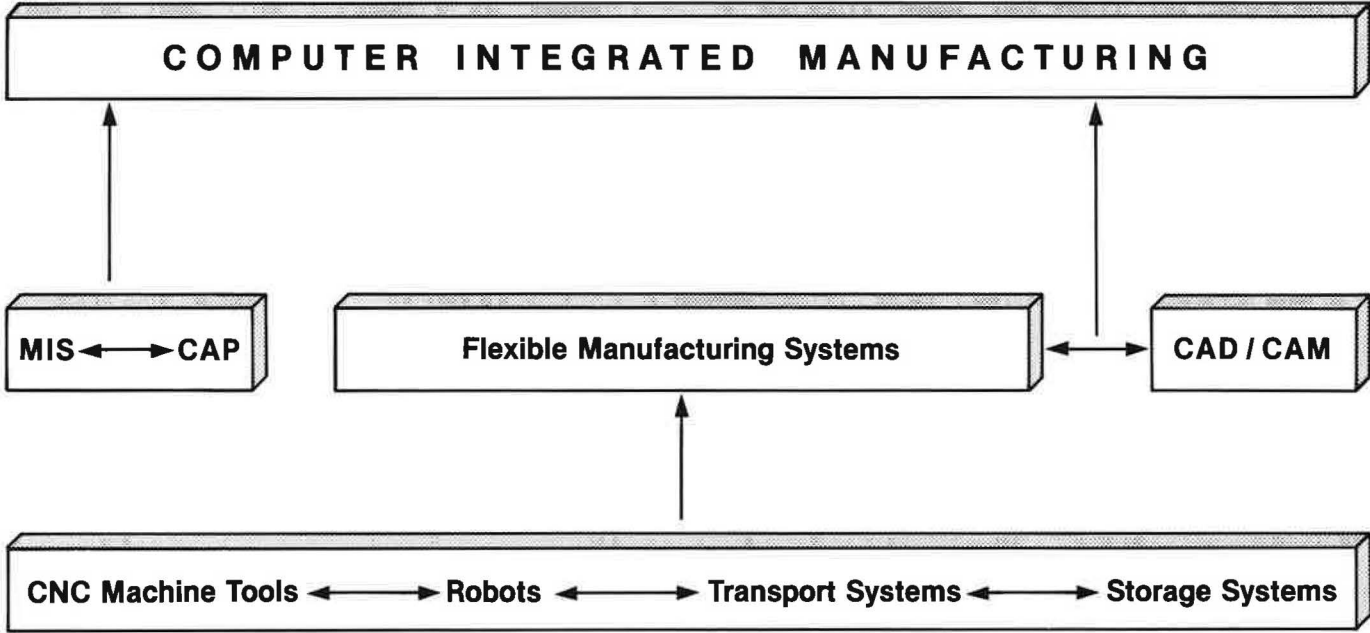
It is worthwhile to note that FMS may be further integrated and controlled by a CAD/CAM system into an overall automated factory which is usually called a computer-integrated manufacturing system (CIM). CIMs are still in an early stage of diffusion and consequently their total employment impact is marginal up to now. A major problem usually involved with linking CAD and CAM is that of incompatibility of different systems. The need for standards in interfaces and program languages is strong and important. Without standards it is extremely difficult to combine equipment of different vendors and to proceed incrementally towards CIM. Typically CIM involves the integration and coordination of design, manufacturing and management using computer-based system (see Vickery et al. 1987). These systems, however, are still in the process of development and there is some uncertainty regarding their final configuration. Figure 1 illustrates the relations between the systems and their components.

There are several other kinds of CAM equipment. For example, programmable process controllers are used quite extensively in both discrete manufacturing and in continuous-process industries (such as oil, chemical, pulp and paper). They are utilized to control a variety of production processes and to collect information about such processes. NC tools may be considered to be specialized forms for controlling a machine tool.

To sum up, programmable automation technologies offer improvements in material handling, fabrication, finishing, assembling, quality assurance and control by applying computerized techniques to control tools of production, to gather and manipulate information about the manufacturing process, and to design and plan the whole process. Moreover they promise an increase in the degree of control over the whole enterprise. Thus, they improve coordination and increase efficiency and flexibility (in terms of both the range of products and volume of a specific product) and increase productivity and control over the manufacturing process (see OTA 1984a). Some of the most significant productivity gains relate to significant energy, materials, capital and labour savings as well as to a more efficient inventory



Figure 1: Relations between Programmable Automation Technologies and Their Components: Horizontal and Vertical Integration



Note: <-> refers to horizontal integration and ↑ to vertical integration

Source: Adapted from Vickery et al. (1987)

control (see Schonberger 1982). Some of the elements under CAM such as NC machine tools have an important, but a more specific sectoral impact; while many of the elements have only an indirect impact on major manufacturing sectors so that it is difficult to follow through and assess the impact of these elements (see OECD 1983).

