INNOVATION AND REQUIREMENTS FOR HUMAN RESOURCES

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PREFACE

No study of technological innovation can be complete without an investigation of its impacts on human resources. Innovation does not always have a positive effect on human resources, as there are many imbalances between technological innovations and the requirements for such resources. However, without technological innovation it would be nearly impossible, in the long term, to improve working conditions and create opportunities for the development and realization of man's social, cultural, and economic capabilities. Thus the relationship between technological and social innovation is critical to the development of human resources.

The present situation with regard to technological and social innovation has arisen from:

1. the growing imbalances between natural and human resources in different regions of the world;
2. the inability of social institutions, using technological strategies, to make better use of human resources, especially in the developing countries;
3. the inability to coordinate socially the innovation cycle of basic innovations in order to make better use of human resources; and
4. the need to improve the quality of human resources and to create suitable conditions for their better use.

This report focuses on problems associated with the last two points.

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SUMMARY

The development and use of human resources are key elements in the relationship between technological and social innovation. Indeed, no study of technological innovation can be complete without an investigation of its impact on human resources. Innovation does not always have a beneficial effect on the development of human resources and their social, cultural, and productive aspects, as there are many imbalances between technological innovations and the quantitative and qualitative requirements for human resources.

The different phases of the innovation process vary widely in their influence on the quantitative and qualitative demand for labor. The authors examine the effects of investment on innovation and show that an important feature is the relationship between expansionary and rationalization investments because of its effect on employment. It is demonstrated that basic innovations lead to a high demand for human labor, while improvement-oriented innovations normally result in labor releases. The authors show the recent labor-releasing and labor-absorbing effects of innovation in the printing, automobile, and microelectronics industries of the Federal Republic of Germany.

In formulating innovation policy, more emphasis should be placed on upgrading the qualifications of the labor force. This has played an important part in the rapid socio-economic progress of the German Democratic Republic. An economic policy that utilizes higher labor qualification levels could reduce the consumption of raw materials and energy in production.

Structural and technological changes tend to lead to a polarization of job functions and job requirements, usually with a growth of requirements for higher skills and greater knowledge, but sometimes with a growing demand at the lower qualification levels. This report stresses the need to formulate economic and innovation policies so as to overcome the difficulties associated with such adjustments.

INTRODUCTION

The Industrial Revolution of the eighteenth and nineteenth centuries made the production of many commodities economically feasible. Before this time, goods had been produced by workers with long and comprehensive professional training. During the Industrial Revolution skilled labor was gradually replaced by unskilled labor as production processes were separated into simpler elements. The revolution was made possible by such basic innovations as the machine tool and the steam engine. Its main social impact was the reshaping of human resources, which, while allowing the rapid growth of capital and profit, had disastrous long-term effects on the living conditions of the workers.

If we examine the current trends in innovation, such as the spread of microelectronics, biotechnology, and new energy options, it becomes clear that we are about to experience a new "innovation push," which could have catastrophic results for mankind, similar to those of the earlier Industrial Revolution, if it is not accompanied by the necessary social innovations. The traditional division of labor in industry is being undermined by recent innovations in microelectronics, flexible automation, and communications, which tend to eliminate the need for simple, unskilled labor. At the same time, a lack of social innovation is preventing improvement in the quality of human resources and their use for meeting social needs. Thus, innovation and the better use of human resources have become a crucial issue.

1 INNOVATION, EMPLOYMENT, AND PRODUCTIVITY

The influence of innovation on the quantitative and qualitative requirements in the labor force was studied in the past in terms of the relationship between automation and human resources. In most cases the results were biased and controversial. Many studies attempted to prove that technological innovations trigger off disqualification and unemployment. One reason for the controversial results is the often poor understanding of the innovation process, as some studies neglected to differentiate between the effects of automation, structural and organizational changes, and innovation cycles.

The authors believe this is why current economic theory has failed to explain satisfactorily the relationship between innovation and the quantitative and qualitative requirements in the labor force. For a better understanding of this relationship, innovation and efficiency need to be explored further.

1.1 Dynamic Efficiency and Relative Efficiency

It is useful to distinguish between dynamic efficiency $e(t)$, the efficiency at time t of the production unit that has adopted a particular innovation, and average efficiency $\tilde{e}(t)$, the efficiency of the entire production system at time t. Relative efficiency is the ratio of the dynamic to the average efficiency: $x(t) = e(t)/\tilde{e}(t)$. This coefficient enables us to understand better how the economic performance of a company, industry, or country is developing. When $x > 1$, economic performance is improving and the influence of efficiency-producing factors on the growth of production is increasing. This situation offers a wide range of opportunities for the creation of new work places. Because production is expanding, more workers will be hired than are released. When $x < 1$, the influence of efficiency-producing factors on the growth of production is diminishing. The result is a slowdown of economic activities and elimination of work places.

1.2 The Innovation Cycle

Unfortunately, we do not yet have appropriate instruments for accurately measuring the development of the relative efficiency of innovation, but we can examine more carefully the phases through which dynamic efficiency moves during the five phases of the innovation cycle: takeoff, rapid growth, maturation, saturation, and crisis (Haustein *et al.* 1981).

Changes in management during this time also follow a pattern, a major variable being the requirements in the quality and quantity of the labor force.

The *takeoff* phase is characterized by:

- a very high demand for experts and craftsmen;
- standard production equipment.

The *rapid growth* phase is marked by:

- a high demand for experts and a growing demand for skilled and semiskilled workers;
- a preponderance of basic product innovations;
- standard production equipment, with efforts being made to develop unified, partly automated production lines;
- domination of expansionary investment;
- growth in the market share.

During the *maturation* phase,

- the production process becomes increasingly unified;
- improvements involving innovations become more and more important;
- there is greater investment in specific production equipment with the aim of achieving a high degree of mechanization and automation.

In the *saturation* phase,

- production approaches saturation;
- incremental innovations aimed at cost reduction gain in importance;
- the production process becomes more and more capital-intensive;
- means of production tend to become fully or partly automated;
- labor productivity grows, or at least stabilizes, this being linked with the elimination of work places.

1.3 Types of Innovation

To understand the development of the relative efficiency of the production unit, it is very important to distinguish between basic, improvement-oriented, and pseudo-innovations (Haustein *et al.* 1981). Basic innovations create a new potential for efficiency and open up new fields and directions for economic activities. The main function of improvement-oriented innovations is to absorb the new potential, thereby balancing and improving the system. Most such innovations are incremental. An improvement-oriented innovation becomes a pseudo-innovation when it is unable to achieve an efficiency level in the production unit that is higher than the average efficiency of the whole system.

At the level of the production unit, the usual practice is to distinguish between major product, major process, and incremental innovations. In the first two phases of the innovation cycle, major product innovations dominate. However, in the third phase, major process innovations become increasingly important; these are linked to other, medium-sized and small improvement-oriented innovations in processes and incremental innovations in products. Phase four is characterized by incremental and pseudo-innovations in both products and processes.

However, at both the macro- and microeconomic levels, it can be difficult to distinguish between product and process innovations, because what is a product for one firm may be processing equipment or a component for assembly for another firm. Thus at the macroeconomic level the distinction between basic, improvement-oriented, and pseudo-innovations is far more clear than the distinction between product and process innovations.

1.4 The Influence of Different Types of Innovation on Employment

Table 1 shows the influence of basic, improvement-oriented, and pseudo-innovations on the creation and elimination of work places. The data were obtained in an empirical study of about nine hundred firms in the plastics, wood and furniture, food, and metalworking industries of the Federal Republic of Germany between 1970 and 1973 (Dostal *et al.* 1977). The results confirm that the effect on employment due to technological changes that are related to the implementation and diffusion of basic and major improvement-oriented innovations is significantly large and positive. On the other hand, medium-sized improvement-oriented innovations and incremental innovations are closely linked with the release of the work force. There is also a short-term reaction, involving a dwindling of orders and a general slowdown of economic activities, as a result of small incremental innovations and pseudo-innovations, which are unable to create new work places or protect existing ones.

Table 1 demonstrates that about 79% of the new work places created in the four industries resulted from basic innovations and major improvement-oriented innovations. Only 19.3% of the new work places are connected with medium-sized improvement-oriented and incremental innovations and 1.6% result from small incremental innovations and pseudo-innovations.

On the other side, of all eliminated work places the fraction due to basic innovations and major improvement-oriented innovations was only 18.4%, whereas 65.4% of the eliminated work places were the result of medium-sized improvement-oriented innovations and incremental innovations and 16.2% the result of small incremental innovations and pseudo-innovations.

1.4.1 Employment Effect

According to Table 1, in the four industries of the Federal Republic of Germany that were investigated, altogether 3.1 times more work places were created than existing

TABLE 1 The effects of innovative technological change on employment in the Federal Republic of Germany. Source: Dostal *et al.* (1977).

Reason for technological change	Number of work places (percentage of total)		Change in number of work places (percentage of total)	Employment effect	Relative release of workers due to higher labor productivity	Contribution to labor productivity growth from technological change (%)
	Created	Lost				
1. *Basic and major improvement-oriented innovations*						
(a) Extension of capacity	42,872(61.5)	3,411(15.1)	+39,461(+83.7)	12.6	34,638	29.6
(b) Manufacture of new products	9,736(14.0)	307(1.4)	+9,429(+20.0)	31.7	2,742	2.4
(c) Improvement of quality of products	2,566(3.6)	437(1.9)	+2,129(+4.5)	5.9	7,997	6.8
Sum	55,174(79.1)	4,155(18.4)	+51,019(+108.2)	13.3	45,377	38.8
2. *Minor improvement-oriented and major incremental innovations*						
(a) Cost reduction	6,602(9.5)	9,422(41.6)	–2,820(–6.0)	0.7	58,296	49.8
(b) Replacement of production equipment	58(0.1)	422(1.9)	–364(–0.8)	0.14	2,514	2.2
(c) Improvement of efficiency	763(1.1)	2,330(10.3)	–1,567(–3.3)	0.33	1,018	0.9
(d) Reduction of shortage of labor	804(1.2)	1,291(5.7)	–487(–1.0)	0.62	1,419	1.2
(e) Reduction of shortage of space	5,019(7.2)	1,303(5.7)	+3,716(+7.9)	3.9	4,848	4.1
(f) Improvement of working conditions	212(0.3)	48(0.2)	+164(+0.4)	4.4	1,885	1.6
Sum	13,458(19.3)	14,816(65.4)	–1,358(–2.9)	0.91	69,980	59.8
3. *Minor incremental innovations and pseudo-innovations (shortage of orders, overall slowdown of business activities)*						
	1,125(1.6)	3,660(16.2)	–2,535(–5.4)	0.31	1,620	1.4
Total	69,757	22,631	+47,126	3.1	116,977	100.0

places eliminated because of technological change. This ratio of the number of jobs created to those lost through innovation is called the employment effect. The highest employment effect resulted from basic innovations and major improvement-oriented innovations: extension of capacity created 12.6 times more work places than it eliminated, the manufacture of new products 31.7 times more, and improvement of product quality 5.9 times more. What is interesting, and in many respects important, is that some improvement-oriented and incremental innovations also have a significant employment effect: improvement of working conditions led to an employment effect of 4.4, and overcoming shortage of space produced an employment effect of 3.9.

The highest labor release was caused by improvement-oriented and incremental innovations that were intended, for example, to replace production equipment (employment effect 0.14), to increase efficiency (0.33), to overcome the shortage of labor (0.62), and to reduce costs (0.7). However, maybe one of the most interesting results of this empirical study is that the greatest release effect, 0.31, occurred through short-term reactions to shortage of orders and slowdown of business activities.

1.4.2 Labor Productivity

The types of technological change involved in basic innovations and major improvement-oriented innovations not only have a positive employment effect but also contribute significantly to growth in labor productivity. Table 1 demonstrates that such changes contributed 38.8% to the entire growth of labor productivity. (In all four industrial branches the annual growth in labor productivity due to technological change was 3.7%.) It is especially interesting that extension of capacity was the overwhelming contributing factor (29.6%), since this activity is characteristic of the second and third phases of the innovation cycle (rapid growth and maturation). Activities in the first phase (takeoff) and in the beginning of the second phase contributed much less to labor productivity growth. The manufacture of new products, an activity of the takeoff phase, contributed only 2.4%, and activities in the rapid growth phase to improve the quality of the products could only contribute 6.8%.

Possibly one of the most important results of our investigation is that the highest contribution to growth of productivity is made by technological changes connected with improvement-oriented and incremental innovations – these are activities of the final, maturation and saturation phases of the innovation cycle. Their contribution to labor productivity growth based on technological change was 59.8%, most of this contribution (83%) resulting from innovations in cost reduction. Short-term activities to improve efficiency or to overcome labor shortages were not so successful, their contributions being 0.9% and 1.2%, respectively. Similarly, short-term reactions to shortage of orders and slowdown of business due to incremental innovations and pseudo-innovations could only contribute 1.4% to labor productivity growth.

1.4.3 Discussion

The figures for improvement-oriented and incremental innovations support our hypothesis that the low employment effect is not so much the result of the development of labor productivity, which is what some economics textbooks claim, but rather the result of incremental innovations themselves, since their contributions to labor productivity growth are low as well (parts 2(b, c, d) of Table 1). Alternatively, the low employment effect can be explained as the result of absorption of efficiency and employment potential that was created through basic innovation. This is an important confirmation of our innovation model.

