INNOVATION, EFFICIENCY AND THE QUANTITATIVE AND QUALITATIVE DEMAND FOR LABOR

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INTRODUCTION

In the past few years the main concern of the economist's analytical work has been more the better use of natural resources, rather than that of human resources. Most of use are more immediately concerned about the shortage of energy than about the shortage of ideas, and the individual and institutional capabilities to overcome this shortage. But most of our natural resource problems are only a reflection of deeper problems, problems occuring through a significant lack of social and technological innovation which hinders the capability of human beings to solve the problems that are facing us at the present time. This is why the relationship between human resources and social and technological innovation is so critical. This relationship is currently challenged through the following issues:

1. The growing imbalance between natural and human resources in different world regions.

2. The inadequacy of technology for the better use of human resources, especially in the developing countries.

3. The social inability to coordinate the innovation cycle of basic and improvement innovations as barriers for the better use of human resources.

4. The necessity to improve the quality of human resources and to create the right conditions for their better use (H.Maier, 1979).

This paper would like to focus on the following three problems:

1. Innovation, human resources and efficiency.

2. Innovation and the employment effect of investment.

3. Improvement in the quality of human resources and their better use.

INNOVATION, HUMAN RESOURCES AND EFFICIENCY

The influence of innovation on the quantitative and qualitative requirements of the labor force has been studied, especially in the past, from the point of view of the relationship between automation and human resources. This is one of the reasons for the domination of a one-sided or controversial approach in this field.

A better understanding of the relationship between innovation and the development of quantitative and qualitative requirements, requires a deeper understanding of the innovation process, especially the interlinkages between innovation and efficiency. For this purpose, we have developed, within the innovation group of the International Institute for Applied Systems Analysis, a research institute which includes researchers from market economies and socialist countries, the following concept. The focus of our approach is the relationship - innovation, human resources and efficiency. In this context it is very helpful to distinguish three kinds of efficiencies:

Dynamic efficiency: that is the efficiency of the production unit that has adopted the innovation ($e_{(i)}t$).

Average efficiency: that is the efficiency of the entire production field ($\tilde{e}(t)$).

Relative efficiency: that is the efficiency of these two kinds of efficiency

$$X_{(t)} = \frac{e_{(i)}t}{\tilde{e}(t)} .$$

Unfortunately, we have until now no appropriate instruments to measure the development of the relative efficiency of innovation in a clear cut way. But, what we can do is to look more carefully at the different phases through which the dynamic efficiency is moving. It is obvious that the relative efficiency is changing during the five phases of the innovation cycle: take-off, rapid growth, maturation, saturation, and crisis. (H. Maier, H.-D. Haustein, Innovation, Efficiency Cycle and Strategy Implications, 1980). Obviously the management situation is also changing during this time.

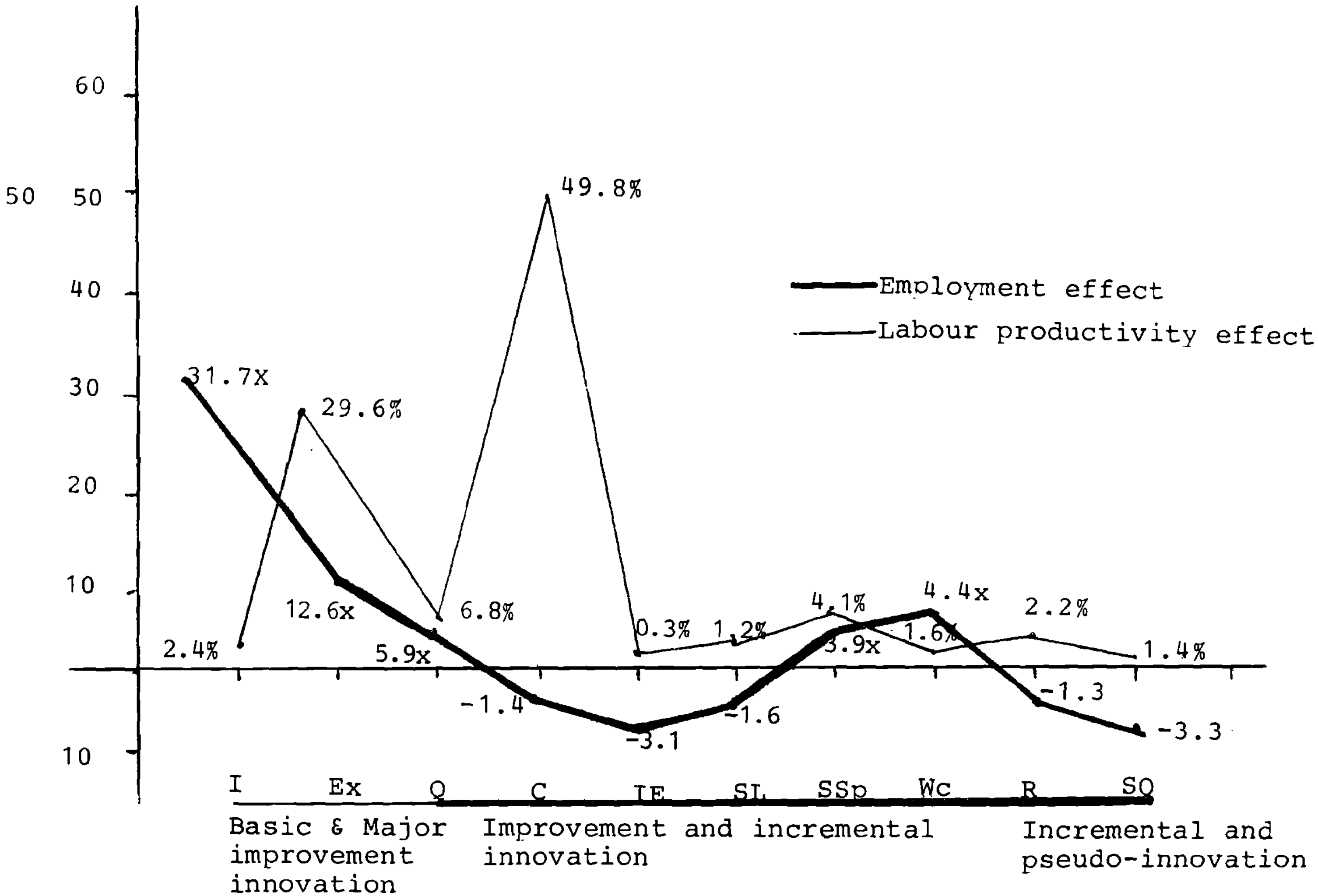
One of the most important factors of this change is the change in requirements for the quality and quantity of the labor force.