Each of these technologies is in a relatively early stage of development and in even earlier stages of applications to date. Only NC and CNC machine tools as well as CAD are somewhat more mature, but even in these cases there are still many unsolved problems. But they continue to develop rapidly, at a rate of growth similar to the computer technologies as a whole. These developments tend to focus on five major directions, namely to increase their power in terms of speed, accuracy, reliability and efficiency; to increase their versatility in terms of the range of problems to which the technologies can be applied; to increase the ease of use in the sense that they require less operator time and training, can perform more complex operations and be adapted to new applications more rapidly; to increase what is commonly called the intelligence of the system; and finally to increase the ease of integration into more comprehensive and coordinated devices (see OTA 1984a, 74).

Even if the rate of use of micro-electronics in products and processes has climbed rapidly since the late 1970s (see Northcott and Rogers 1984, Northcott et al. 1985, Northcott 1986) their potential impacts are still a long way from being fully realised. Despite the potential of micro-electronics applications there are several problems which have slowed the rate of diffusion at the firm level. The technical factors tending to slow the rate of adoption include the complexity of the new equipment and problems with software. The non-technical factors affecting the use include the high costs of development and implementation, lack of capital and know-how, organisational resistance to change, problems of standardization and the availability of appropriate education and training programs. A series of comparable surveys of manufacturing industry shows clearly that the set of problems encountered is similar in different countries and moreover that many countries face skill shortages as one of the principal barriers when applying micro-electronics in both products and processes (see Northcott et al. 1985). This is illustrated in Table 1.

The overall impacts of METs have been masked by the uneven patterns of applications which are concentrated in particular countries and industries. There are marked differences in the rates and patterns of application in both products and production processes between different countries and different industries. Some countries such as, the USA, the FRG, Sweden and especially Japan have been clear leaders in both the rate of uptake and in the breadth of product applications, whereas other countries such as the Netherlands and France have trailed significantly. Although potential product applications are widespread, metal working/engineering, electrical/electronics and transportation equipment industries have taken the lead in all the five countries for which detailed information is available (see Table 2). Their products evidently show the greatest potential for applying sensing, processing and transmitting functions in order to enhance performance and extend the range and quality of products.

Table 1: Main Disadvantages and Problems in the Use of Micro-Electronics Based Technologies: Product and Process Users (1983)

(percentages)

Disadvantages and Problems	Product Users			Process Users		
	France	FRG	UK	France	FRG	UK
Lack of people with expertise	58	65	50	51	54	43
Problems with software	10	38	14	11	27	16
High costs of development	30	34	38	24	23	25
General economic situation	26	25	45	23	19	42
Lack of finance for development	18	23	30	19	17	29
Problems with microprocessors/ components	9	19	9	8	16	14
Problems with sensors	9	19	11	15	14	8
Higher production costs	19	17	18	4	14	7
Opposition from shop-floor/unions	16	17	6	9	13	10
Difficulties of communications with subcontractors or suppliers	6	15	9	15	12	15
Opposition in management	1	6	4	2	4	5
Opposition from other groups in firm	3	3	4	2	3	4

Source: Northcott et al. (1985)

Table 2: Use of Micro-Electronics Based Technologies in Selected Countries and Industries (1983)

Percentage of Manufacturing Establishments Using	Metalworking/ Engineering	Electrical/ Electronics	Transportation- Equipment	Print	Chemicals	Food	All Industries
<b>Product Applications</b>							
France	23	28	23	1	1	0	6
FRG	42	42	9	6	7	0	13
Japan (1982)	30	42	10	0	0	0	13
Netherlands	10—30	>30	10—30	n.a.	n.a.	n.a.	5
UK	28	50	14	0	0	0	10
<b>Process Applications</b>							
France	31	33	58	50	43	39	35
FRG	59	54	39	77	52	46	47
Japan (1982)	71	72	73	69	62	44	59
Netherlands	10—30	10—30	10—30	>30	n.a.	10—30	30
UK	45	51	33	62	51	60	43

Source: Vickery et al. (1987)

n.a. not available

Table 2 shows that the use of microelectronics in production processes is much more widespread than in the products themselves. There are also quite clear country-specific differences. Manufacturing establishments in Japan and the FRG use microprocessors and their electronic equivalents as part of process and production equipment more frequently than in the Netherlands and France. Also some industry-specific differences do exist. Printing, transportation equipment, electrical/electronics, metalworking/engineering and chemicals industries are twice as likely to use micro-electronics based process equipment than clothing, some parts of textiles and wood products industries. The use of more advanced programmable automation technologies is restricted to a small set of industries up to now, even if their potential for wider applications is high. For example, industrial robots have been mainly used for material handling, machine (un)loading, spray painting, welding, machining and assembling in general and precision machinery and electrical/electronics industries up to now (see Vickersy et al. 1987)

### **3. General Issues in Measuring Employment Effects**

This section intends to discuss some major types of employment effects (see Figure 2) first and then some methodological problems involved in the task of identifying and measuring such effects.