We can draw from our model, and from the empirical results in Table 1, two conclusions of importance for national innovation policy and cooperative strategy. First, to secure the better use of human resources we need efforts to coordinate the innovation cycle. If the main industries are approaching the saturation phase, there will necessarily be a delay between the release of labor and the creation of new work places. This is without doubt one reason for the employment problem in some developed market countries. In contrast, the European socialist countries are currently faced with the problem of releasing manpower through improvement-oriented and rationalization innovations as a necessary step toward innovation in the energy, microelectronics, and machine tool industries. However, coordination of the innovation cycle calls for planning and coordination of its economic conditions and effects. In this way national innovation policy is becoming more and more combined with structural change and employment policy.

The second conclusion is that it is pointless to maintain a high share of skilled and experienced workers when production is shifting from the maturation to the saturation phase. It is much better to employ these people in the preparation of new innovations, otherwise society will waste the most important resource: the creativity of man. (The issue of the place of creativity in society and its importance to innovation and production has been discussed by Haustein (1981).) Therefore, it is important to establish initiatives for moving particular kinds of skilled workers from one phase of the innovation cycle to another and for creating more flexible organizational patterns that will facilitate this mobility.

1.5 Innovation and Investment

In several studies and statements we can find a very one-sided interpretation of the relationship between investment and labor demand. People usually assume that employment is just a function of investment: "If we have enough investment we will have enough work places." The recommendation for government policy is consequently to create conditions for higher returns on investment, but the returns are very much dependent on the efficiency potential of the innovation that is covered by the investment. Moreover, we must differentiate between two groups of innovations:

- Innovations that are driven by investment: these are generally improvement-oriented and incremental innovations, which have a negative effect on employment and are, in the authors' opinion, related to rationalization and replacement investments, though it is hard to prove this decisively.
- Innovations that drive investment: these are basic innovations that open up new fields of economic activity and create opportunities for expansionary investment, with potential for raised productivity through increased efficiency.

In reality the relationship between innovation and investment is more complicated than we at first assumed. Empirical data from the investigation of the four previously mentioned branches of industry in the Federal Republic of Germany during 1970–73 show

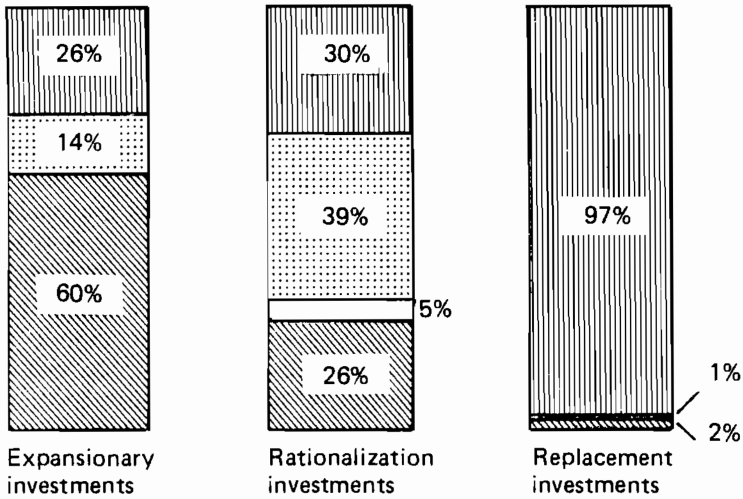

FIGURE 1 The effects of different types of investment. Diagonal shading: expansion combined with innovation; dotted shading: rationalization, savings in materials, personnel, and other costs, combined with some innovation (e.g. introducing electronic data processing); vertical shading: replacement of old equipment; 5% of rationalization investments result in shutdown of departments and production facilities. Source: Dostal *et al.* (1977), with authors' additional computation.

TABLE 2 Distribution, in the Federal Republic of Germany, of highly innovative and less innovative technological changes according to the amount invested. The total investment considered was DM 1,500–2,000 million. Source: Dostal *et al.* (1977, p. 8) with authors' additional computation.

Investment (DM)	Number of technological changes: Highly innovative (percentage)	Less innovative (percentage)	Total (percentage)
$<10^4$	2,176(42.1)	2,991(57.9)	5,167(16.1)
10^4-10^5	8,171(56.4)	6,316(43.6)	14,487(45.2)
10^5-10^6	7,667(70.9)	3,154(19.1)	10,821(33.8)
10^6-10^7	1,295(85.1)	226(14.9)	1,521(4.7)
$>10^7$	59(80)	15(20)	74(0.2)
Total	19,368(60.4)	12,702(39.6)	32,070(100)

that expansionary investment also includes rationalization and replacement effects. However, Figure 1 confirms in principle that the assumed relationships between certain types of investment and certain types of innovation exist.

Unfortunately the data from this investigation do not allow us to distinguish clearly between basic, improvement-oriented, and incremental innovations in their connections to investment. The data allow us only to differentiate between high and low levels of innovative technological change. In Table 2, highly innovative changes, associated with basic and improvement-oriented innovations, comprise new plants for extension of production and replacement of old plants, new equipment, computerization, and new processes. Less innovative changes, those of small improvement-oriented innovations and incremental innovations, comprise replacement of plants on the same technological basis, shutdown of production facilities, reorganization, and the use of other materials or types of energy.

The table shows how technological changes with high and low levels of innovation are distributed according to the size of the investment. Investments amounting to DM 1,500–2,000 million in the plastics, wood and furniture, food, and metalworking industries during 1970–73 were connected with 32,070 technological changes. Of these changes, 19,648 (61.3%) required investment up to a scale of DM 0.1 million (about US $50,000); about half of this number were associated with small innovations (47.3%). As investment increases, there is a growing dominance of highly innovative technological change, confirming our hypothesis that highly innovative technological change is an important driving force for investment. Such change is obviously much more likely to attract large-scale investments than is small innovation. Identifying attractive fields for investment is closely tied to the problem of identifying prospective areas for innovation.

1.5.1 Relationships Between Different Kinds of Investment

There has been a drastic change, especially over the past few years, in the relationship between expansionary and rationalization investment in developed market economies. The result of this change has been a decline in the effect of investment on employment. Figure 2 shows data for the Federal Republic of Germany, a typical example. The European socialist countries show a rather different picture, however. Because of high demand

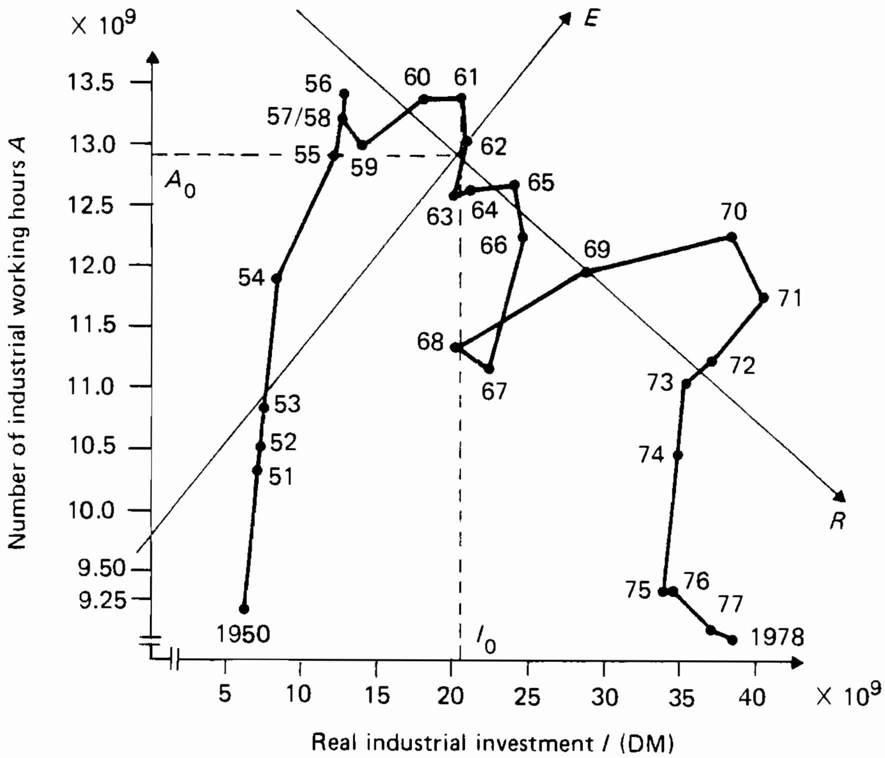

FIGURE 2 Variation of hours of labor, A, with real investment capital I in industry in the Federal Republic of Germany. E is the index of expansionary investment and R the index of rationalization investment. $I_0 = I_{1961}$ = DM 20.7 × 10^9; $A_0 = uA_{1961}$ = 12.9 × 10^9 h, where u is the labor capacity utilization ratio, based on 4% "full employment overload": u = 100/104 = 0.962. Source: Mensch *et al.* (1980).

for industrial goods there has been a great deal of expansionary investment. Figure 3 indicates the situation in the German Democratic Republic, where the demand for higher flexibility and for structural change has created different situations in different industries. The textile industry obviously had a high degree of rationalization investment, with a significant release of the work force, whereas in the electrical engineering and electronics industry expansionary investments were dominant and created a large number of work places.

At the present time, in industries of the CMEA countries more work places are being created because of greater demand and efficiency than are being eliminated as a result of investment. The result of this is that countries like the German Democratic Republic and Czechoslovakia have a significant number of vacant work places. For this reason the desire for improvement-oriented and incremental innovations is very high since these countries are trying to increase the relative amounts of rationalization and replacement investments.

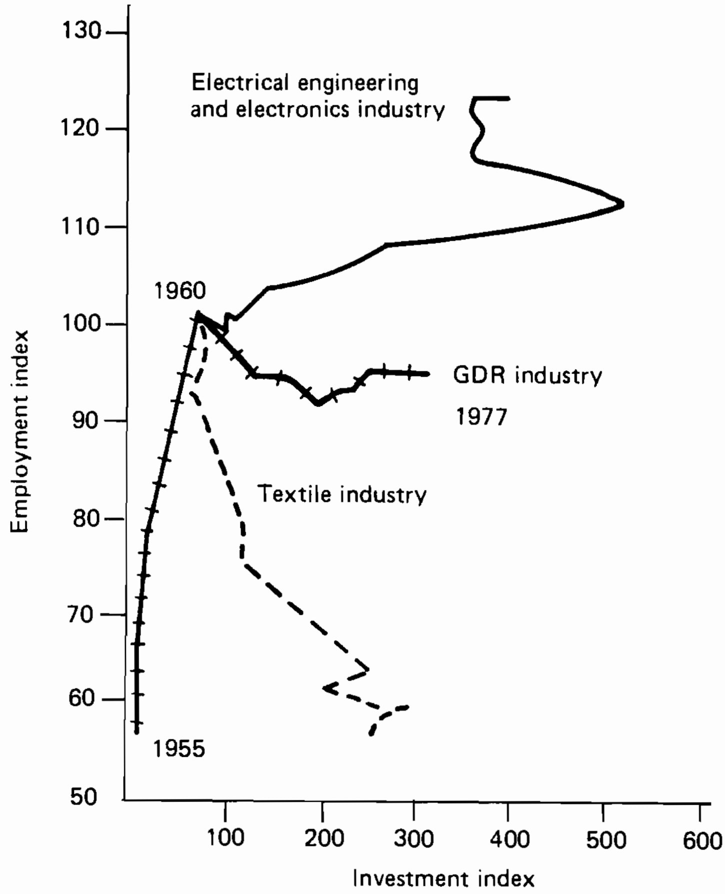

FIGURE 3 Variation of employment index with investment index in the industry of the German Democratic Republic. From 1960 onward, information has been available on individual industries (as shown up to 1977).

This must be understood as an attempt to strengthen economic performance and to improve the capability to implement basic, urgently required innovations in various industries. We shall return to the subject of investment in Section 2.2 for the case of the German Democratic Republic.

Improvement-oriented innovations create the economic power for implementation of basic innovations, and a parallel relationship exists between rationalization and expansionary investment. Recommendations that put the emphasis only on expansionary investment without taking into account its links with special types of innovation fail to give appropriate guidance for the management of innovation. For example, an increase of expansionary investment without basic innovation will have an adverse effect on the efficiency of investment and only a short-term employment effect. Rationalization and replacement investments that are not connected to improvement-oriented innovations that exploit the efficiency potential created by basic innovations will protect existing work from the competition of an innovative rival.

1.6 Innovation in Three Industries of the Federal Republic of Germany

1.6.1 The Printing Industry

The labor force in the printing industry in the Federal Republic of Germany has shrunk in recent years. As Figure 4 shows, during 1970 there was a slight reduction, then between 1973 and 1975 employment dropped sharply. Since 1977 there has been a slight increase. The index of net production in Figure 5 shows, by comparison with Figure 4, how production and economic development influence employment.