It is not possible to explain in detail the application of this model in different industries and countries. However, maybe the most important thing we can learn from the relative efficiency concept is the importance of making a difference between basic, improvement and pseudo-innovation (H.-D. Haustein and H. Maier, 1980).

Basic innovations are innovations which create a new efficiency potential, and open new fields and directions for economic activities. The main function of improvement innovations is the absorption of this efficiency potential through balancing and improving the given system. Most of them are incremental innovations. The improvement innovation becomes a pseudo-innovation at the point where it is unable to secure higher efficiency of the production unit than the average efficiency of the whole system.

We are trying to prove our hypothesis about the importance of different kinds of innovations with the help of empirical data. For the purpose of this paper our findings about the employment and productivity effect of the different kinds of innovation were especially revealing. We can identify the two effects with the help of data gathered from the "Institut für Arbeitsmarkt und Berufsforschung" in Nürnberg, Federal Republic of Germany. This is data from 2266 technological changes within 909 firms from 4 industrial branches (plastics, metal-work industry, food industry, wood and furniture industry) in the Federal Republic of Germany during the period 1970-1973. (W. Dostel, G. Lahner, and E. Ulrich, 1977.) By the employment effect of innovation we mean the relationship between created and eliminated working places due to technological change. The productivity effect is the contribution of the different kinds of innovation to labor productiivty growth due to technological change.

Figure 1 demonstrates that basic and major improvement innovation have the highest employment effect and a high contribution to productivity growth too. Among them the implementation of new products had the highest employment effect. It created 31.7 times more new working places than it eliminated. But this contribution to labor productivity growth due to technological growth was relatively low - only 2.4%. This is a typical activity in the take-off stage of the innovation cycle. The extension of innovations - an activity in the rapid growth stage of the innovation cycle - is able to contribute significantly to labor productivity growth (29.6%) and is also able to secure a high employment effect (12.6x). The major improvement in the quality of the product has been able to contribute to labor productivity growth by 6.8% and to create 5.9 times more working places than it eliminated. It is important to realise that basic innovation is doing both, i.e. creating many more working places than any other type of technical change and contributing significantly to productivity growth.



I: implementation of new products. Ex: extension of capacity. Q: new quality of products.
C: cost reduction innovation. IE: improvement of efficiency. SL: reduction on shortage of labor.
SSp: reduction on shortage of space. Wc: improvement of working conditions.
R: replacement of product equipment. SO: shortage of orders.

Figure 1. Employment effect and labor productivity effect of different kinds of innovation (results of an investigation of 2260 technological changes within 909 firms in 4 branches of industry in the Federal Republic of Germany)

Improvement innovations devoted to cost reduction have naturally the highest contribution to labor productivity growth (49.8%), but they are the starting point from which the employment effect is becoming negative. They eliminated 1.4 times more working places than they were able to create. Only in the case of improvement of working conditions and production space is the employment effect becoming positive again, for obvious reasons.

But in other types of technical change due to medium improvement and incremental innovation, which occur in the fourth phase of the innovation cycle, the employment and productivity effects are very low. For example, the short-term reaction of a shortage of workers has an employment effect of only -3.3 and a productivity effect of 1.4%.

That proves our hypothesis that a low employment effect is not so much a result of the development of labor productivity - which is what some of our colleagues have claimed up to now - but the result of the dominance of medium improvement and incremental innovation in economic activities. This can also explain why, at the present time, some of the industrially developed countries are faced with both a decline in productivity growth rates and a high rate of unemployment.

INNOVATION, INVESTMENT AND THEIR EMPLOYMENT EFFECT

The exploration of the causes for the change in the quantitative and qualitative demand for human resources requires a better understanding of the relationship between innovation, investment and employment. This linkage is far from being well understood. In several studies and statements we can find a very one-sided interpretation of the relationship "Investment and Labor Demand". People usually assume that employment is only a function of investment. The statement is: If we have enough investment we will have enough work places or if we have too many working places we need investment to eliminate the inefficient ones. The recommendation for government policy is consequently to create the conditions for higher returns on investment. But it is dangerous to follow blindly such a recommendation.

The returns on investment are very much dependent on the efficiency potential of innovation which is incorporated in investment. The innovation which is incorporated in investment is also different and has different employment effects. Obviously we have to differ between two kinds of innovation:

- Innovation which is driven by investment. This is the improvement and incremental innovation. As Figure 1 shows there is a negative employment effect.

- Innovation which is driving investment. This is basic innovation which opens new fields for investment activities with higher potential efficiency rewards. According to our empirical findings the employment effect is very high here.

Basic innovations which are creating a new efficiency potential and open new fields for economic activities are naturally closely connected to extensionary investment. Improvement and incremental innovations are more connected with rationalization and replacement investment. Obviously we have seen in the last few years in market economies a very important change in the direction of investment. Investment was directed more and more towards improvement and replacement innovation and not so much towards basic innovation. Figure 2 shows the development of the relationship between investment and employment. The case of the Federal Republic of Germany is here typical for OECD countries (G. Mensch et al., 1980).