The overall impact of METs on employment at the macro level may be considered as outcome of direct and indirect, labour displacing and job creating effects. Direct effects may be regarded as the net changes in jobs at the point of introduction of the new technology (Brainard and Fullgrabe 1986). If micro-electronics is introduced to improve production processes, the direct employment effects tend to be negative, and if the technology is used to create improved or new products, additional jobs may be created, especially if the product innovations are radical (i.e. not substituting for established products and services). The direct employment effects are only one aspect of the full impact of METs. The introduction of a new technology in general and a new process innovation in particular and the effect it has on relative costs of production induces several processes which tend to increase the level of employment at the macro level usually after some time lag. These effects are termed indirect labour or compensating effects (see Brainard and Fullgrabe 1986).

There are various indirect effects which tend to offset some, if not all of the direct employment displacement effects (see Stoneman, Blattner and Pastre 1982). The two major types of such effects are technology multiplier effects on the one side and price and income effects on the other. Technology multiplier effects account for the required increase in gross investment to install the new technology. This increase may generate demand and employment (for a period) in supplier industries and the capital goods sector. There may be also implications for intermediate demands in the input-output sense.

Income and price effects act to yield increased profits or wages or a reduction in prices in the case of process innovations, all of which increase real income which can stimulate demand and consequently may lead to more jobs. Product innovations resulting in improved or new

products should lead to better price/quality ratios for goods to the consumer. This may imply increased incomes and higher demand. But there is no guarantee that compensation via increased demand will be realised.

The strength of such indirect effects is of central importance in the impact of METs on employment at the macro level. Strength and the time profile of this type of effects depend inter alia on investment behaviour, success in foreign markets, the characteristics of the new technology, the skill structure of the labour force and especially on the price and wage flexibility which is considered to be a key determinant of whether the impact of the new technology falls on employment or real wages (Stoneman, Blattner and Pastre 1982).

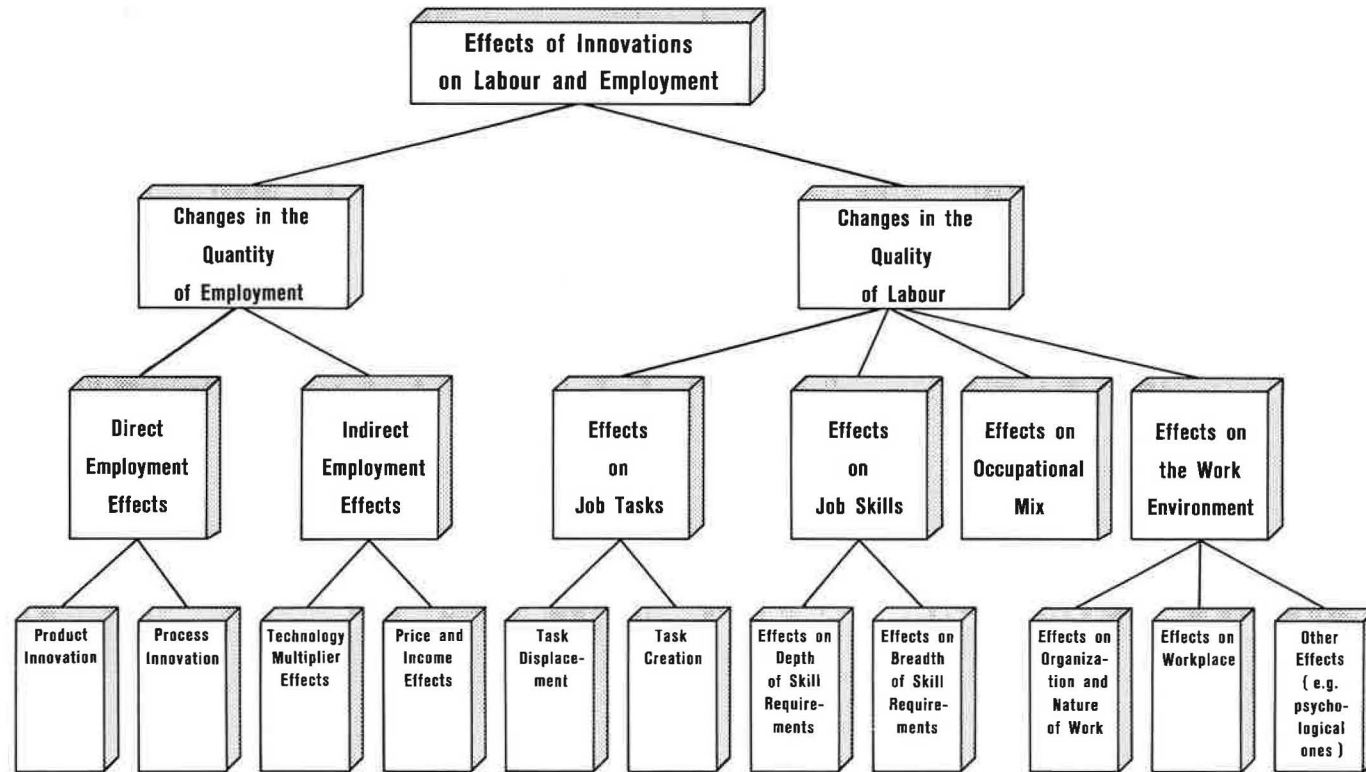
Of course, employment induced by compensating effects need not necessarily to match the labour force released through direct effects in skills, other characteristics and in space. Such mismatches might result in technology induced structural unemployment. Moreover, it is worth mentioning that labour released directly may not come from the innovating firm or sector, but from non-innovators.