The introduction of computers and electronic typesetting equipment in the composing room and in editors' offices during 1974–76 brought major problems, as typesetters, printers, and editors went on strike in fear of losing their jobs, or at least in protest against more stressful working conditions. Figure 6 compares the relative efficiency (based on

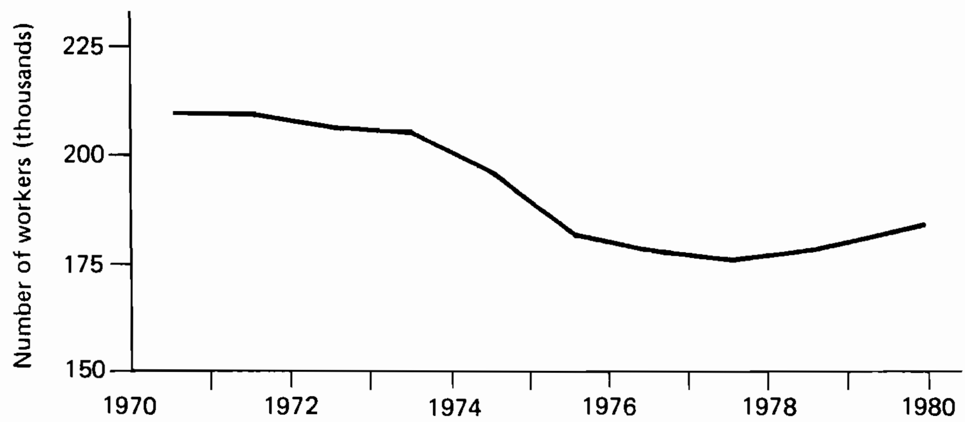

FIGURE 4 Employment in the printing industry of the Federal Republic of Germany.

FIGURE 5 Labor productivity and net production in the printing industry of the Federal Republic of Germany, based on a productivity and a net production of 100% for 1970.

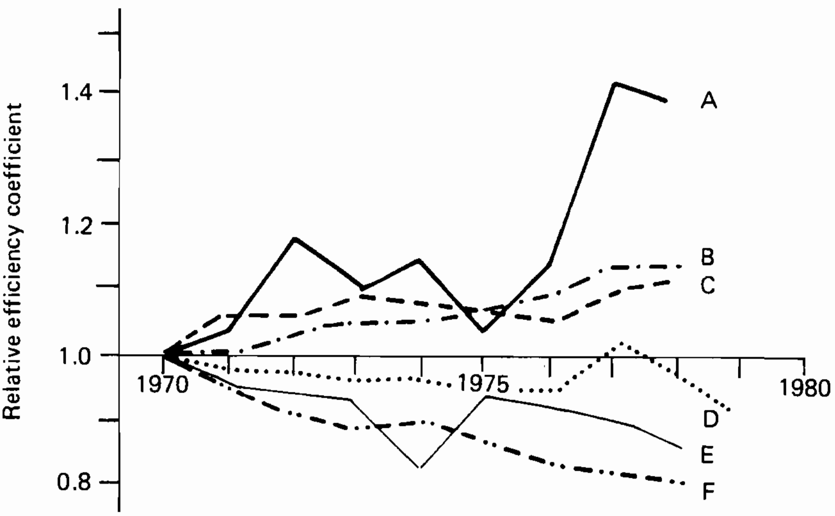

FIGURE 6 Relative efficiency coefficients for several branches of industry in the Federal Republic of Germany, calculated from labor productivities. A, manufacture of automatic data-processing equipment; B, electrical engineering (excluding the manufacture of data-processing equipment); C, plastics processing; D, printing; E, automobiles; F, manufacture of mechanical engineering machinery. Source: Federal Bureau of Statistics, Wiesbaden, FRG, with authors' additional computation.

productivity) of the printing industry (line D) with the efficiencies of other processing industries during the 1970s and reveals that the efficiency decreased during this time. That is, the relative efficiency was lower than 1.0, the mean level of all manufacturing industry (except in 1977, when it grew to 1.01), despite the technological changes and diffusion of innovation into the industry.

How can this be explained? Relative efficiency in the printing industry depends not only on innovative and highly productive equipment, but also on utilization of capacity during economic recessions. If we look at unemployment in printing, typesetting, and related occupations, we find increases during the general recessions of 1967 and 1975, as shown by Figure 7. After these peaks, unemployment decreased as a result of increased quantity and quality in production. The number of unemployed people in printing and allied occupations varied between 0.2 and 0.44% of the number of persons employed in these occupations during 1950–70; we should not suppose that this is atypical for this particular branch of industry and technological development.

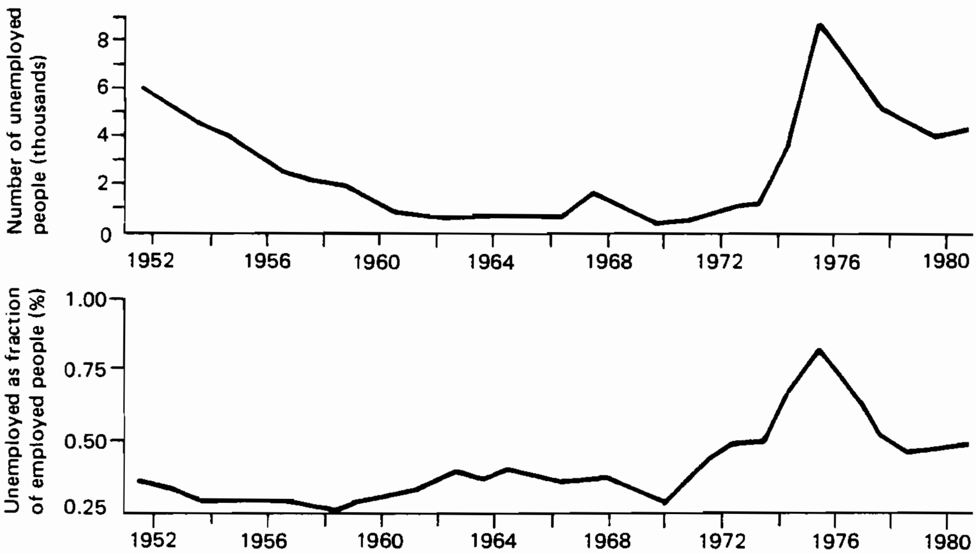

FIGURE 7 Unemployment in printing, typesetting, and related occupations in the Federal Republic of Germany. Source: Federal Employment Institute, Nuremberg, FRG.

Since 1970 the Institute of Employment Research in Nuremberg has been investigating the effects of technological change on employees in different industries in the FRG. The studies include all cases of reorganization of enterprises and look at the effects of reorganization on the numbers of new employees, transfers, and dismissals, as well as on changes in job requirements and duties and working conditions. In 1976 the printing and duplicating industry was investigated using a method similar to that used from 1970 to 1974 for the plastics-processing, woodworking, food, mechanical engineering, electrical engineering, steel, iron, tin, and nonferrous products industries. The effects of technological change on employees and jobs were found to be surprisingly similar in the different industries (Lahner and Grabiszewski 1978).

A sample survey of 13% of all enterprises with 20 or more employees in the printing and duplicating industry (260 enterprises with a total of 46,000 employees) was extrapolated to apply to the whole industry. It was found that there were fewer technological and other reorganizations in the printing and duplicating industry than in the other industries investigated. In 1975 about 1,100 people were hired (0.6% of the total work force in the industry, particularly offset press workers and press assistants), about 3,900 persons were transferred between firms within the industry (2% of all employees, mainly offset and letterpress men), and about 2,900 persons were dismissed or left (1.5% of the employees, mainly compositors, bookbinders and people in related occupations, electrotypers, and letterpress men). Five thousand people were no longer needed because of increased productivity resulting from changes in the printing technique (2.6% of the employees, especially letterpress men and compositors). Thus, the number of employees was reduced by 1,800 (0.9% of the employees) because of technological changes.

In 1975 the number of employees in the entire printing industry of the FRG decreased by 15,400, 12.5% resulting from the introduction of new or improved technologies. In the same year, production in the industry diminished by 7% compared with the preceding year, as shown in Figure 8. In other words, the decrease in the number of employees corresponded to the decline in production and to dwindling orders, which were due primarily to the economic situation and not to the adoption of new technologies. On the other hand, this indicates a lack of basic innovations that could create new markets for the printing industry.

Recent developments in the printing industry of the FRG have been characterized by:

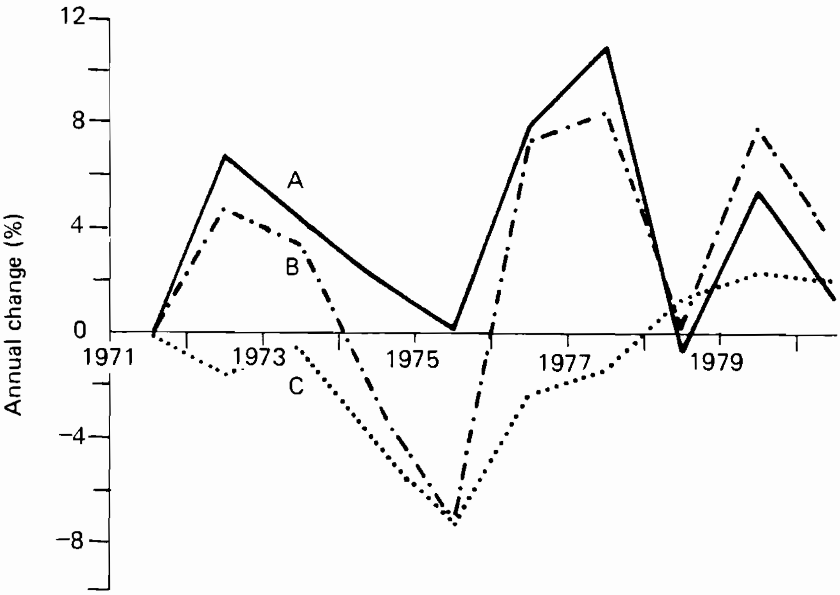

FIGURE 8 Annual changes in labor productivity (A), net production (B), and employment (C) in the printing industry of the Federal Republic of Germany.

- the need for more highly qualified workers in printing and setting;
- the new orientation of management toward the integration of new technologies into the whole process of producing information and away from the traditional, more limited manufacture of printed information;
- a broadened approach to setting and printing information that includes information processing and communications technologies such as teletext, office automation, telesetting, and teleprinting;
- the increased importance of information in many industries and businesses, including the private sector. It is forecast that more than fifty percent of all employees will eventually be working in the information sector, which will outstrip both the manufacturing and service sectors.

1.6.2 The Automobile Industry

Between 1780 and 1890 several basic innovations occurred in the development of the automobile. The first of these, in 1789, was Cugnot's steam-driven carriage, which was followed by Lenoir's internal combustion engine in 1859 and Otto's gas engine of 1878. In 1885, Benz produced the first automobile driven by an internal combustion engine, which represented a major advance. The automobile industry, which went through a long prototype stage, has had a great impact on economic growth and the labor market. Every eighteenth employed person in the industrially developed countries is said now to work directly or indirectly with the automobile industry.

Before mass production, most jobs in the automobile industry were specialized. At the beginning of the twentieth century, for example, when cars were still being produced singly, the industry employed mechanics, electricians, and engineers. A number of firms were in operation (thirty to forty in Germany) and widespread efforts were being made to facilitate economical breakthroughs for innovations.

When the assembly line was introduced in the 1920s and flow production began, the number of companies decreased while the industry itself expanded. The industry began to work increasingly with less qualified people in conveyor belt production but new occupations were not introduced. The main jobs outside car production were the traditional ones of selling, financing, and contributing to the maintenance of production.

In studying trends in the automobile industry, it becomes clear that over the years the labor force has changed with demand rather than with the technology of production. During the last ten years productivity in the automobile industry of the FRG has been consistently lower than the average productivity of all branches of industry in the country (Figure 6). This trend contradicts the assumption that an efficient, high-technology industry such as this makes use of fully automated transfer lines, robots, automatic finishing, inspection, and control, and so on. Since 1975, the number of workers has grown at about the same rate as in other industries. Despite speculation about fully automated car plants, the work force is still significantly large. Fears of full automation in other industries can be allayed by looking at this example. The figures from all branches of industry in the FRG show that structural change in demand is more important than automation in its influence on the labor force.

The relative efficiency coefficient, computed on the basis of output per working hour, in the automobile industry reaches 90% of the average labor productivity of all branches of industry (Figure 6). Labor productivity, measured as output per capita, is sometimes, with respect to short-range influences, more a measure of the utilization of capacity and less a measure of the effect of labor-saving equipment. In finding a way to measure labor-saving effects, we have to distinguish between various factors, such as human resources available in the labor force, and examine their influence on capacity utilization, as well as the influence of production methods on productivity, and the impacts on the labor force of organizational or technological change within a factory or a branch of industry.

1.6.3 The Microelectronics Industry

If we are to make better use of human resources in the innovation process it is important to identify the impact of a given innovation on the quantity and quality of the labor force. Table 3 shows how the demand for manpower from different economic sectors in the FRG up to 1990 will affect employment in various branches of industry. The forecasts are based on data from 1975, during which year employees first felt the impact of microelectronics in such areas as fabrication of precision instruments, mechanical engineering, printing, credit and insurance, and both wholesale and retail trading.

The microprocessor is frequently labeled as a "job killer" because of work places lost during 1974–76 in the production of such items as computers, small clocks, taximeters, televisions, typewriters, cash registers, and teleprinters. Enterprises that were traditional leaders of industry made spectacular reductions in their work forces. However, recently finished studies have shown that the assessment of the labor "release effect" demands a different form of appraisal (Dostal 1982).

A strong release effect can generally be expected if an electronic device is incorporated into a product whose principal function is automatic measurement, control, or calculation (e.g. computers, watches, teleprinters, cash registers). If the electronic device introduces additional functions that increase demand for the product, the release effect will be weaker. Use of microelectronics has a labor-saving effect because mechanical and electromechanical components require more labor-intensive production technology, and automation of a product leads to a cut in the number of stages of manufacture.