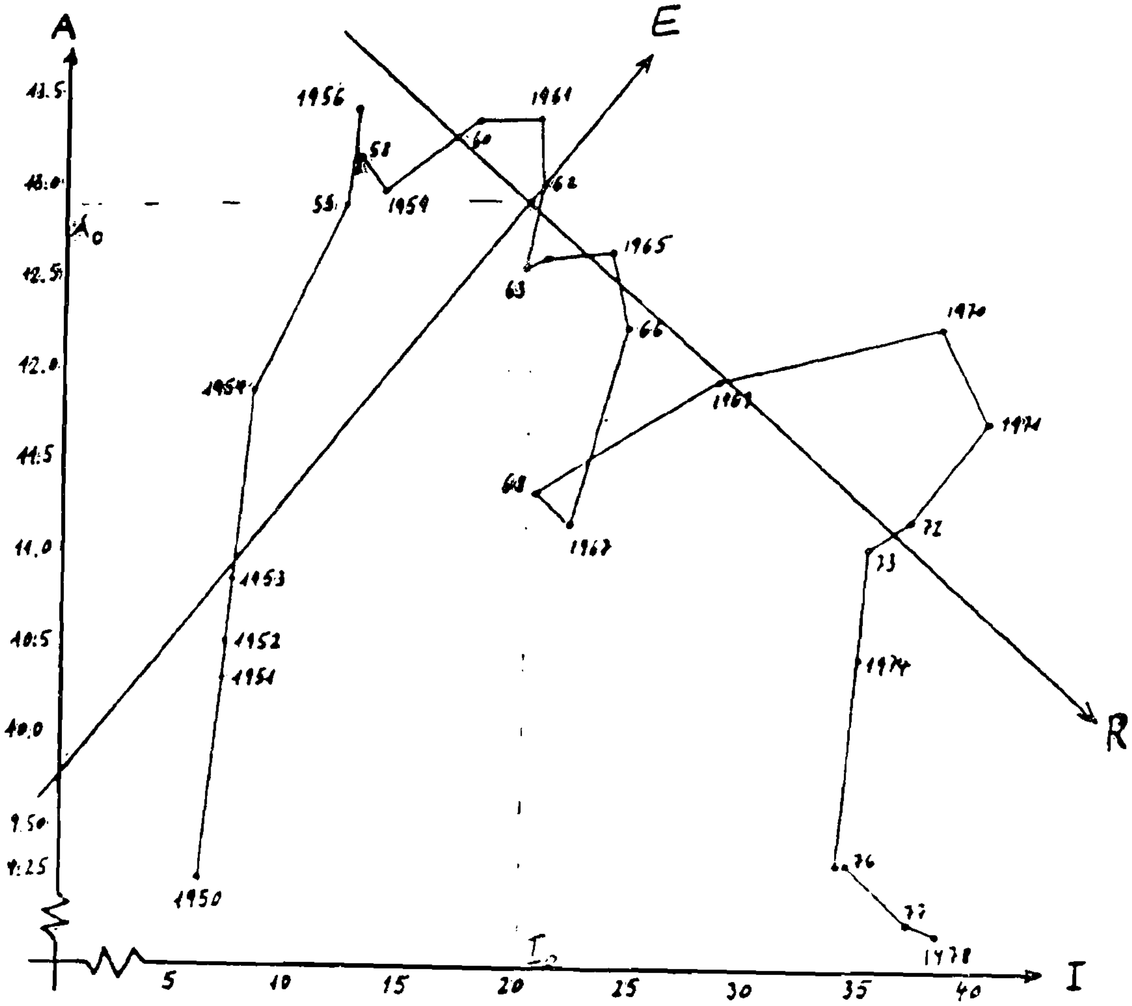
In the European socialist countries we have the opposite situation. Through high demand for industrial goods and high growth rates in industrial production, there has been a great deal of expansionary investment.

However, the demand for higher flexibility and structural change create different situations in different industries. Figure 3 shows us the situation in the entire GDR industry and the rather different situations in the textile and electro-engineering industries in the GDR. The textile industry of the GDR obviously had a high share of rationalization investment with a significant release in the work force. In the electro-engineering industry the expansionary investments were dominant with the effect of creating a large number of work places.

At the present time, the process of creating work places through the influence of demand and efficiency factors in the industries of the CMEA countries, is higher than the elimination effect of working places through investment.

The result of this is that in socialist countries like the GDR and CSSR we have a significant shortage in the labor force or many vacant work places. For this reason the desire for improvement and rationalization innovation is very high and these countries are therefore trying to increase the share of rationalization and replacement investment. But this must be understood as an attempt to strengthen the economic performance of these countries and to improve their capability to implement basic, urgent innovations in the fields of energy, microelectronics, machine-tool industry, etc.

Therefore, I think it is dangerous to ignore both the linkage between expansionary, rationalization and replacement investment and the linkages between basic, improvement and incremental innovations. Basic innovations are preconditions for improvement innovation and improvement innovations create the economic power for implementation of basic innovations. A parallel relationship exists between expansionary investment and rationalization investment. Therefore recommendations which only put emphasis on expansionary investment without taking into account their interrelationship and their linkage to special types of innovation fail to give appropriate



Legend: A = Industrial working hours (10^9 h)

I = Real Industrial Investment (10^9 DM)

E = Index of expansionary investment

R = Index of rationalizing investment

$I_o = I_{1961} = 20.7 \; 10^9$ DM

$A_o = uA_{1961} = 12.9 \; 10^9$ h

u = labor capacity utilization ratio, based on 4% "full employment overload"
= 100/104 = .962

Figure 2. Labor Hours and Real Investment Capital Input in West German Industry 1950 - 1978.