The employment impact of METs on any individual country strongly depends on the diffusion speed and pattern of the technologies throughout the economy which themselves are conditioned by several factors such as the industrial structure of the country, the technological position of the economy, the availability of labour skill, social attitudes to technological change etc. Employment effects are also strongly influenced by the overall economic and social environment in which the technologies are being introduced. The employment effects vary from country to country, from industry to industry and from company to company also due to differences in the levels of automation and organisational efficiency attained prior to the introduction of the new technologies, the labour and management practices, the workers' adaptability etc.

Direct and indirect effects are especially conditioned by macro economic conditions. Conditions of slow growth and low demand encourage process innovations and delay possible indirect or compensating effects. This seems to be the case in many countries in Europe to date. In contrast rapid economic growth and high demand stimulate product innovations and increasing capital investment in new technology based machinery which can result in shorter time lags of the indirect or compensating effects.

Moreover, employment impacts have to be considered in relation with the country's role in international economic and trading relations. This international dimension of the relationship between technological change and employment is becoming more and more important nowadays. Countries which are experiencing slower technological change in comparison to other countries might forego some or all of the positive price and income effects while countries leading in innovation may obtain extra employment via expanded exports and internalisation of compensating benefits. Moreover, if such countries import new technology capital goods, the technology multiplier effects will be reduced. All this means that differences in the competitiveness between countries induced by technological change can

Figure 2: The Impact of Innovations on Labour and Employment: A Categorization of Different Effects



lead - via international trade - to the transfer of jobs from non-innovating to technologically leading countries (Brainard and Fullgrabe 1986).

Regardless of whether METs have a positive or negative effect on aggregate employment, they will change certain job tasks, affect job skills required, the occupational mix and the work environment. The scope of such changes - which may be termed changes in the quality of labour in contrast to the changes in employment levels or changes in the quantity of labour - is quite often neither obvious nor immediate because micro-electronics based technologies are often accompanied by significant transformations of manufacturing organisation. The more extensive such transformations, the broader the set of the personnel affected by the introduction of micro-electronics based technologies, and the more difficult it is to attribute employment effects to METs, per se.

The identification and the measurement of both changes in the employment levels and changes in the quality of labour is a complex and difficult task. There are several conceptual and technical problems and difficulties involved in this task. The issues which will be discussed here refer to the problem of isolating employment effects induced by technological change, the choice of an appropriate methodological approach and technical statistical problems.

One of the major analytical problems one faces in analysing the technical change-employment relationship is the problem of isolating employment effects induced by the introduction of METs from effects resulting from all the other changes, taking place at the same time, internal and external to the establishment. A change in employment may be the result of individual factors such as governmental fiscal and monetary policy, world trading conditions, energy prices, exchange rate changes, exogenous shocks and technological change, but may be also affected by the numerous interactions between these factors. As a consequence it is generally agreed that it is not only conceptually difficult, but also infeasible to measure direct and indirect employment effects with great precision.

A second major difficulty is the choice of a methodological approach. In principle there are two major categories of approaches: micro-oriented and macro-oriented ones. Both perspectives have shortcomings. The case study approach relying on the fact that the impact of technological change on employment can be most readily observed at the plant level inherently neglects any compensating effect and is not able to capture the aggregate trends associated with the introduction of a major new technological system. Consequently, the estimates derived generally overstate the negative effects of technological change.

The macro-economic perspective derives employment estimates from models of the interaction among industries based on their requirements for labour and other production inputs and is able to take into account direct and indirect employment effects. But it generally lacks the detailed information provided by the case study approach, even in the case of a disaggregated input-output framework, and is often rather poor in its assessment of new



technologies. Traditional neo-classical compensation model approaches generally identify only the effects of changes induced by process innovations within a broadly static framework with demand and substitution elasticities. The introduction of new products and services is by and large ignored in most partial or general equilibrium approaches (see Freeman and Soete 1985). Evidently, there is a need to integrate micro- and macro-approaches on the one side and to explicitly incorporate the essentially dynamic nature of the relationship between technological change and employment on the other.