If microelectronics are introduced into a product where automatic measurement, control, or calculation is only a secondary function (e.g. televisions with game attachments, cars with electronic fuel injection), this hardly ever leads to dismissal of workers engaged in the manufacture of the product. On the contrary, the incorporation of microelectronics frequently extends the functions of the product and improves its quality.

Adverse effects on employment can occur only indirectly in these applications. If the artifacts are capital goods and allow a new type of automation in production, labor could be released on a large scale. Loss of employment is generally not expected in the manufacture of consumer products, though the decrease in repair time involved with the incorporation of microelectronics will lead to a certain release of labor.

Empirical data on unemployment (Federal Employment Institute 1981) for occupations such as mechanics, clerical workers, bookkeepers, printers and typesetters, and typists and stenotypists show that the numbers of dismissals and new entrants result in a stock figure for unemployed people that does not support the thesis of a high release of labor (Figure 9). If we suppose that indicators of the numbers of unemployed in these occupations as fractions of all the unemployed exclude the effect of economic growth (or decline) on unemployment, we see from Figure 10 that the relative impact on unemployment has been decreasing for several years, and not increasing as might have been expected from the adoption of microelectronics.

TABLE 3 The demand for manpower (in thousands) according to economic sectors up to 1990 in the Federal Republic of Germany. Projections are based on figures for 1975. The data for 1973–78 are revised figures. Source: Federal Employment Institute (1980, p. 108).

Economic sector	1960	1970	1973	1974	1975	1976	1977	1978	1980	1985	1990
Agriculture and forestry	3,850	2,262	1,954	1,882	1,823	1,743	1,655	1,608	1,450	1,200	1,000
Manufacturing	12,500	12,973	12,761	12,303	11,529	11,317	11,247	11,266	11,870	11,600	11,360
1. *Mining and energy*	560	537	496	489	490	483	474	467	450	420	410
2. *Processing industry*	9,700	10,117	9,901	9,629	9,063	8,870	8,853	8,849	9,540	9,380	9,250
Chemicals and oil	760	1,031	1,038	1,034	991	969	968	967	1,050	1,060	1,070
Pottery, china, and earthenware	480	454	458	424	394	389	387	385	360	330	300
Iron and nonferrous metal ores	1,020	947	893	879	846	821	808	780	760	710	660
Steel, mechanical engineering, and vehicles	2,140	2,517	2,527	2,483	2,363	2,341	2,354	2,384	2,730	2,820	2,910
Electrical engineering, precision instruments, and hardware	1,640	1,929	1,951	1,938	1,796	1,757	1,760	1,755	1,920	1,930	1,960
Wood, paper, and printing	1,070	997	979	939	872	842	850	865	920	890	860
Textiles	670	561	485	442	401	381	370	359	380	330	280
Leather and clothing	880	697	610	540	500	485	473	465	540	470	410
Food, beverages, and tobacco	1,040	984	960	940	900	885	883	889	880	840	800
3. *Building*	2,040	2,319	2,364	2,185	1,976	1,964	1,920	1,950	1,880	1,800	1,700
Trade	3,300	3,348	3,388	3,282	3,179	3,161	3,172	3,186	3,310	3,300	3,290
Transport and communications	1,460	1,421	1,518	1,519	1,485	1,443	1,416	1,406	1,470	1,470	1,470
Services	2,380	2,943	3,039	3,063	3,059	3,120	3,221	3,315	3,400	3,640	3,880
1. *Credit and insurance*	380	597	678	694	689	689	690	703	760	820	890
2. *Other services, including hotels and catering*	2,000	2,346	2,361	2,369	2,370	2,431	2,531	2,612	2,640	2,820	2,990
Public sector	2,110	2,978	3,328	3,441	3,512	3,558	3,575	3,638	3,480	3,680	3,880
Nonprofit organizations	760	645	660	665	679	691	707	741	720	780	840
Total	26,090	26,570	26,648	26,155	25,266	25,033	24,993	25,160	25,700	25,670	25,720

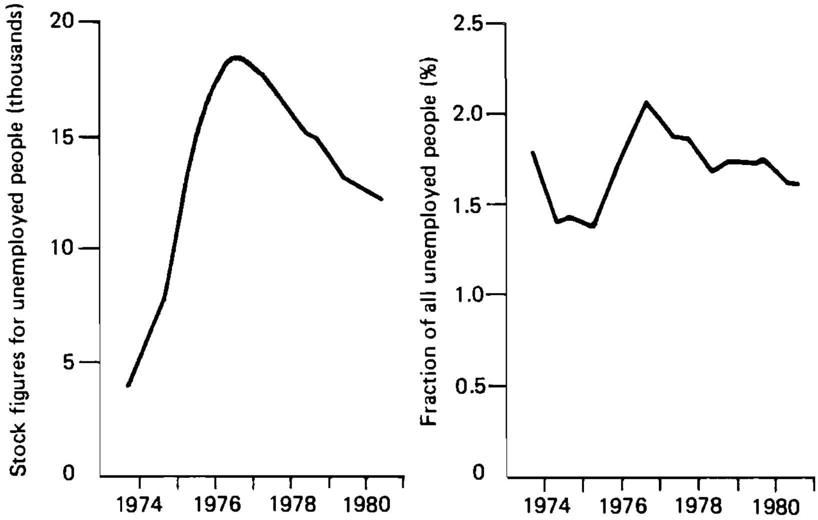

FIGURE 9 Unemployment among typists, stenotypists, and secretaries in the Federal Republic of Germany. Source: Federal Employment Institute, Nuremberg, FRG.

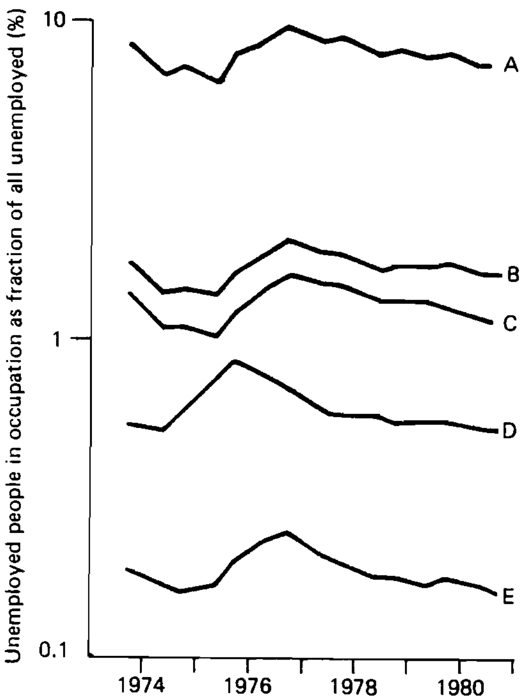

FIGURE 10 Unemployment in various occupations in the Federal Republic of Germany. A, bookkeepers; B, electronic data-processing personnel; C, qualified clerical workers; D, typists, stenotypists, and secretaries; E, mechanics and instrument makers. Source: Federal Employment Institute, Nuremberg, FRG.

2 IMPROVEMENTS IN THE QUALITY AND USE OF HUMAN RESOURCES: AUTOMATION, INNOVATION, AND SKILL REQUIREMENTS

2.1 The German Democratic Republic

In the German Democratic Republic the number of working people has risen consistently over the last twenty years in spite of the fact that the total population has decreased (Figure 11). There are two main causes:

a. The possibilities for women to work, both full- and part-time, have improved and so the level of female employment has steadily increased. In 1978 the participation rate was approaching 87% and is now close to its natural limit.
b. The increase in life expectancy meant that the country was faced with creating work places for older people who might wish to continue working after retiring age. In the GDR in 1978, 18.1% of pensioners were continuing to work; 85% of them were male and 15% female. This added more than half a million to the number of employed people.

With the increasing degree of employment it was possible to extend the free time of all employees, especially through such social measures as:

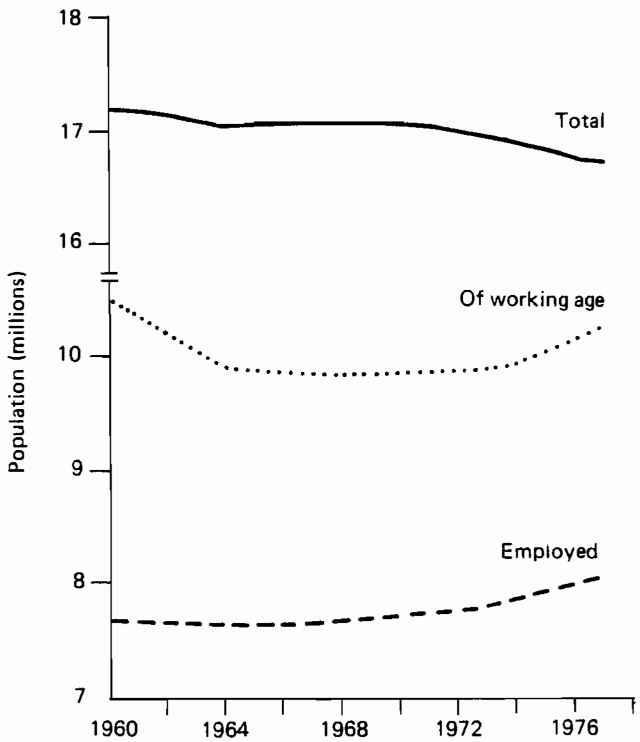

FIGURE 11 Changes in the total population, the population of working age, and the number of employees in the German Democratic Republic.

- reduction of the working time for all employees, especially for shift workers and mothers with more than two children;
- implementation of the five-day working week;
- extension of vacation time;
- extension of maternity leave; and
- extension of social support for women with more than one child.

The free time gained by these measures in one year was equivalent to the working hours of one million people in 1960. The reduction of working hours to this extent was possible because the increase in the number of employees led to higher labor productivity. More than 90% of the production growth in the period from 1962 to 1978 was due to the increase in labor productivity, which was in turn connected with better use of capital and material resources and a better scientific and technological basis of production.

One factor contributing to the scientific and technological basis of production was the rise in quality of labor resources. In the GDR the fraction of employees that were graduates from technical schools and universities increased from 6.8% in 1962 to 17.2% in 1977 (Table 4). During the same period the fraction of skilled workers and foremen rose from 33.6 to 58.2% and the fraction of semiskilled and unskilled workers declined from 59.6 to 24.6%. More than 90% of pupils who passed through the eighth form in school continued in the ninth and tenth forms and then received vocational training. It is foreseen that by the end of this century the quota of graduates of technical schools and universities will increase to about 20–25% and the quota of skilled workers to about 65%. The fraction of semiskilled and unskilled workers is expected to decrease to about 10–15% (Korn and Maier 1977).

Clearly, public expenditure on education has much greater importance today than was the case even in the developed industrial countries at the beginning of this century. At that time, funding amounted to only 1 to 2% of national income, but today in several countries, including the GDR, more than 5% of national income is devoted to education (Table 5).

The increasing importance of qualified labor for production is evident from Figure 12, which shows the rise in educational funds (human capital) in the GDR, from 66.5 billion marks in 1962 to 250.8 billion marks in 1975. That is about one-quarter of the funds for fixed assets (material capital) in the GDR economy today. During this period, educational funds increased by about 377%, whereas expenditure on fixed assets rose by only 165%. Over the same period, research funds rose by 333.5%.

TABLE 4 Qualification structure of employees (percentages) in the German Democratic Republic in 1962 and 1977, and the prediction for 2000.

Type of employee	1962	1977	2000
Skilled worker	33.6	58.2	65
Semiskilled/unskilled worker	59.6	24.6	10
University graduate	2.4	6.1	10
Technical school graduate	4.4	11.1	15

TABLE 5 Public expenditure on education as a percentage of gross national income (market economies) or of national income (planned economies). Sources: Unesco Statistical Yearbook (1963–1977), Jahrbuch der DDR, Rocznik Statystyczny, Poland, and Narodnoji Chozjaistvo, USSR.

	1955	1960	1965	1970	1975
Planned economies					
Bulgaria	(2.8[a])	(5.0[b])	4.5	4.9	(5.3[c])
Czechoslovakia	–	4.2	5.3	4.4	(4.5[c])
GDR[d]	4.7	5.1	5.1	5.3	5.8
Poland	(3.7[e])	4.6	3.8	3.6	4.0
USSR	5.8	5.9	7.3	6.8	7.2
Hungary	(5.0[a])	4.4	5.4	4.5	(5.6[c])
Market economies					
Austria	4.0	3.7	3.7	4.6	5.7
France	2.0	3.4	4.2	4.7	5.6
FRG	3.5	3.7	3.4	4.0	(4.5[c])
Italy	2.5	3.9	5.2	4.3	5.0
UK	3.2	4.2	5.1	5.0	(6.2[c])
Japan	6.1	6.5	4.3	3.9	5.5
USA	4.0	6.2	5.3	6.4	6.2
Sweden	2.6	4.5	6.2	7.7	7.4

[a]1954 figure; [b]1961 figure; [c]1972 figure; [d]excluding funds for investment; [e]1954 estimate.