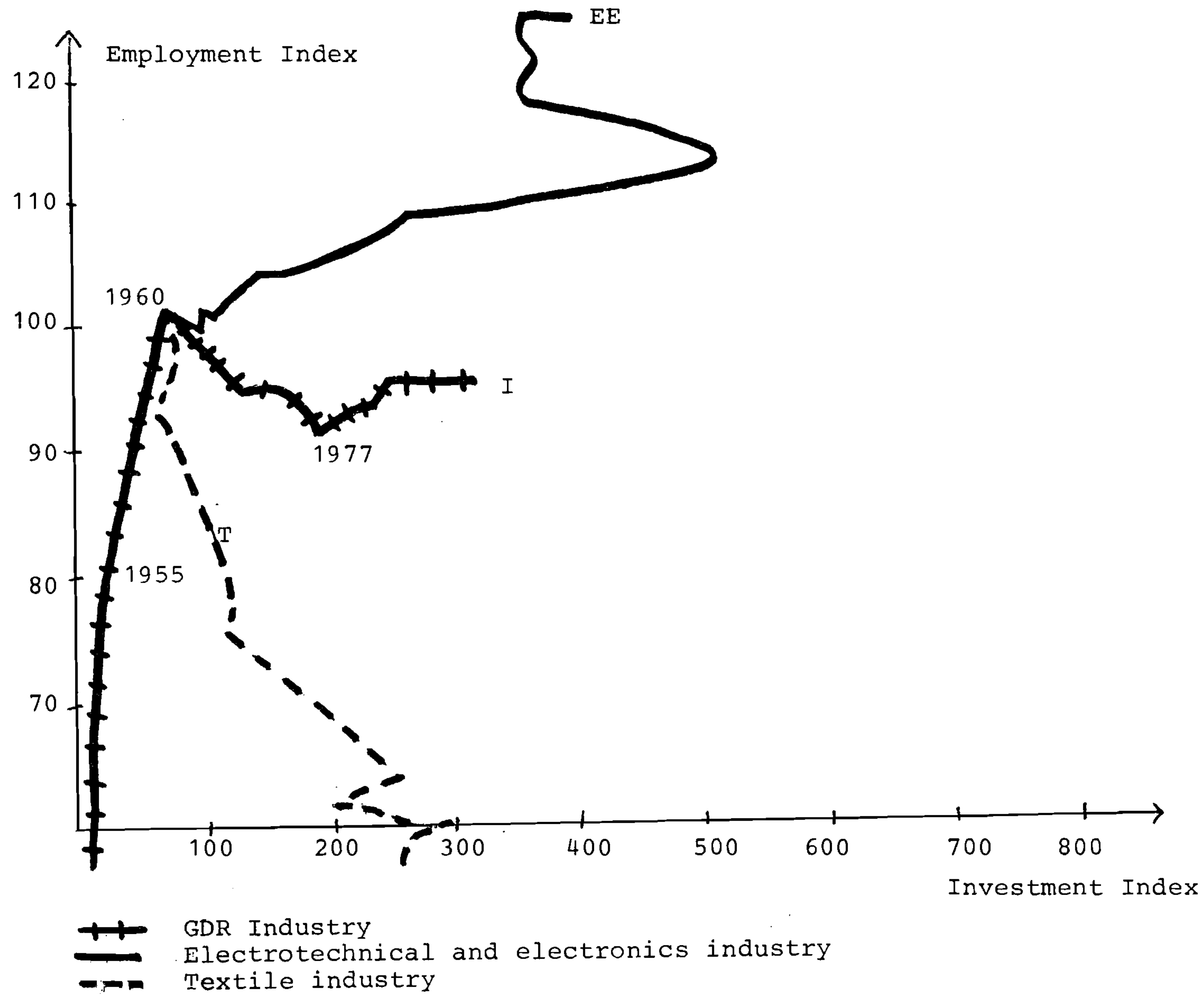


Figure 3. Development of differences between the three major industries in the GDR.

guidance for the management of innovation. For example, the increase in 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 investment which are not connected to improvement innovation adopting the efficiency potential created by basic innovation, will make the existing work places vulnerable against any attack from an innovative rival or will create working places with lower efficiency which only exist because of the protection policy of the government.

From the nature of the innovation process we can draw one conclusion: To secure the better use of human resources we need efforts to coordinate the innovation cycle. If the main industries are approaching the saturation stage then there will necessarily be a gap between the elimination of working places and the re-employment capability of industry. It is without doubt that this is one reason for the employment problem in some market economies. That means that the cycle must be kept going.

However, coordination of the innovation cycle calls for planning and coordination of the innovation process. In this way innovation policy is becoming more and more unified with structural employment policy. The situation in countries with different social systems is certainly rather different. For example, the European socialist countries are currently faced with the problem of providing a high rate of release of manpower through improvement and rationalization innovation as a pre-condition of innovation in the field of energy, microelectronics and the machine tool industry.

THE IMPROVEMENT IN THE QUALITY OF HUMAN RESOURCES AND THEIR BETTER USE

Most of the industrialized countries have seen a significant improvement in the quality of human resources in the last two decades. On one side the higher quality of human resources is an important pre-condition for technological and social innovations, and on the other side it is not possible to approach a higher quality of human resources without social and technological innovations. The creation of social conditions in which the quality of human resources can grow and become a decisive social and economic force is a crucial point for the further social progress of mankind.

In the economy of the GDR for example, the quota of graduates from technical schools and universities increased from 6.7% of employees in 1962 to 17.2% in 1977. During the same period the quota of skilled workers and foremen rose from 33.6% to 48.2% and the quota of semi-skilled and unskilled workers declined from 59.6% to 24.6%.

It can be foreseen that up to the end of this century the quota of graduates of technical schools and universities will increase to about 20-25%, the quota of skilled workers to about 65%. The quota of semi-skilled and unskilled workers will decrease to about 10-15% (Korn and Maier, 1977). See Figure 4.

Therefore, today's educational outlays are by no means of slight importance when it comes to the distribution of national income, as was actually the case even in the developed industrial countries at the beginning of this century. At that time, they amounted to only 1 to 2 percent of national income, but today in countries like the GDR, 5-7 percent of national income is devoted to education (see Table 1).

The increasing importance of qualified labor in the production process can be seen in the rising volume of educational funds (human capital) in the GDR economy. The educational funds (human capital) are the expenses of society for education and qualifications, materialized in the qualification level of employees. The educational funds in the GDR increased from 66.5 billion marks in 1962 to an amount of 150.8 billion marks in 1975. That is about one quarter of the funds of fixed assets (material capital) of today's GDR economy (see Figure 5).

In the period between 1962 and 1975 the growth rate of educational funds (human capital) was essentially higher than that of the funds of fixed assets (material capital). During this time the educational funds increased to an amount of 227%, compared with an increase of 165% of the funds of fixed assets. The research funds in the material sphere - the research expenses materialized in the scientific level of production - increased to an amount of 333.5%. Educational funds, production funds, and research funds are the technological funds of a society, which gain more and more importance for the scientific-technical revolution. In 1972 the technological funds of the GDR consisted of 73% production funds, 21% educational funds, and 6% research funds (see Figure 6).