Finally, there are significant technical problems of quantifying employment effects of METs because of inadequacies in industrial and occupational statistics. The current national and international classification schemes have been only poorly adjusted to reflect the recent changes in production technologies, products and services even if considerable efforts are being made to devise and collect new statistics in some countries such as France and Japan and at the international level by the OECD Information, Computer and Communications Policy Group.

The reliability of inferences about quantitative effects on national economies and industries is, thus, limited because of the scarcity of good data describing shifts in skill requirements, types of jobs or the structure of manufacturing and especially service industries producing and using METs. One consequence of this lag in satisfactory classification and measurement in most countries is that the impact of METs is quite often underestimated, especially with respect to changes in the quality of labour.

In spite of these problems and difficulties there is a large and increasing number of studies in several countries which have attempted to assess and to forecast the impacts of METS on employment and labour. It is the purpose of the next two sections to summarize and integrate some of the major findings. In section 4 attention is being paid to employment effects on aggregate and sectoral employment while section 5 considers changes in the quality of labour due to the introduction of METs. Stress is laid here upon the identification of trends and direction of likely changes rather than their magnitudes.

#### **4. Changes in the Level of Employment: Aggregate and Sectoral View**

In view of the large body of literature dealing with the relationship between micro-electronics based technologies and employment at the aggregate or at the sectoral level it would be not practical to refer to all the individual studies which have been studied in detail. Instead a general overview of their conclusions will be presented.

All the studies show more or less severe methodological deficiencies. Most ignore the productivity effects on inputs other than labour. Only few take explicitly the international dimensions of the technological change-employment relationship into account. Relatively little attention is given to the factors influencing the speed and pattern of applications of

METs. The overall impact on employment in any particular country, however, crucially depends on the domestic rate of diffusion of the METs. The faster they diffuse, the more rapidly the potential productivity gains will be realised. The slower the new technologies diffuse relative to other countries, the more likely it is that other countries will gain a permanent advantage via the indirect employment effects.

Most studies devote a great deal of effort to identifying the direct effects, especially the negative implications induced by process innovations. There have been only few attempts to assess the importance of compensating effects. Especially price and income effects are rarely taken into consideration. Some of the few exceptions can be found in an OECD Information Computer Communications Policy report (1981) on the issue of micro-electronics, productivity and employment. These studies attempt to simulate the possible employment effects using different macro-economic approaches to assess the implication of an acceleration in the pace of technical change where various feedback mechanisms are taken into account. The authors *inter alia* conclude that faster diffusion of METs has greater negative direct effects, but also greater positive effects on employment as it would be the case if the METs would diffuse more slowly. Usually, however, positive direct and indirect employment effects are strongly underestimated or even neglected. These shortcomings certainly do not arise primarily from a lack of understanding the factors and the dynamic nature of the technological change-employment relationship, but are associated with the methodological and statistical problems already discussed in section 3 (see also Brainard and Fullgrabe 1987).

Most studies have a relatively narrow focus, dealing with the effects of specific new technologies (such as, for example, robotics) and/or considering specific sectors (such as, for example, engineering). The few studies addressing the issue of current employment effects at the macro level tend to agree that employment and unemployment levels in recent years were not significantly influenced by technological change (see, for example, the OECD (1982) report of the effects of micro-electronics, robotics and jobs based on studies from thirteen countries). Up to now, there is no strong evidence to support the fear of widespread unemployment caused by METs even if there is a weak indication that METs may have a labour saving bias (i.e. a slight tendency to increase the capital/labour ratio *ceteris paribus*). Shifts in demand patterns, international competition and economic growth patterns were much more important. A comprehensive OECD review of recent evidence on the impacts of technological change - carried out by Brainard and Fullgrabe (1986) - suggests that the increase in jobs seems to have exceeded losses induced by the introduction of METs, mainly due to job growth in business, financial and communications services and to a much lesser extent in high technology industries.

Perhaps more important than the impact in the current period is the potential significance for future patterns. The effect of new technologies on future employment levels is extremely difficult to forecast with confidence because such assessments have to be based upon assumptions on several key factors, such as the rate of diffusion of the technologies, the size

and distribution of productivity gains and general economic trends. Nevertheless, there is a wide range of forecasts of future employment effects in several countries. These studies often differ in their forecasts due to several reasons, including the use of different methodologies, different theoretical assumptions, differences in the structure of national economies and in the characteristics of the labour forces, differing extents of use and rates of diffusion of the new technologies (see Brainard and Fullgrabe 1986). Despite of all these differences they can be broadly grouped into three types.