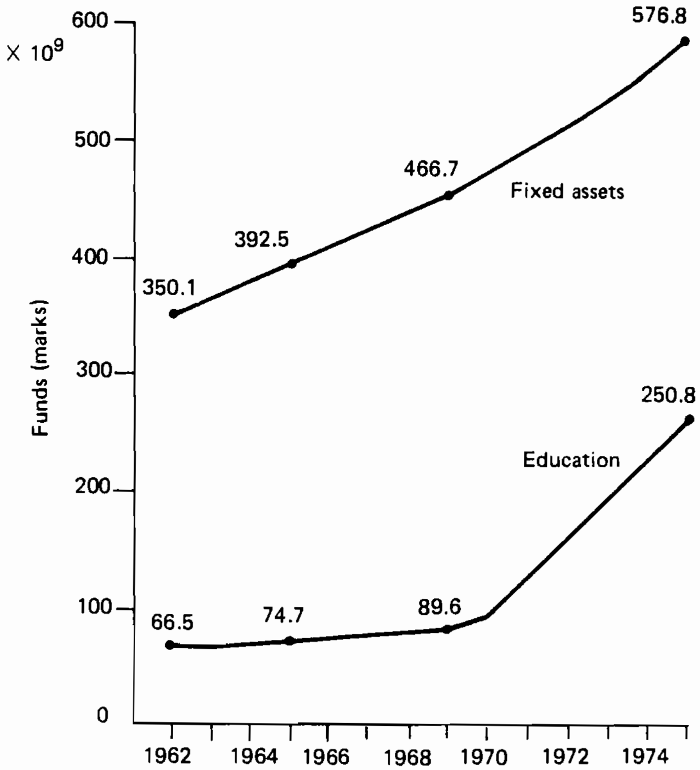

FIGURE 12 Changes in funding for education and fixed assets in the German Democratic Republic during 1962–75.

2.2 The Relationship Between Technological Funds and Labor Productivity

In most of the developed countries technological funds are becoming more and more essential for the improvement of labor productivity. Up to now, each increment in labor productivity has required an extension of funds for investment in production, occupational education, and research. There is no indication of a change in this trend, particularly in view of skill and research requirements for new fields of innovation, such as: electronics, especially the application of microelectronics in automation; energy and the environment; biochemistry and food production; technologies that are able to provide new organizational solutions to problems of communications, traffic flow, settlements, health, and recreation; and technologies appropriate for developing countries, especially systems combining advanced with traditional technologies. This means that the extension of technological funds will remain an important condition for the improvement of labor productivity. A break of the direct dependence of labor productivity growth upon the extension of technological funds could only result from more efficient use of the funds themselves. This might become one of the most significant problems for the developed countries in the next ten to twenty years in their efforts to achieve higher economic performance. Higher efficiency of use of technological funds could only be brought about by more innovativeness in the machine tool industry and the educational system and by more effective research and development. Especially important is the improvement of efficiency in the service sector.

To explore the links between labor productivity and technological funds, we shall use data from the GDR. In our calculations, production funds comprise the capital for production of equipment, buildings, etc., but without floating funds. Occupational education funds include expenditure for occupational and professional training but not for general education. For example, in 1975 the entire educational funds in the production sphere of the GDR were 110,556 million marks but the occupational funds only accounted for 20,588 million marks. To avoid double counting we included in our estimations only the change in qualification structure and not the quantitative extension of the labor force, because the latter is taken into account in the labor productivity coefficient P_L. Research funds comprise expenditure for all research activities, including those that prove unsuccessful. In the GDR, approximately 70% of research funds are for applied, industrial research and 30% for fundamental, scientific research.

Table 6 shows labor productivity and the efficiency of funds used for production (F_P), occupational education (F_E), and research (F_R). Labor productivity is the ratio of the national income to the number of employees (P_L = NI/E), and the efficiency, q, of funds is the ratio of the national income to the funds themselves. To relate labor productivity to the efficiency of technological funds we use the following equations:

$$\frac{I_n}{I_0} = \frac{\mathrm{NI}_0/E_0}{\mathrm{NI}_n/E_n} + \alpha\left(\frac{\mathrm{NI}_0/F_{\mathrm{P}0}}{\mathrm{NI}_n/F_{\mathrm{P}n}}\right) + \beta\left(\frac{\mathrm{NI}_0/F_{\mathrm{E}0}}{\mathrm{NI}_n/F_{\mathrm{E}n}}\right) + \gamma\left(\frac{\mathrm{NI}_0/F_{\mathrm{R}0}}{\mathrm{NI}_n/F_{\mathrm{R}n}}\right)$$

where subscripts 0 and n denote the base year and another year, or

$$\Delta I = \Delta(\mathrm{NI}/E) \pm \alpha\Delta(\mathrm{NI}/F_{\mathrm{P}}) \pm \beta\Delta(\mathrm{NI}/F_{\mathrm{E}}) \pm \gamma\Delta(\mathrm{NI}/F_{\mathrm{R}})$$

$$= \Delta P_{\mathrm{L}} \pm \alpha\Delta q_{\mathrm{P}} \pm \beta\Delta q_{\mathrm{E}} \pm \gamma\Delta q_{\mathrm{R}} \qquad (1)$$

TABLE 6 Changes in labor productivity and efficiency of technological funds from 1960 to 1975 in the German Democratic Republic.

	1960		1965	1970	1975
National income NI (million marks)	71,540		84,760	109,470	142,370
Working population E (thousands)	6,495		6,411	6,414	6,434
Production funds F_P (million marks)	161,932		217,466	275,985	366,704
Occupational education funds F_E (million marks)	8,629		11,445	16,047	20,588
Research funds F_R (million marks)	6,300		11,600	22,300	40,300
Technological funds $F_P + F_E + F_R$ (million marks)	176,861		240,511	314,332	427,538
ΔNI (%)		*a*			+99.01
		b	+18.48	+29.15	+30.05
ΔE (%)		*a*			−0.94
		b	−1.29	+0.05	+0.31
ΔF_P (%)		*a*			+126.46
		b	+34.29	+26.91	+32.87
ΔF_E (%)		*a*			+138.59
		b	+32.63	+40.21	+28.30
ΔF_R (%)		*a*			+539.68
		b	+84.13	+92.24	+80.72
$\Delta(F_P + F_E + F_R)$ (%)		*a*			+141.74
		b	+35.99	+30.69	+36.01
$\alpha = F_P/\text{NI}$	2.264		2.566	2.521	2.576
$\beta = F_E/\text{NI}$	0.121		0.135	0.145	0.145
$\gamma = F_R/\text{NI}$	0.088		0.137	0.204	0.283
$P_L = \text{NI}/E$ (marks per capita)	11,015		13,221	17,067	22,128
$q_P = \text{NI}/F_P$	0.4418		0.3898	0.3967	0.3882
$q_E = \text{NI}/F_E$	8.291		7.504	6.908	6.981
$q_R = \text{NI}/F_R$	11.356		7.307	4.909	3.533
ΔP_L (%)		*a*			+100.89
		b	+20.03	+29.09	+29.65
Δq_P (%)		*a*			−12.13
		b	−11.77	+1.77	−2.14
Δq_E (%)		*a*			−16.00
		b	−10.67	−7.90	+1.01
Δq_R (%)		*a*			−68.89
		b	−35.66	−32.82	−28.03

[a]Based on 1960; [b]based on previous five-year period.

where α, β, γ are weighting coefficients:

$$\alpha = F_{Pn}/\text{NI}_n \qquad \beta = F_{En}/\text{NI}_n \qquad \gamma = F_{Rn}/\text{NI}_n$$

We see from the values of these weighting coefficients in Table 6 that, over the period 1960–75, an increase in capital efficiency, Δq_P, of 1% would have improved labor productivity by 2.6%, raising the efficiency of educational funds, Δq_E, by 1% would have improved productivity by 0.1%, and raising the efficiency of research funds, Δq_R, by 1% would have resulted in an increase of 0.3%. By comparing the change in labor productivity

P_L with the changes in efficiency of the technological funds, it is possible to identify the part of productivity growth that can be used for the extension of technological funds and the part that is available for the fulfillment of individual and social requirements.

Using the key data, in Table 6, from our investigation of the relationship between labor productivity and technological funds for the period 1960–75, we have the following results according to eqn. (1):

1960–65:

$$\Delta I = +20.03 - 2.566 \times 11.77 - 0.135 \times 10.67 - 0.137 \times 35.66$$

$$= 20.03 - 30.20 - 1.44 - 4.89$$

$$= -16.50\%$$

1965–70:

$$\Delta I = +29.09 + 2.521 \times 1.77 - 0.145 \times 7.90 - 0.204 \times 32.82$$

$$= 29.09 + 4.46 - 1.15 - 6.70$$

$$= +25.70\%$$

1970–75:

$$\Delta I = +29.65 - 2.576 \times 2.14 + 0.145 \times 1.01 - 0.283 \times 28.03$$

$$= 29.65 - 5.51 + 0.14 - 7.93$$

$$= +16.35\%$$

1960–75:

$$\Delta I = +100.89 - 2.576 \times 12.13 - 0.145 \times 16.00 - 0.283 \times 68.89$$

$$= 100.89 - 31.25 - 2.41 - 19.50$$

$$= +47.73\%$$

We have calculated that during 1960–75 the labor productivity increase was 100.89%. To extend technological funds, 53.16% of finances produced by the increase in productivity were absorbed: 31.25% were used to increase production funds, 19.5% were devoted to the expansion of research funds, and 2.41% were given to increasing funds for occupational education. The remaining 47.73% of the productivity increase was made available for improving wages, health care services, and residential accommodation, for cultural and social expenditure, and for other governmental activities.

In the period 1960–65 the extension of technological funds was much higher than the economic resources created through the increase of labor productivity. The additional expenditure had to be obtained by reallocation of resources. This investment in technological funds produced a much higher increase of labor productivity than of expenditure for the extension of technological funds during 1965–70. In this period the share of economic resources created by higher productivity that was available for individual and societal expenditure was 88%. In the period 1970–75 it was again necessary to expend a greater part of the productivity gains for the extension of technological funds.

The German Democratic Republic and other developed countries are still faced with the problem of increasing the efficiency of technological funds so that they can raise the contribution of productivity growth to the improvement of material and cultural living conditions. The high efficiency of expenditure on education can be seen in the close connection between the increase in the overall level of qualification and the growing contribution of innovation to the efficiency of the national economy. The benefits of innovation (the cause of more than 50% of the prime cost reduction in the nationally owned economy of the GDR) per unit of educational funds were 2.5 times higher in 1970–75 than during 1960–65.

Figure 13 shows the relationship between adoption of innovation and the level of qualification. In 1976 alone 1.6 million employees participated in innovative activities, resulting in a benefit of 3.6 billion marks. The majority of these activities were concerned with improvement-oriented and rationalization innovations.

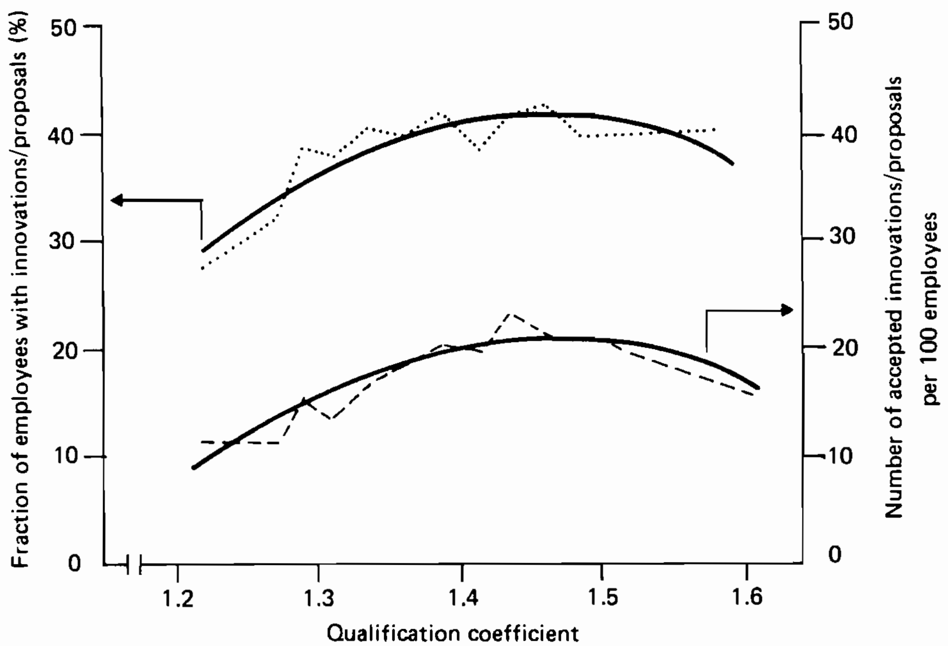

FIGURE 13 Variation of innovative activity with qualification coefficient for the GDR national economy in 1975. The qualification coefficient is the ratio of highly skilled work to unskilled work. The production costs associated with labor forces at different levels of qualification were used as weights for work at different levels. Maier *et al.* (1972) describe the method of estimating the qualification coefficient.

A structural policy is required that utilizes more fully people's qualifications in order to reduce the intensity of use of raw materials and energy, while raising the intensity of use of human intelligence. The problem is the effective employment of working people, that is, according to their qualifications, to implement and control technical innovations. Only by an effective use of qualified labor can the productive potential created by educating people be realized. In this way not only labor productivity but the quality of life will be improved. It is also likely that the demands of the economy and the individual's way of life will become more closely linked.