The necessity to extend the technological funds, absorbs 53% of the increase of labor productivity during the 1960-1975 time period, but 47% was available for improvement of the labor payment, social and cultural expenditure and other governmental activities.

Currently in the industrialized countries, each percentage of the labor productivity growth is connected with the extension of technology funds. This is due to the fact that up until now the development of technological funds has been in the extensionary phase of development. In other words, that each improvement of labor productivity needed an extension of investment, occupational funds and research funds. During the time period of 1960-1975, the labor productivity increased by 1%, in connection with the extension of production funds by 1.25%, the occupational education funds by 1.35% and the research funds by 5.35%.

Occupational education funds included the expenditure for occupational and professional training, but not the expenditure for the general education. The occupational funds were only a part of the entire educational funds. For example, in 1975, the

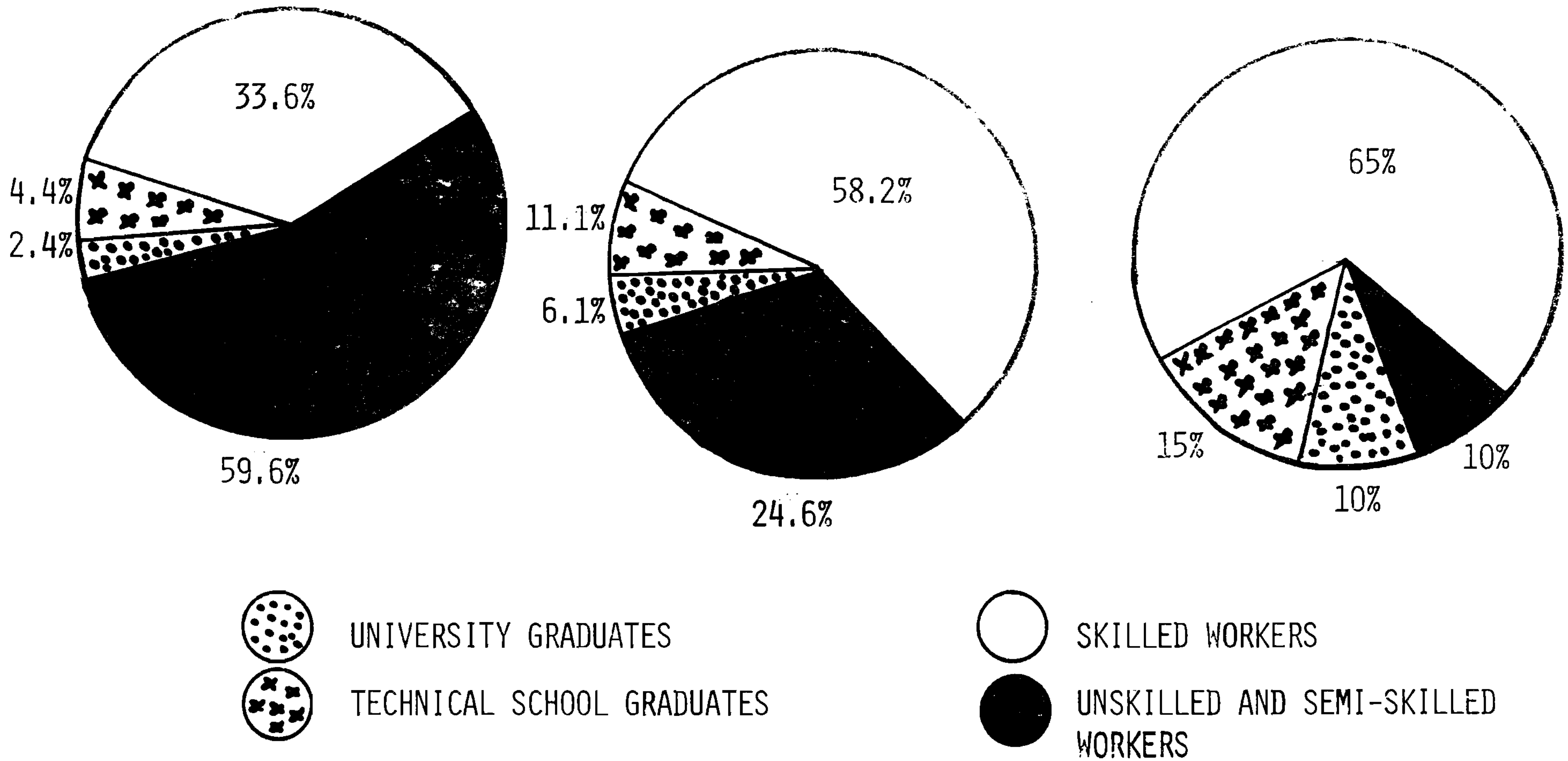


Figure 4. Qualification structure in the economy of the GDR (%)

Table 1. Development of public expenditure on education as percent of gross national income (market economies) or national income (planned economies).

COUNTRY	1955	1960	1965	1970	1975
Planned economies					
1. BULGARIA	2.8[2]	5.0[4]	4.5	4.9	5.3[5]
2. CZECHOSLOVAKIA	-	4.2	5.3	4.4	4.5[5]
3. GDR[1]	4.7	5.1	5.1	5.3	5.8
4. POLAND	3.7[3]	4.6	3.8	3.6	4.0
5. USSR	5.8	5.9	7.3	6.8	7.2
6. HUNGARY	5.0[2]	4.4	5.4	4.5	5.6[5]
Market economies					
1. Austria	4.0	3.7	3.7	4.6	5.7
2. France	2.0	3.4	4.2	4.7	5.6
3. FRG	3.5	3.7	3.4	4.0	4.5[5]
4. Italy	2.5	3.9	5.2	4.3	5.0
5. U.K.	3.2	4.2	5.1	5.0	6.2[5]
6. Japan	6.1	6.5	4.3	3.9	5.5
7. U.S.A.	4.0	6.2	5.3	6.4	6.2
8. Sweden	2.6	4.5	6.2	7.7	7.4

1 = without investment; 2 = 1954; 3 = 1954 estimate; 4 = 1961; 5 = 1972.