The first type of studies forecast a more or less significant net growth in aggregate employment and assume that any possible loss in direct employment will be more than offset by compensating employment effects in the long run. Only rather few studies take on this optimistic view. Wilson and Whitley's (1982) UK study, for example, belongs to this category. This study finds the possibility of a large net gain in employment from greater applications of micro-electronics based technologies. The results indicate that productivity could be raised by 0.5 per cent per year (over the trend growth rate) during the period of 1985-1990 through increased use of these new technologies. Job loss due to direct employment effects will be significantly offset by the strong compensating effects.

The second type of studies, on the contrary, argues that the macro impact of micro-electronics applications on employment is bound to be negative, at least in the short and medium term periods. This pessimism derives from the labour saving nature of much MET when applied to production processes, coupled with its pervasiveness and the limited prospects for the generation of new products in general and in particular from considerations, such as the possibility of jobless growth; the widespread applicability of METs, especially in the service sector where compensation effects may not be strong enough to balance direct job losses; and a change from the present pattern of step-wise introduction of new technologies to the introduction of large integrated technology systems which may have a great labour saving potential that may not be compensated by job creation from increased demand. A recent ILO study carried out by Kaplinsky (1987) on the likely future employment impacts of micro-electronic applications predicts that radical shifts will be most likely anticipated if wide micro-electronics based changes will occur.

These pessimistic studies tend to overestimate the labour saving effect of METs due to several reasons. First, they ignore the possibility of different modes of application by smaller firms and underutilization of the new machinery installed. Second, the fact that the very flexibility of METs tends to augment the average amount of work incorporated in each unit of final output, *inter alia* by encouraging product differentiation and more frequent model changes (the so-called amplifying effect), is neglected (see Watanabe 1986). Third, they are strongly concentrated on process innovations. Finally, they fail to take product innovations and the many compensating effects into account. All this means that they tend to overstate the early negative impacts on aggregate employment and to understate the later positive effects.

The third type of studies finds that job gains and losses are and will be approximately equal in number (i.e. that the employment impact is neutral). The actual and the likely future effects

of the new technologies on the levels of employment are likely to be minor , especially in comparison with the effects of factors such as fluctuation in macroeconomic demand and growth. This point of view is supported by an increasing number of recent studies from different countries (see, for example, OTA 1984, Brainard and Fullgrabe 1986). These studies emphasize that the major impacts are reflected less in increases or decreases in levels of total employment rather than in the distribution of labour in terms of sectors of employment, occupations, skill and regions.

Technological change has quite different employment effects in different economic sectors and industries. There seems to be a general consensus of opinion that the introduction of METs has contributed to the overall decline in manufacturing employment in most countries , but the magnitude of the impact was relatively small in comparison with the total losses of jobs in the sector. A recent study by Northcott et al. (1985) based on a series of plant level surveys and weighted to a national basis provides a good overview of the current state as far as the application of METs in both products and processes in the manufacturing industries of France, the FRG and the UK during 1981-83 is concerned. Applications in products were generally associated with increases in jobs or small decreases while larger declines were generally associated with applications in production processes over the two-year period. The overall assessment for users of METs is summarized in Table 3. It should be noted that these estimates do not include indirect effects, particularly those of non-users which may result from a failure to remain competitive. Moreover, they do not include the impact of MET on office employment within manufacturing. The term MET is restricted to the use of micro-electronics in products and its applications for the direct control of the manufacturing process and materials handling.

Even if the figures are subject to such uncertainties and limitations they give a good indication of the broad orders of magnitude, better in any case than any other figures presently available. It is important to note that the net losses were rather small in comparison with the total reductions in manufacturing in each country. Moreover, much of the loss appears to have been absorbed in natural wastage. In the British case the total figure of actual redundancies due to the use of micro-electronics amounts to only 34 000 (equivalent to about 5 per cent of the total decrease in employment in manufacturing and to about 0.6 per cent of total employment in manufacturing at the time of the survey). About half of them are suggested to have been involuntary redundancies.

Table 3: Changes in Manufacturing Employment due to Use of Micro-Electronics Based Technologies in Selected Countries (1981 — 1983)

Country	Gross Decrease (in thousands)	Gross Increase (in thousands)	Net Change (in thousands)
France	—25	13	—12
FRG	—47	17	—30
UK	—54	20	—34

Source: Northcott et al. (1985)

A more recent plant-level survey of manufacturing establishments in the UK for the period of 1983-85 undertaken by Northcott (1986) shows an accelerating loss of manufacturing jobs with the increasing application of METs. The net losses amount to 87 000 (about 2.7 per cent of total UK unemployment) for this more recent time period in comparison with 34 000 during 1981-83. Most of the increase in job losses are attributed to the greater use of more sophisticated CAM systems.