2.3 Technological Change and Skill Requirements

There is disagreement about how structural and technological change will affect skill requirements (Figure 14). In our investigation we came to the conclusion that neither Blauner's theory (Blauner 1964), according to which mechanized production requires low skills and automated production high skills, nor Bright's theory (Bright 1958), that mechanized production requires high skills and automated production low skills, is entirely appropriate.

Structural and technological change sometimes tends to lead to a polarization of job functions and job requirements, with a growing dominance of requirements for greater skills and knowledge. While very simple and usually monotonous jobs have been created

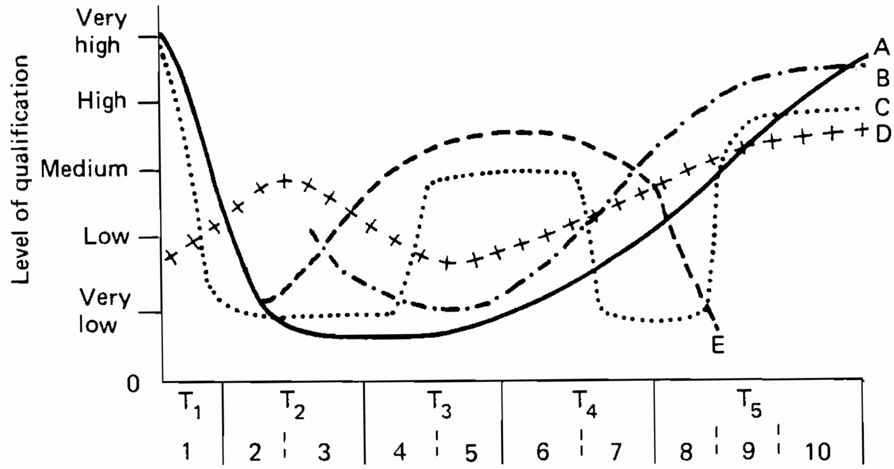

FIGURE 14 Different opinions from the literature about the influence of mechanization/automation on the required level of qualification at different stages of technological development. T_1, manual work places; T_2, partly mechanized; T_3, fully mechanized; T_4, partly automated; T_5, fully automated. 1, simple manual tools, hand- and foot-driven machinery; 2, energy-driven machine tools; 3, manually steered and regulated machinery; 4, manually steered and regulated machinery, and mechanisms for subsidiary processes; 5, remote-controlled machinery, manual or remote steering or regulation, and mechanisms for subsidiary processes; 6, machinery driven or controlled by regulating mechanisms, and mechanized subsidiary processes; 7, machinery with flexible programmed steering, and mechanized subsidiary processes; 8, machinery with flexible programmed steering, and subsidiary equipment steered manually; 9, subsidiary process machinery with flexible programmed steering; 10, complex machinery and subsidiary processes with flexible programmed steering, and possibly self-optimizing steering program. Curve A, from Blauner (USA); B, Richtá (Czechoslovakia); C, Kern and Schumann (FRG); D, sociological analysis (GDR); E, Bright (USA).

that call for little qualification or skill, the relative number of activities requiring higher skills has risen because of their increasing importance. At the same time the proportion of complex activities demanding a medium level of qualification has declined. Even if requirements in manpower vary widely, depending on the level of technological development, the basic tendency is for the importance of qualified labor to increase with the degree of mechanization and automation, as shown in Figure 14.

Studies of methods for analyzing the development of technological equipment show that there is the possibility not only of mere description but also of scaling, categorizing, and, in some cases, measuring the development. By grading and splitting complicated developments that are normally difficult to assess in their entirety, it is easier to identify certain innovations in technology, production, or economic units. However, instead of development along a single path, we have in reality development along a branched and well distributed network of traditional equipment and innovations.

The development of technology and of the industrial system clearly includes various "distributions," such as:

- equipment of different ages;
- organizational patterns of different functions;
- research and development at different levels of maturity; and
- human factors – differences in experience, knowhow, behavior, and qualifications.

It is therefore very difficult to present a complete picture of the relationships between technological development, expressed for example in terms of the level of mechanization and automation, characteristics of manpower, such as qualification patterns, and different occupations in order to describe the requirements for human resources.

The relationship between labor requirements and technological development has often been investigated, and the general trend that has emerged is a polarization of qualifications – the number of skilled and highly qualified people increases and there are fewer unskilled and unqualified workers (see Figure 14). There is a net growth of qualified people and the number of jobs for qualified people increases as a result of innovation. Figure 15 shows how polarization in qualification structure may take place as a result of changes in the numbers of unskilled and skilled personnel, and indicates the qualification patterns of the past, present, and future.

It should not be overlooked that the qualification structure of a society and the distribution of work with high and low skill requirements among different groups in a society are, in general, not so much the results of technological development but more of societal structure. The creation of equal possibilities for all members of society to develop their capabilities and realize them in socially and individually useful work is an important criterion for the progress of society.

In Figure 16 we have collected data about required and existing skills in industry in the GDR at different technological levels of production. This analysis includes more than 2.5 million workers, that is, more than half of the workers involved in production. The data show that there is, especially in the partly mechanized work places (T_2), fully mechanized work places (T_3), and partly automated work places (T_4), a higher share of skilled workers than at the lower level, T_1. At the same time there is a shortage of semiskilled workers and a surplus of unskilled workers at nearly all levels. This last problem can be solved by training unskilled workers.

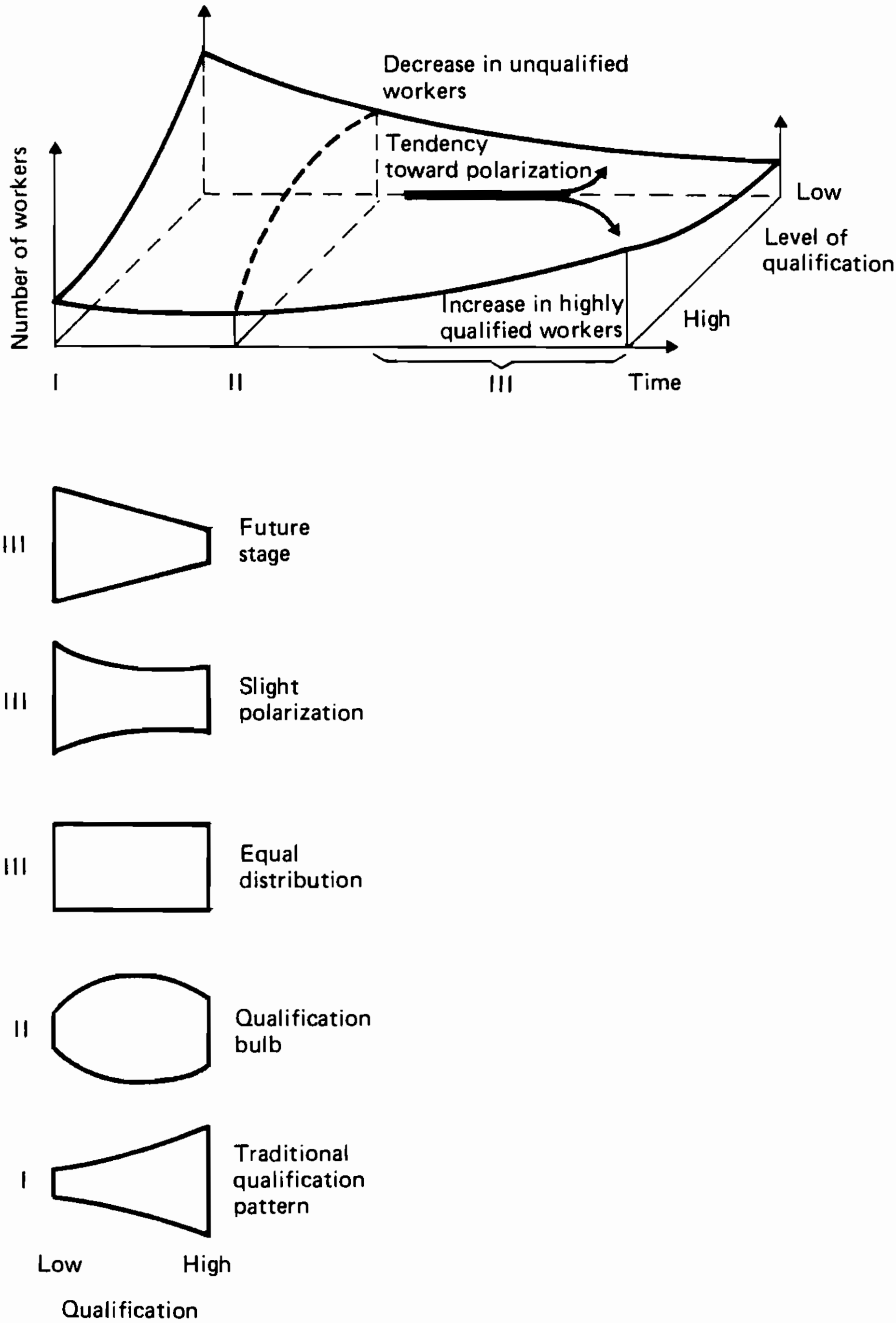

FIGURE 15 The change in qualification structure over time.

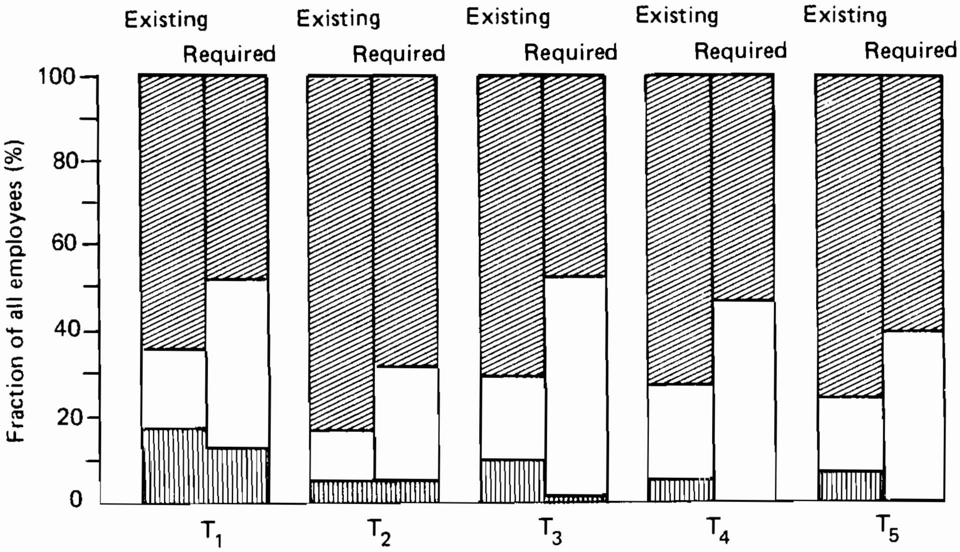

FIGURE 16 The existing and required qualification structure of production workers employed in industry at various stages of technological development in the German Democratic Republic. Diagonal shading, skilled workers; no shading, semiskilled workers; vertical shading, unskilled workers. T_1, manual work places; T_2, partly mechanized; T_3, fully mechanized; T_4, partly automated; T_5, fully automated.

Our conclusion is not simply that the qualification of a worker should be appropriate to a certain technological level, but also that human resources should be better used where the technological demand for qualifications is relatively low. Conditions of employment must be conducive to the elimination of unskilled work places.

The change in demand for a qualified labor force indicates that society faces the task of overcoming the incompatibility between the existing structure of work places and emerging new work places. One solution might be to increase the occupational flexibility and mobility of workers at all levels of qualification. This would require each individual to have a sound general education and to have developed specialized capabilities in order to appropriate new knowledge and to assimilate, expand, and apply it in an effective manner. There are no rigid limits to the development of these capabilities on the basis of a thorough general education, but there is a limit to how much factual knowledge can be digested. Any aim to reduce schooling to a pure supply of factual knowledge has little connection with the object of teaching an individual to think independently, and would leave underdeveloped those faculties that are critical for dealing with social and technological innovation. Innovative learning requires a capacity for independent and creative thinking and an optimistic attitude to problem solving.

2.4 The Impacts of Innovation on Work Content and Skill Requirements

Our innovation model demonstrated that it is wrong to equate innovation with automation. Automation often occurs only in the maturation and saturation phases of the innovation cycle, which is why the skill requirements of the automation process are not typical for the entire innovation process. Until now, there has been no report in the literature of an attempt to find how different kinds of innovation influence work content and skill requirements. On the basis of empirical data on technological changes in about nine hundred firms in four industrial branches in the Federal Republic of Germany over the period 1970–73, we discovered some interesting facts (Dostal *et al.* 1977).

Unfortunately, it was impossible to identify relationships of the different kinds of innovation with work content and skill requirements because, as shown by Tables 7 and 8, the distinction between high-innovation and low-innovation work places is too rough. The high-innovation work places are associated with basic innovations as well as major improvement-oriented innovations, whereas low-innovation work places are mostly connected with smaller improvement-oriented innovations and incremental innovations. However, we can make some observations that are more general in nature:

1. The new work places created in the four industries during the period of investigation included 56.3% with a higher work content and 43.7% with a lower work content than before the innovative technological change.
2. Of these new work places, 67.3% were connected with large innovations and only 32.7% with small innovations. Of the high-innovation work places, 32,960 or 55.3% had a higher work content and 26,638 or 44.7% a lower work content than before the technological change. Of the low-innovation work places, 16,878 or 58.3% had a higher work content and 12,086 or 41.7% a lower work content than before the change. On average, we cannot see any significant difference between large and small innovations in their effects on work content.
3. Of the work places with a higher work content created through highly innovative technological change, 55.4% were concerned with such activities as controlling and adjusting machines, checking and planning products and processes, supervision, and giving advice. The same activities constituted 60.3% of the new work places created through less innovative change. Evidently, both kinds of technological change significantly extended work content, calling for greater vocational experience and responsibility.
4. Highly innovative technological changes eliminated 11.8 times more manual work places than they created, whereas less innovative technological changes eliminated only 2.8 times more manual work places than they were able to create. Highly innovative changes eliminated 1.6 times more office work places than they created, and less innovative changes 1.5 times more.