Source: Unesco Statistical Year Book 1963 - 1977, Paris, Jahrbuch der DDR, Rocznik Statysty czny VR Polen, Norodnoje chozjaistvo SSSR

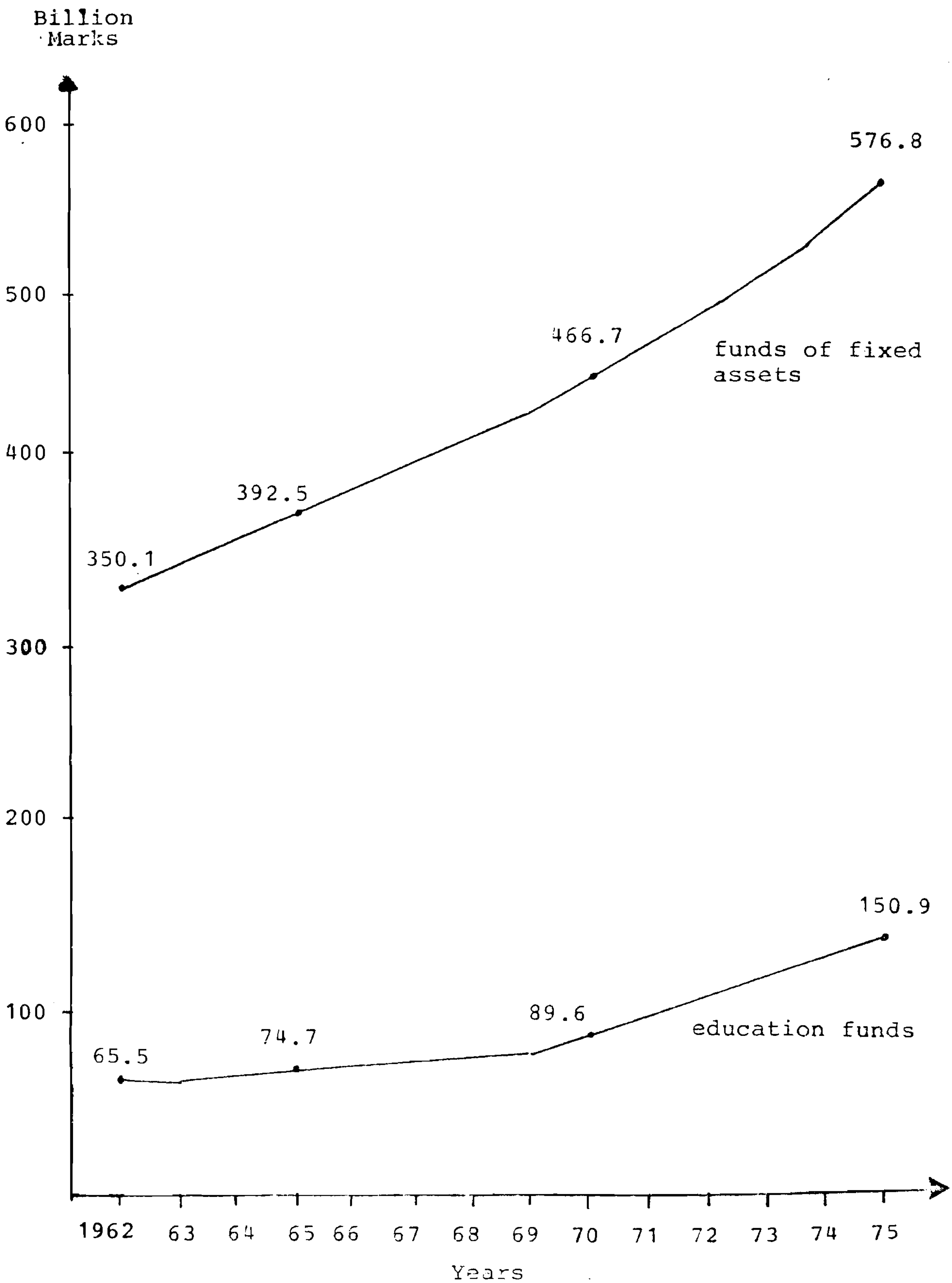


Figure 5. Development of education funds (human capital) and funds of fixed assets (material capital) in the socialist economy of the GDR (Billion Marks).

1972

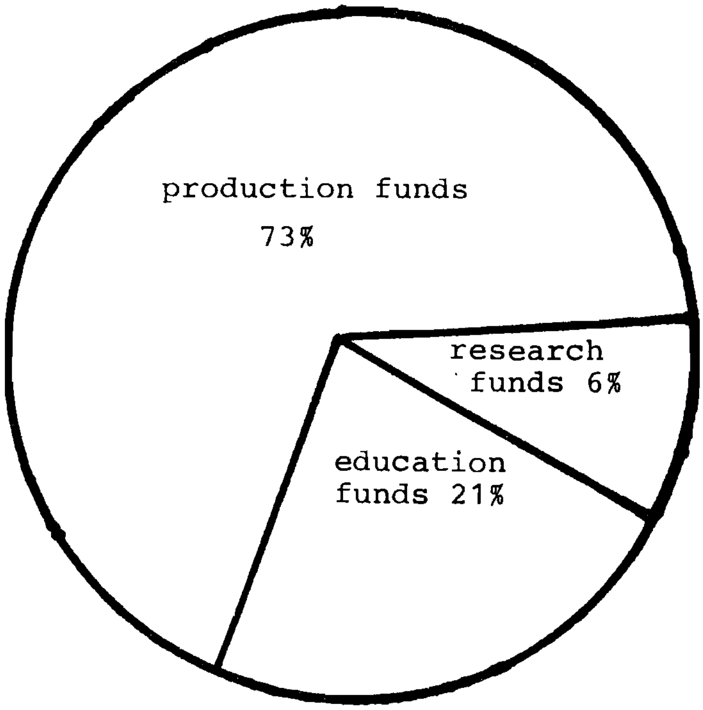


Figure 6. Composition of the Technological Funds of the GDR Economy (%).

entire educational funds in the GDR were 110.556 million marks in the production sphere, but the occupational funds were only 20.580 million marks. The occupational funds were included in the estimation as they related closer with the development of labor productiivty than with the entire educational funds. This does not mean, however, that there is no relation existing between general education and labor productivity growth.