These and similar case studies indicate that job losses are expected to increase substantially as companies introduce more sophisticated METs into production processes. Currently the full impact on employment is being eased temporarily, because the displaced workers are often assigned to other jobs in the firm. This mode of adjustment, however, diminishes prospects for hiring new employees in future (see Brainard and Fullgrabe 1986). But it is not likely that technological change will generate significant unemployment in the near future. It may, however, exacerbate regional unemployment problems, especially in regional economies where metal working industries with mature and declining products are concentrated.

Of course, the introduction of METs has quite different employment effects in different manufacturing industries. Some have been more affected than others. The principal users of METs have been firms in the metal working industries, especially in car industries, electrical and non-electrical machinery. The effects in the watch industry are well known. But also other industries such as printing have begun to be significantly adversely affected. Also firm size may influence the incidence of employment effects. To date large firms dominate as users (see, for example, Northcott and Rogers 1984).

Finally, the service sector deserves some brief notice. Estimates of the impact of METs (such as office automation, advanced telecommunications, automated transactions, expert systems) on employment are not so readily available. Up to now, only little attention has been paid to the relationship between technological change and employment in the service sector, partly because of the more difficult conceptual and statistical problems in pursuing studies in this area, in comparison to manufacturing industries (see Gleave 1986). Nevertheless it is quite clear that the effects strongly depend on the nature of METs, on institutional and regulatory conditions and also on the labour management methods. The impact of technological change on service employment has been most obvious and strongly positive in producer services (such as financial services, computer services etc.). Employment growth in these services is primarily attributed to high levels of capital investment in information technology which enabled to improve the quality of services to customers, and most recently to develop wholly new types of services as part of the intensifying competition and diversification. The net impact of new technologies on employment in public and distributive services are much more ambiguous, but seems to have been rather small while other factors dominating the trends in job growth (Brainard and Fullgrabe 1986).

In so far as likely future impacts in the service sector are concerned there is considerable variation in the predictions. Some argue that increasing automation in the service sector will change the trend of employment growth, making the sector a net loser of jobs. Others like Brainard and Fullgrabe (1986) expect that a more extensive application of new technologies is likely to create more jobs in services. Barras (1987) argues in a more differentiated way. He predicts that in the short term (0-5 year horizon) the predominant effect of further investment in information technology may be labour displacing because the major impact of the investment is likely to be manifested in terms of further process innovations in existing services, while in the medium term (5-10 year horizon) employment generating effects might predominate.

## **5. Changes in the Quality of Labour**

Regardless of whether the micro-electronics based technologies are essentially neutral or not in their impact on employment levels they will affect job tasks, job skills and the work environment (compare Figure 2). This section attempts to discuss the likely impact of the introduction of new technologies in this respect and basically draws on case studies in manufacturing industries and in particular on the OTA (1984a) study on programmable automation in the USA.

The introduction of METs alters the tasks to be done in manufacturing. It eliminates tasks and ultimately jobs and/or creates tasks and consequently jobs. Programmable automation technologies perform tasks - such as, for example, welding, materials handling and assembling - previously done by production and related workers. In particular, FMSs and CIMs show a great potential for displacing labour, greater than stand-alone MET applications. Because these systems are still in a rather early stage of development, significant labour displacement by such systems is unlikely to occur in the near future. On the other hand, new tasks and, thus, jobs may be created, especially in the maintenance of the automated equipment, but also in the design of products stimulated by the introduction of CAD systems and computer-aided engineering applications of CAD.

Micro-electronics based technologies affect also the job skills required in manufacturing. The issue of how technological change affects the skill of those who operate the new technologies has received increasing attention in recent years (see, for example, Attawell 1987, Zicklin 1987). Much of this research draws its inspiration from Braverman's (1974) view on the radical deskilling of machinists who operate NC machines. Empirical research about the effects of NC machines on the skills of machinists, however, is rather ambiguous. Some authors suggest that a radical deskilling of machinists has been taking place. Others claim that the operation of NC machines requires more skills than that of conventional machines. Still others report that only the types of skills may be different (see Zicklin 1987). In general programmable automation technologies give rise to a greater need for conceptual

skills (e.g., diagnosis, problem solving and programming) and a lesser need for motor and routine mental skills (e.g. machining).

The OTA (1984a) study on programmable automation in the USA argues that METs will alter both the depth and breadth of skill requirements. Skill depth refers to the input necessary to perform an individual task or a cluster of interrelated tasks. Skill breadth refers to the input necessary to perform a set of (non similar) tasks and, thus, more to jobs or occupations than to single tasks. Skill depth shows two dimensions, namely time to proficiency and judgement. Jobs consisting of tasks requiring little or no time to master and limited judgment tend to be low skilled jobs which have a broad access and a relatively low pay. It is argued that programmable automation technologies tend to lower skill depth in both dimensions for many tasks, including those performed by professionals and craftworkers. The potential effects on skill breadth are less evident than effects on skill depth. In some cases the introduction of automation, especially of more sophisticated technologies, may require a less intimate knowledge of a single process or task, but a broader familiarity with production activities and their interconnections.