The influence of technological change on work content is also confirmed by the examination of how work requirements are affected by innovation (Table 8): more than 90% of the work places that were created through technological change needed higher skills and only about 10% lower skills. Of the higher skill requirements for all new work places, 95%

TABLE 7 Impact of highly innovative and less innovative technological changes on work content in the Federal Republic of Germany. High-innovation work places are created by the following types of technological change: new plants for extension or replacement of old plants, new equipment, computerization, and new processes. Low-innovation work places are created by replacement of existing plants on the same technological basis, replacement of used equipment, shutdown of production facilities, reorganization, and the use of other materials or energy. Source: Dostal *et al.* (1977, p. 11).

Kind of work	Impact on work content	Number of high-innovation work places (percentage)	Number of low-innovation work places (percentage)	Sum	Requirement coefficient Innovation: High	Requirement coefficient Innovation: Low
Work by hand	Increase Decrease	1,073(36.4) 12,620(70.7)	1,874(63.6) 5,218(29.3)	2,947 17,838	–11.8	–2.8
Work with/ on machines (operation of machines)	Increase Decrease	10,695(79) 2,100(56)	2,851(21) 1,628(44)	13,546 3,728	5.1	1.8
Control of machines	Increase Decrease	10,398(61.1) 795(70.5)	6,619(38.9) 333(29.5)	17,017 1,128	13.1	19.9
Adjustment of machines	Increase Decrease	2,646(77.3) 159(76.4)	775(22.7) 49(23.6)	3,421 208	16.6	15.8
Transportation by hand	Increase Decrease	760(40.3) 6,979(63.6)	1,124(59.7) 3,995(36.4)	1,884 10,974	–9.2	–3.6
Maintenance	Increase Decrease	537(46.2) 207(72.6)	626(53.8) 78(27.4)	1,163 285	2.6	8.0
Checking	Increase Decrease	2,374(68.3) 906(67.8)	1,100(31.7) 431(32.2)	3,474 1,337	2.6	2.6
Planning of processes	Increase Decrease	1,728(66.7) 149(100)	862(33.3) 0(0)	2,590 149	11.6	0.0
Office work	Increase Decrease	1,651(88.0) 2,715(88.6)	226(12.0) 350(11.4)	1,877 3,065	–1.6	–1.5
Supervision, advice	Increase Decrease	1,098(57.2) 8(66.7)	823(42.8) 4(33.3)	1,921 12	137.3	105.8
Subtotals	Increase Decrease	32,960(66.1) 26,638(68.8)	16,878(33.9) 12,086(31.2)	49,838(56.3) 38,724(43.7)	1.24	1.39
Total number of new work places investigated		59,598(67.3)	28,964(32.7)	88,562(100)		

are connected with higher vocational experience and responsibility. In this case we cannot find any significant difference in impact between small and large innovations.

High-innovation technological change seems to trigger off a greater need for high skills than is shown in Table 8. The increased requirement for vocational experience and

TABLE 8 Impact of highly innovative and less innovative technological changes on work requirements in the Federal Republic of Germany. High-innovation work places are created by the following types of technological change: new plants for extension or replacement of old plants, new equipment, computerization, and new processes. Low-innovation work places are created by replacement of existing plants on the same technological basis, replacement of used equipment, shutdown of production facilities, reorganization, and the use of other materials or energy. Source: Dostal *et al.* (1977, p. 10).

Work requirement	Impact on work requirement	Number of high-innovation work places (percentage)	Number of low-innovation work places (percentage)	Sum	Requirement coefficient	
					High innovation	Low innovation
Education	Increase Decrease	18(100) –	– –	18 –	–	–
Vocational training	Increase Decrease	1,472(68) 528(69)	675(32) 242(31)	2,147 770	2.8	2.8
Vocational experience	Increase Decrease	11,626(73) 1,631(66)	4,213(27) 849(34)	15,839 2,480	7.1	5.0
Responsibility for own work	Increase Decrease	5,212(71) 730(71)	2,142(29) 295(29)	7,354 1,025	7.1	7.3
Responsibility for process	Increase Decrease	3,955(41) 197(90)	5,648(59) 22(10)	9,603 219	20.1	256.7
Responsibility for equipment and facilities	Increase Decrease	6,592(68) –	3,063(32) –	9,655 –	Very high	Very high
Responsibility for security of others	Increase Decrease	124(38) 215(95)	204(62) 12(5)	328 227	–1.7	17.0
Sums of responsibility categories	Increase Decrease	15,883(59) 1,142(78)	11,057(41) 329(22)	26,940 1,471	10.4	283.0
Subtotals	Increase Decrease	28,999(64.5) 3,301(69.9)	15,945(35.5) 1,420(30.1)	44,944 4,721	8.8	11.2
Total number of new work places investigated		32,300(65)	17,365(35)	49,665		
Mental stress	Increase Decrease	16,809(71) 6,675(75)	6,836(29) 2,264(25)	23,645 8,939	2.5	3.0
Physical strain	Increase Decrease	1,701(36) 34,906(60)	3,061(64) 22,888(40)	4,762 57,794	–20.5	–7.5

responsibility can only be satisfied if there is a broad basis for formal education and efficient vocational training. Our results demonstrate that high professional and vocational training is a necessary but not a sufficient condition for innovation to succeed.

2.4.1 Skill Requirements in the Innovation Cycle

Based on the results of our investigation, the following employment structure can be proposed for the various phases of the innovation cycle.

1. Takeoff

In this phase it is essential to employ experts who have access to information necessary to implement the innovation and who are capable of managing the technological and organizational problems. Skilled workers with handicraft experience are also very important. That is why this phase has predominantly standard production equipment and very few process innovations to unify the production process. The low scale of production does not require great numbers of skilled and semiskilled workers and thus has a small effect on employment.

2. Rapid Growth

Experts are still of importance to this phase in order to overcome the problems of extending production and making improvements in products and processes. The extension of production requires more specialized production equipment, as a result of which there is a very high demand for certain skilled and semiskilled workers. At the same time, the demand for skilled workers with handicraft experience drops. This phase has a large positive effect on employment.

3. Maturation

In this phase there is a high level of mechanization and automation, with a very high demand for semiskilled workers and a high demand for skilled workers, but with a very low demand for experts. The effect on employment is positive but low, or can be negative.

4. Saturation

By this phase the production processes are standardized and automated. There is a high demand for skilled and semiskilled workers but only a low demand for unskilled workers. The effect on employment is negative.

2.5 Innovation, Occupational Structure, and Requirements for Further Education

Only some basic innovations are able to stimulate the introduction of new occupations that require new forms of education. Most occupations are able to broaden their scope and adopt the new skill requirements, thereby changing their internal structure. Figure 17 shows the frequency with which new occupations are created as a result of innovation. Of 40 basic innovations, only 13 have triggered off particular professions and occupations over the time span 1680–1970. That is why only a small number of contemporary occupations are new. In the United States, for example, only 3% of all current occupations

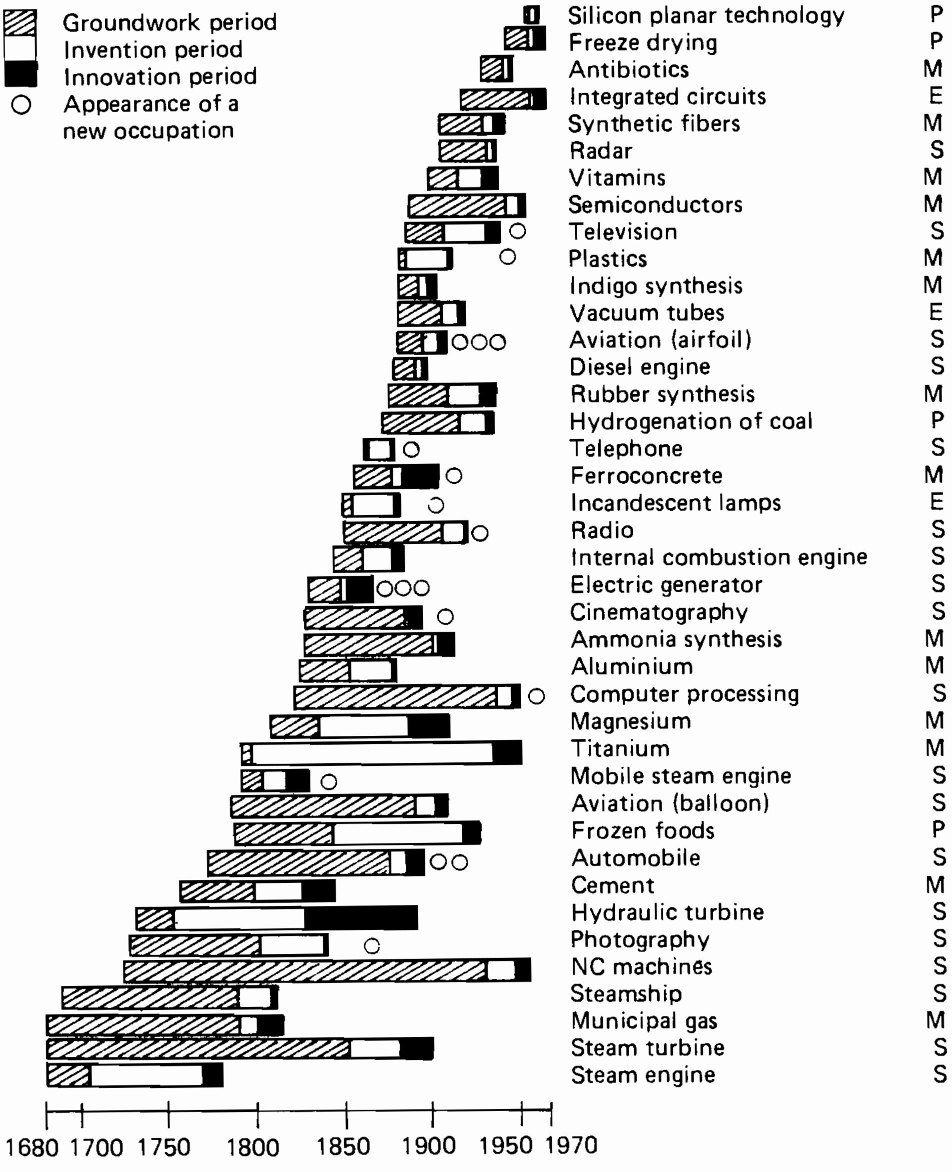

FIGURE 17 Innovations and new occupations. E, element invention; M, material invention; P, process invention; S, system invention. Source: Dörfer *et al.* (1977).

have been created since 1950. Therefore, vocational training is not challenged so much by the emergence of new occupations as by new requirements for existing occupations.

However, we should not underestimate the value of the educational system and vocational training in the process of implementation and diffusion of innovation. The stock of well educated chemistry engineers in Germany at the beginning of this century was an important foundation for the start of the chemical industry and the fast diffusion of chemistry technologies across the country.

A modern example is the development of computing technology. Figure 18 demonstrates that vocational and professional training started in the early 1950s, long before many work places existed and before most of the important technological breakthroughs. The early reaction of the educational system was obviously important.

Beside the connection between the level of mechanization and automation of the work and the level of qualification of the worker, there is a connection between the occupation and the level of mechanization and automation. Figure 19 demonstrates this with 21 occupations and their connections to low, medium, and high levels of mechanization.

Under the pressure of accelerating technological change, there is a natural tendency to integrate some specialized vocations into more basic vocations. In the GDR, for example, the number of vocations for which training was given decreased from 972 in 1957 to 658 in 1964 and 305 in 1971. The growing importance of scientific and technical training and basic vocations is, of course, by no means an expression of the reduced significance of specialized knowledge and training. Indeed, a broad differentiation in trained and basic occupations is the very precondition for specialization. Thus in the GDR at the present there are 49 broadly differentiated trained occupations and 28 basic occupations, which form the basis for about 700 specializations. The effectiveness of vocational training depends greatly on how well it is linked to practical occupational activities and how much it helps the individual to acquire specialized knowledge.

The increase in requirements for qualifications and the decrease in the number of jobs that entail hard physical work are obviously related. Mechanization not only contributes to the abolition of physical, unskilled work but also creates the conditions for automation. There is a relatively high number of unskilled workers on automated equipment at present because automation does not completely cover the production cycle: for example, feeding and emptying of automatic machines, as well as connection to other sections of the production cycle, have to be done manually. Mechanization and automation are affecting more and more of these auxiliary processes, leading to release of manpower as the emphasis on qualified workers increases.

For the better use of human resources it is necessary that management concerns itself with the following problems.