At the moment there does not exist in the industrial countries any identification of a change in trend for the extension of technological funds, especially in reference to investment requirements in energy, environment, etc., skill and research requirements for the new fields of innovation, which are cited from the current resource situation and technological possibilities. This means that the extension of technological funds will also in the future be an important pre-condition for the improvement of labor productivity.

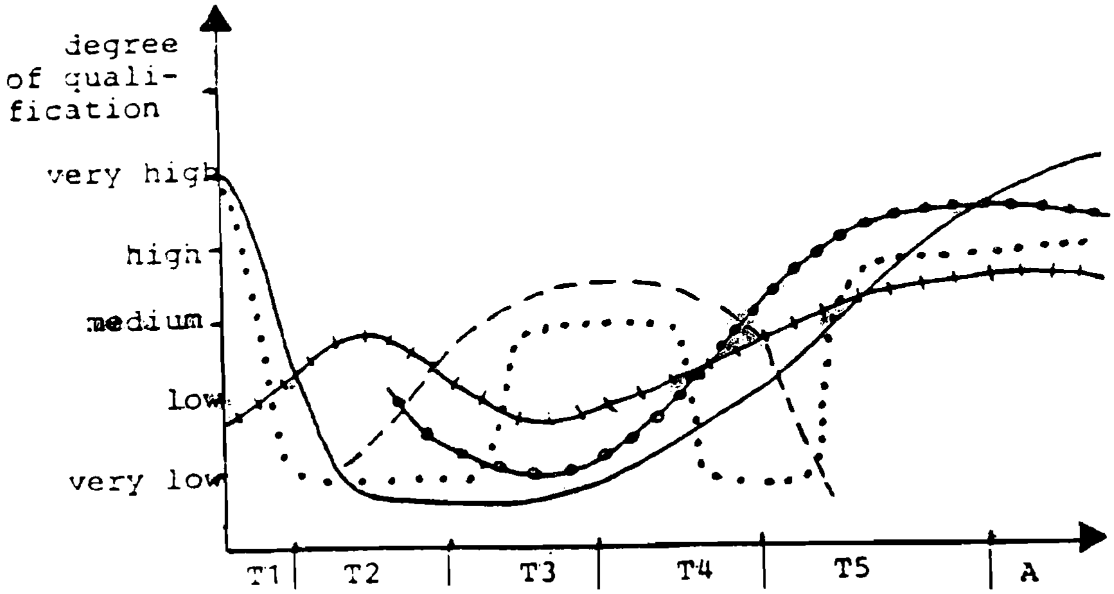
The break of links between the labor productivity growth and the extension of technological funds, could only be the result of the improvement of the efficiency of the technological funds themselves. This may well be one of the most important problems for the developing countries in the next 10-20 years in their battle for higher economic performance. A higher efficiency of technological funds could only be the result of higher innovations in the machinery/tool industry, the educational system and the efficiency of R&D activities.

Countries like the GDR, with a very fast improvement in the quality of human resources in the last two decades and with the possibility of an even higher improvement, are now faced with the problem of having to use the higher professional and occupational levels to increase innovativeness of production.

In contemporary literature, there exists a bias which assumes that automation is the highest step of innovativeness and therefore, skill requirements occuring through automation are typical for high innovative processes.

Our innovation model pointed out that it is impossible to equate innovation with automation. Automation is a process which occurs in the maturation and saturation stages of the innovation cycle. That is why the skill requirements of the automation process are not typical for the entire innovation process. However, the different stages of mechanization and automation are connected with different skill requirements. In discussions, there is disagreement about the direction in which mechanization and automation will shift the skill requirements. Theories about "deskillization", higher skills, and polarization are being discussed at the same time (see Figure 7).

Our investigation about the impact of structural and technological change could neither confirm Blauner's theory - according to which mechanized production requires low skills and automated production higher skills - nor Bright's theory - according to which mechanized production requires high skills and automated production low skills.



Blauner (USA) ---- Bright (USA) .... Kern/Schumann (BRD)

Richta (CSSR) Sociological Analysis (GDR)

T1 - manual work places

T2 - partly mechanized working places

T3 - fuzzy mechanized working places

T4 - partly automated working places

T5 - fully automated working places

Figure 7. Different Opinions from the Literature about the Influence of Mechanization/Automation on the Qualification Structure.

Instead, it must be assumed that technological and structural change have the tendency to lead to polarization of job functions and job requirements with a growing dominance of higher skills and knowledge requirements. On the one hand, very simple and usually monotonous jobs were created on a lower level, while on the other hand, activities requiring higher skills remained the same or were newly created - by increasing their importance. At the same time, the proportion of complex activities demanding a medium level of qualifiactions declined.

In Figure 8, we have collected data about requirements and existing skills in the GDR industries according to the different technological levels of industrial production. (This analysis includes more than 2.5 million workers of the GDR - i.e., more than 50% of the workers involved in production in the GDR.) The data shows us that we have, especially in the partly mechanized workplaces (T_2), fully mechanized workplaces (T_3) and partly automated workplaces (T_4) a higher share of skilled workers, than from the pure technical point of view seems to be necessary. At the same time there is a shortage of semi-skilled workers and a surplus of unskilled workers. This last problem requires the training of unskilled workers to become semiskilled workers. In the GDR there exist well established procedures to deal with this problem. A more serious problem is the existence of a problem which could at the first glance be termed 'overqualification'. Does this so-called 'overqualification' exist? From our point of view it is not possible to reduce the skill requirements only on the level, which is necessary from the technical point of view. We must also take into account that a high proportion of unskilled workers could be a momentum for the reduction of unskilled workers and the development of new options for the better use of skilled workers through new organizational arrangements and the development of an innovative movement of workers.

However, it is necessary to repeat that skill requirements which occur at the different levels of mechanization and automation are not equal with the different stages of the innovation process. Up until now, the change in skill requirements during the innovative process was not really investigated. This is a disadvantage for both the management of innovation processes and the use of human resources.

It is true that only a part of basic innovations are able to trigger-off the development of new occupations which require new forms of education. Most occupations are able to broaden their outlook and make appropriate changes within the occupation profile. Figure 9 shows the frequency of occupations created in connection with innovation. From 40 basic innovations in the time span 1680-1970 only 13 have been able to trigger-off particular professions and occupations.