New technologies do not only alter skill requirements, but also occupations and their distribution. The overall pattern of change in occupational mix which is expected to arise may be characterized by the following broad trends (OTA 1984a, 144-148):

- \* in all sectors, a decreasing proportion of lower managerial and supervisory occupations, with remaining personnel more restricted to prepare and transmit information to upper management,
- \* in manufacturing, a large decline in the proportion of production and related workers engaged in low skill and routine activities, such as materials handling and assembling, but also inspection and quality control,
- \* in manufacturing, an increasing proportion of occupations installing, operating and repairing automated equipment and providing related support,
- \* in manufacturing, some deskilling of tasks in some craft occupations (for example fitting and toolmaking) due to transfer of prior operator functions to machines and
- \* in services, a decreasing proportion of more routine information handling occupations, such as low skilled clerical.

These broad trends identified in several studies will reinforce the long term shift from blue-collar to white collar employment as well as the growth in professional, technical and higher management occupations.

Research on the social impacts of METs on the (manufacturing) work environment is modest in scope and support. This issue seems to be more common only in those countries with a stronger tradition in labour unions. The new technologies may affect the work environment (the organization of work, the nature of work, the workplace) of most manufacturing

personnel. To date, however, it is certainly too early to predict how these technologies will affect the work environment. Nevertheless there seems to be a general agreement in the literature that there is nothing inherent in micro-electronics based technologies to impose a particular form of work organisation. Thus, it might be expected that they will be adapted to traditional structures of work organisation in the short term. Major changes will arise only in the longer term because of two major reasons. First, micro-electronics based technologies (except NC and CNC machines) are still in a relatively early stage of development and in even earlier stages of applications. Second, managers seem to lack up to now the necessary background to assess the technological options on the other (see OTA 1984a, 204 pp.). The effects on the work environment will be primarily determined by the management's motivation for the introduction of METs and by the labour-management relations. Cooperation between employers and workers in union or non-union settings to determine the design and implementation as well as the pace of change might be a useful approach to minimize potential negative effects such as, for example, automation related stress and boredom.

#### **6. Some Concluding Comments**

It is unlikely that the impact of micro-electronics based technologies will be revolutionary in nature. The impact will be certainly more likely evolutionary. To some degree the extent of gains and losses in employment will depend on the rate at which the new technologies diffuse. For some industries, in particular those facing strong international competition (such as engineering), a fast introduction of new technologies may be beneficial in terms of output and employment. A failure to adopt in these cases will result in greater job losses even in the medium term through lack of international technical change competitiveness. In other cases, for example, in office-based services and banking, a very fast rate of new technology introduction may be to the detriment of employment in the absence of product innovations.

Up to now and most likely also in future the major impact of micro-electronics based technologies is reflected less in decreases or increases in levels of aggregate employment than in changes in the occupational structure and in skill requirements of the labour force. The increasing adoption of micro-electronics devices is likely to increase the mismatch between skills and job opportunities and may lead to severe adjustment problems of technical change, in particular in the absence of comprehensive retraining schemes. Labour training and retraining policies are, thus, of central importance. The efforts undertaken by private firms have to be complemented by public programs in order to minimise the adjustment problems of structural change, especially for young people. The major concern of training and education policies should focus on the adaptability and flexibility of the labour force. For flexibility will be a key feature to retraining especially if one can not predict the future development in the skill composition of labour demand with great precision (see OECD 1987, 81). But it would be a mistake to assume that training and retraining policies alone would be able to solve the present and especially the upcoming labour market adjustment problems.



Governments have also an important role to play to manage technological change and its impact on employment by policy decisions taken at a macro level, for example, in setting the general economic conditions which may stimulate the development of MET applications and investments in them, in identifying market failures in the supply of information, finance and technical expertise as well as in developing and maintaining the supporting infrastructure. Soete and Freeman (1985) claim for a greater emphasis on diffusion of the new technologies as well as on the further development of key technologies. They identify three major sets of technology policies which seem to be particularly relevant to affect the rate of technological change:

- \* policies aiming at stimulating directly firms to take up radical inventions/innovations,
- \* policies aiming at promoting widespread diffusion of successful new technologies and lowering the institutional barriers and
- \* promotion of international transfer of new technologies.

These policies ranging from direct financial support to various forms of indirect risk-taking support to promote the emergence of radical innovations seem to be important to stimulate productivity growth based upon technical change, especially in times of recessions when private firms tend to hesitate to invest in radical, but risky innovations.

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