1. At the stage of devising and constructing new equipment, decisions have to be made on the amount of reduction of unskilled and physical work and on the kinds of qualifications needed for the new work. At this stage there are opportunities for increasing efficiency. The exact determination of the necessary qualifications can contribute to raising productivity.
2. Planning and realization of investments require a well timed determination of the abilities and knowledge necessary for operating new equipment. Enterprises must introduce programs for additional training. Underestimation of this aspect of preparation can lead to economic losses, caused, for instance, by breakdowns.
3. The number of women employed to do unskilled work is still relatively high. Everything should be done to prevent discrimination against them. Work should be reorganized to reduce operations that only require simple and unskilled work, as well as to reduce the monotony of work. It is necessary to analyze experiences in organizing job rotation and improving the mental climate within work teams. Where equipment still requires monotonous and unskilled operation, ways have to be found to create more meaningful work by adopting new combinations of labor, job rotation, and job enlargement.

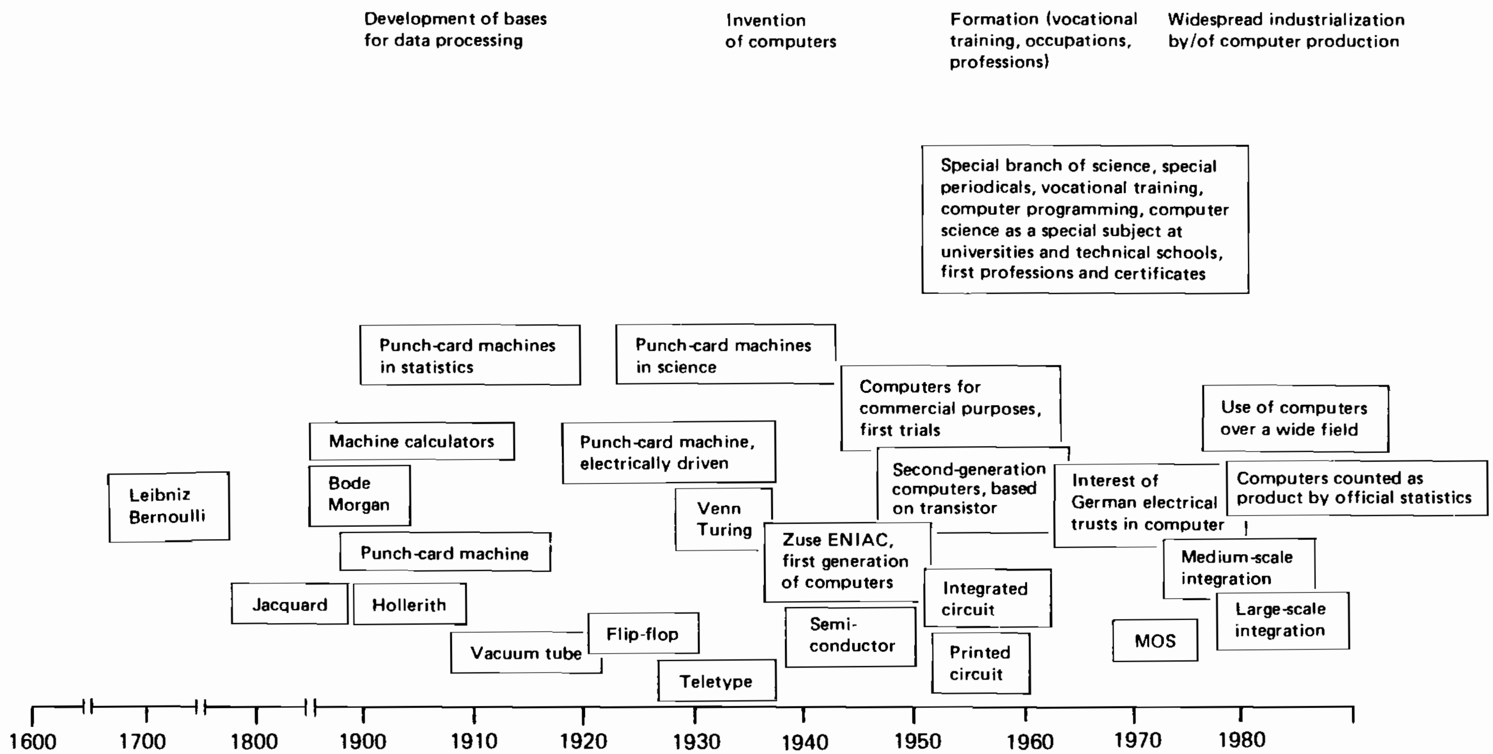

FIGURE 18 The development of computer technology (from Dostal *et al.* 1977).

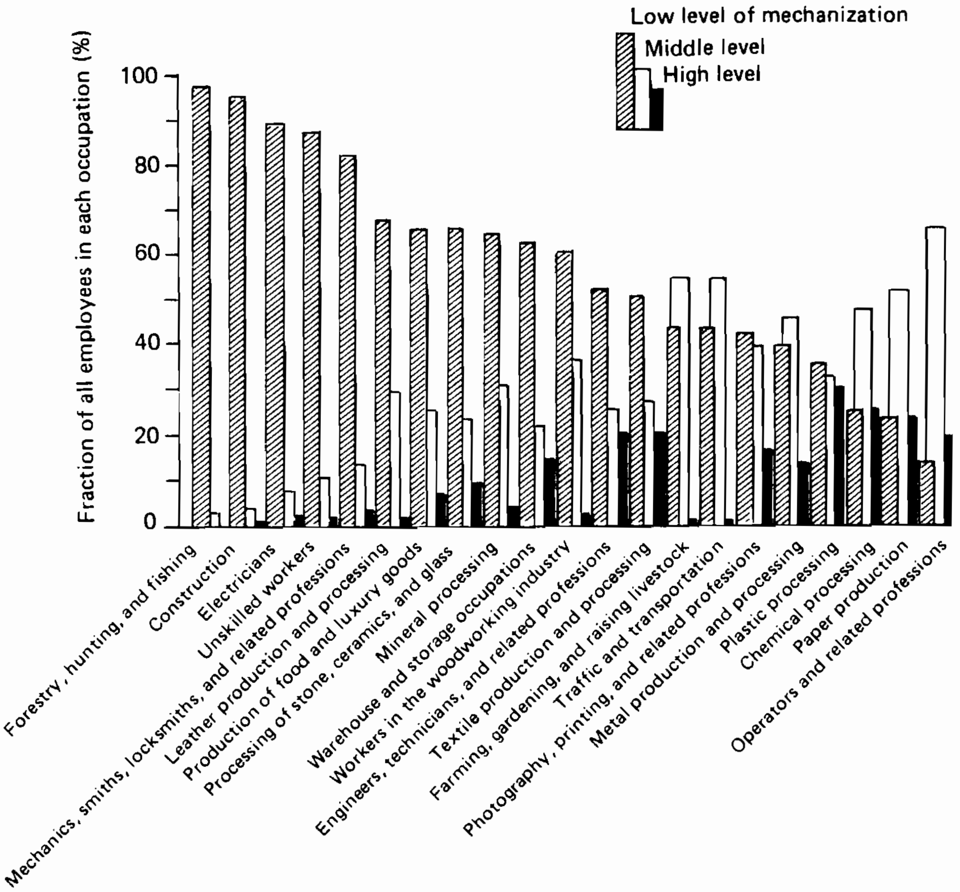

FIGURE 19 Degrees of mechanization in various occupations, as reflected by the fractions of all employees in each occupation working at different levels of mechanization in the Federal Republic of Germany in 1970. Source: Dostal *et al.* (1977).

4. The better utilization of higher education and qualification levels does not imply blocking innovations that lead to a reduction of qualification requirements. Doing so would mean preserving complicated technologies that are difficult to master. For instance, the qualifications required for operating the first computers were incomparably higher than those now necessary for operating microprocessor-based equipment. Simplification of operation and shortening of the training period are part of scientific and technological progress and contribute substantially to economic efficiency. The reduction of the mental work required to perform a particular job can have benefits for the individual. Working people need less time to gain the necessary qualifications for operating automatic equipment, and so have more time for learning about other fields. Rather than preserve mentally difficult operations, we have to reorganize work, which takes increased qualification levels into account, in order to give working people the opportunity of using their physical, social, and mental abilities in various ways to increase the efficiency of labor.

It is necessary to consider the different situations that skilled workers have to manage in various stages of mechanization and automation. In mechanized production the particular qualification of a skilled worker is a prerequisite for operating machinery that manufactures a special product. In contrast, although it is necessary for a skilled worker to have a particular qualification in automated production, this qualification is not really needed for carrying out some operations typical of automated production, such as steering and controlling. Therefore, in order to make better use of skilled workers, labor should be reorganized to enrich and enlarge the job of the individual (Langen 1979). The new division of labor should guarantee:

- new combinations of labor for creating substantial and ambitious operations;
- job rotation;
- the increased responsibility of workers in managing and planning production processes;
- the possibility for the worker to "identify" with the final product;
- a balance between physical and mental requirements;
- job enlargement;
- possibilities for communication and cooperation;
- possibilities for realizing new ideas and initiatives;
- a pleasant working environment.

An important way of securing a higher quality of human resources is to create conditions for lifelong learning by working people. In the past, the educational system confined itself largely to transferring the knowledge of the working generation to the generation

TABLE 9 Methods of adult education in the building, transport, and post and telegraph industries of the GDR in 1975.

Type of education	Percentage of employees who participated
Systematic general education	22.2
Special on-the-job training	37.3
Training for a trade	5.2
Training for skilled workers	8.4
Training for foremen	2.7
Training for technical school graduates	4.9
Training for university graduates	1.3
In-service training of skilled workers	12.9
In-service training of foremen	4.2
In-service training of technical school graduates	0.5
In-service training of university graduates	0.4

that would follow. This approach is out of date. Today, a modern educational system that excludes people already trained is unthinkable. Thus, for instance in the GDR about 20% of public expenditure on education is devoted to further training, and almost one-quarter of all workers in industry take part in training courses (half of them are women). In recent times adult education has made a noticeable contribution to the increase in the number of skilled workers and university and technical school graduates. Between 30 and 40% of today's skilled workers in the GDR gained their qualifications by adult education; every third university graduate and every second technical school graduate received their diplomas after external studies. Adult education should in future take up the function of reproducing the existing qualification level. Table 9 shows how employees in the building, transport, and post and telegraph industries of the GDR gained qualifications through adult education in 1975.

A consequence of scientific and technological progress is the obsolescence of knowledge. If we assume that the rate of progress of knowledge is 3% per annum, the following expenditures of time are needed for in-service training during the working life of an individual: skilled workers, 2.8 yr (10% of working life); technical school graduates, 6.7 yr (24%); university graduates, 7.8 yr (28%) (Figure 20). Of course, there exists no "law of

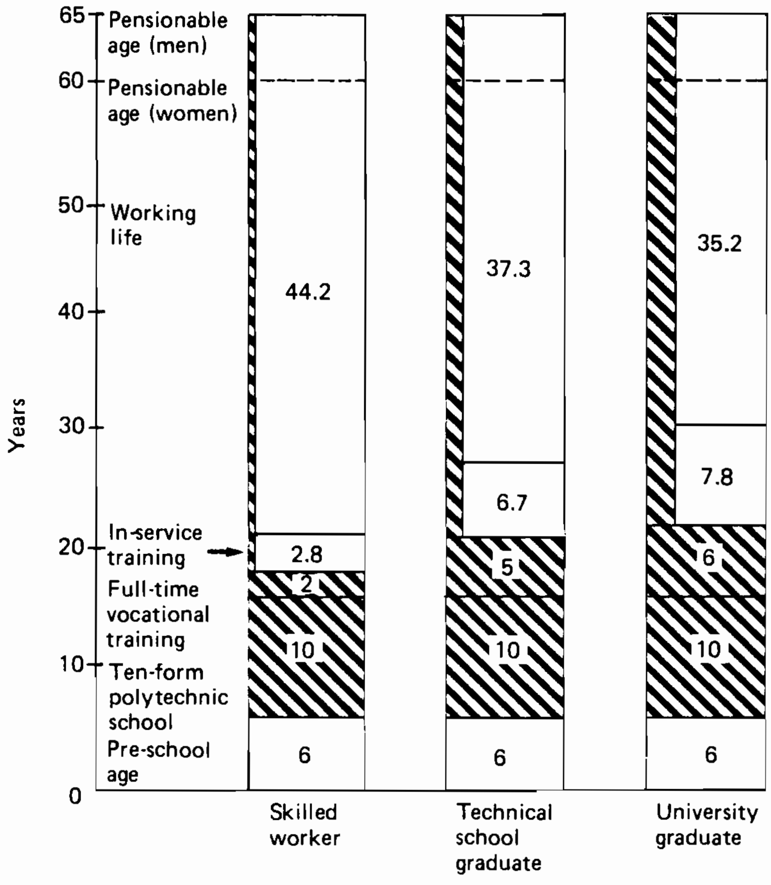

FIGURE 20 Full-time education, in-service training, and working life of different qualified workers in the German Democratic Republic.

increasing expenditure" for in-service training, but these numbers show how important it is to take measures in good time to compensate for this obsolescence of knowledge and to ensure a mixing of education and work so that adequate in-service training is available. In-service training should also strive to raise the capacity of the individual for self-education (innovative learning). At present about 80% of organized in-service training in the GDR is during working hours, which is expensive. Furthermore, there is the danger that if in-service training is too tightly bound to the operations and tasks of the work place, it will not succeed. The desirable characteristics of in-service training are that it is organized, that it is compatible with personal interests, and that it includes participation in various forms of intellectual and cultural activities.

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