New professions are only a small part of the entire contemporary occupations. In the U.S. for example, only 3% of the entire occupations were mostly able to adopt the new skill requirements within the existing occupation. This very much enriches the features of the existing occupations and changes the internal structure of the occupation. This means that

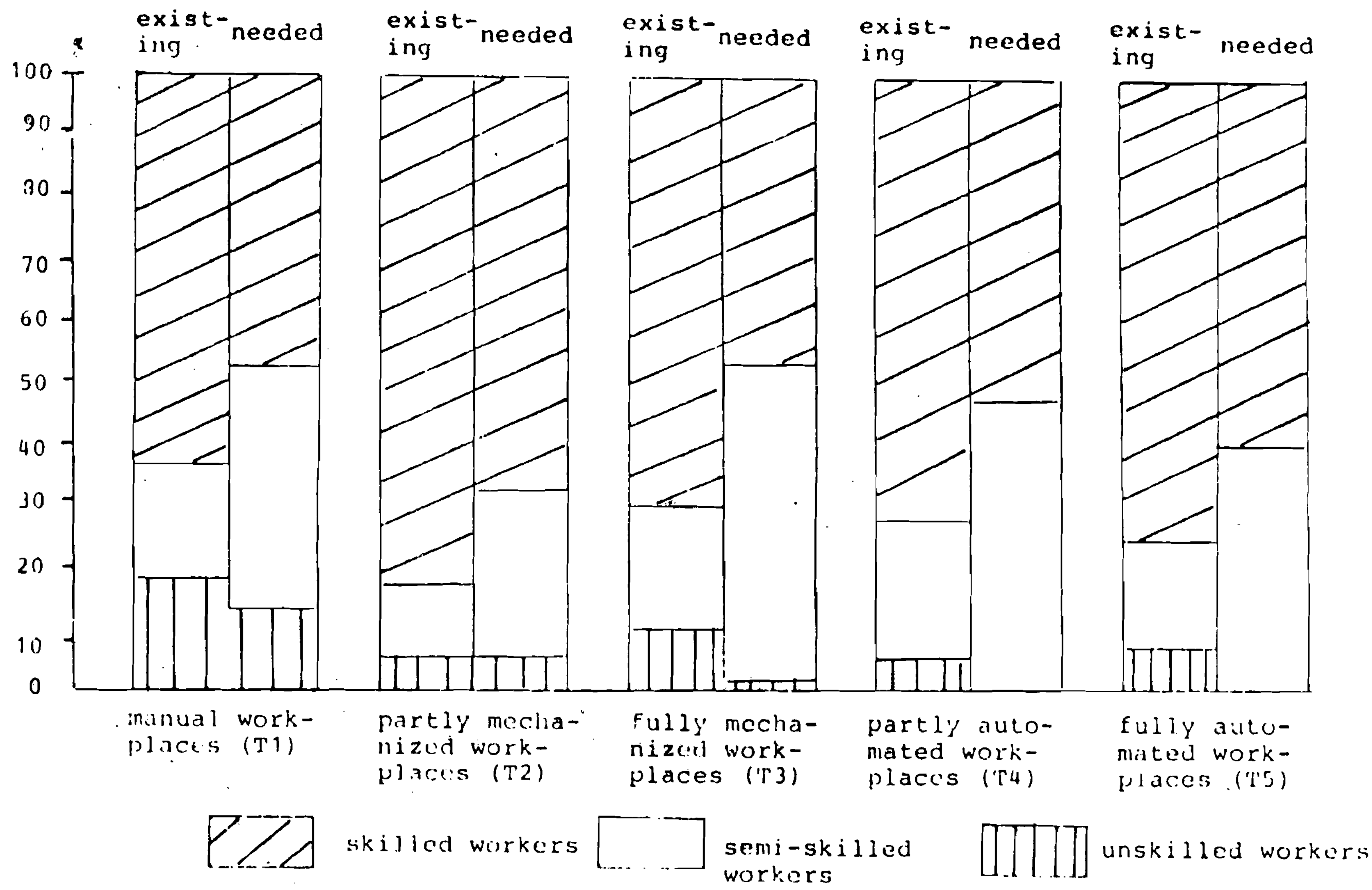


Figure 8. Existing and needed qualification structure of production workers in various stages of technological development in industry (%).

vocational training is not challenged so much through the emergence of new occupations but through new requirements for and within existing occupations. This stresses the importance of in-service training.

On the other hand, the educational and vocational system has always played an important role in the process of implementation and diffusion of innovation. If we consider computer technology: Because of education activities which began in the late 1950's and the beginning of the 1960's in data processing, it was possible, very soon, to react to the technological breakthroughs at the beginning of the 1970's and to significantly speed-up their implementation and diffusion.

However, if we look at the change in the work content and skill requirements due to high innovative and low innovative technology, we will not find any significant differences. At IIASA we have tried to use the above mentioned data from 909 firms from four industrial branches (plastics, wood and furniture, food and metalwork) of the Federal Republic of Germany for 2266 different technological changes from 1970 - 1973 to gain insights about the influence of high and low innovative processes on work content and skill requirements. Figures 10 and 11 demonstrate the results of our investigation. Does this mean that higher skills, professional and vocational education are not so important for the innovation process? That would not be the correct conclusion from our findings. Our results only demonstrate that high professional and vocational training is a necessary, but not a sufficient condition, for innovation. But the better use of human resources is calling for a more detailed investigation of the different skill requirements in the particular stages of the innovation process.

Based on the data presented above, we can assume that the following relationship exists (see Figure 12): That means in the <u>Implementation Stage</u>

- o highly skilled experts are decisive. These are people who have access to information necessary to implement the innovation and the capability to manage the technological and organizational problems. Here the technological and managerial skills are decisive. The openness of the organization and productive relationships between knowledge and power promoters are important pre-conditions.

- o very important in this stage are skilled workers with handicraft experience. That is why in this stage we have a domination of universal production equipment and very few process innovations to unify the production process.

- o through the low scale of the production process we have medium requirements for skilled and semi-skilled workers and a low employment effect.

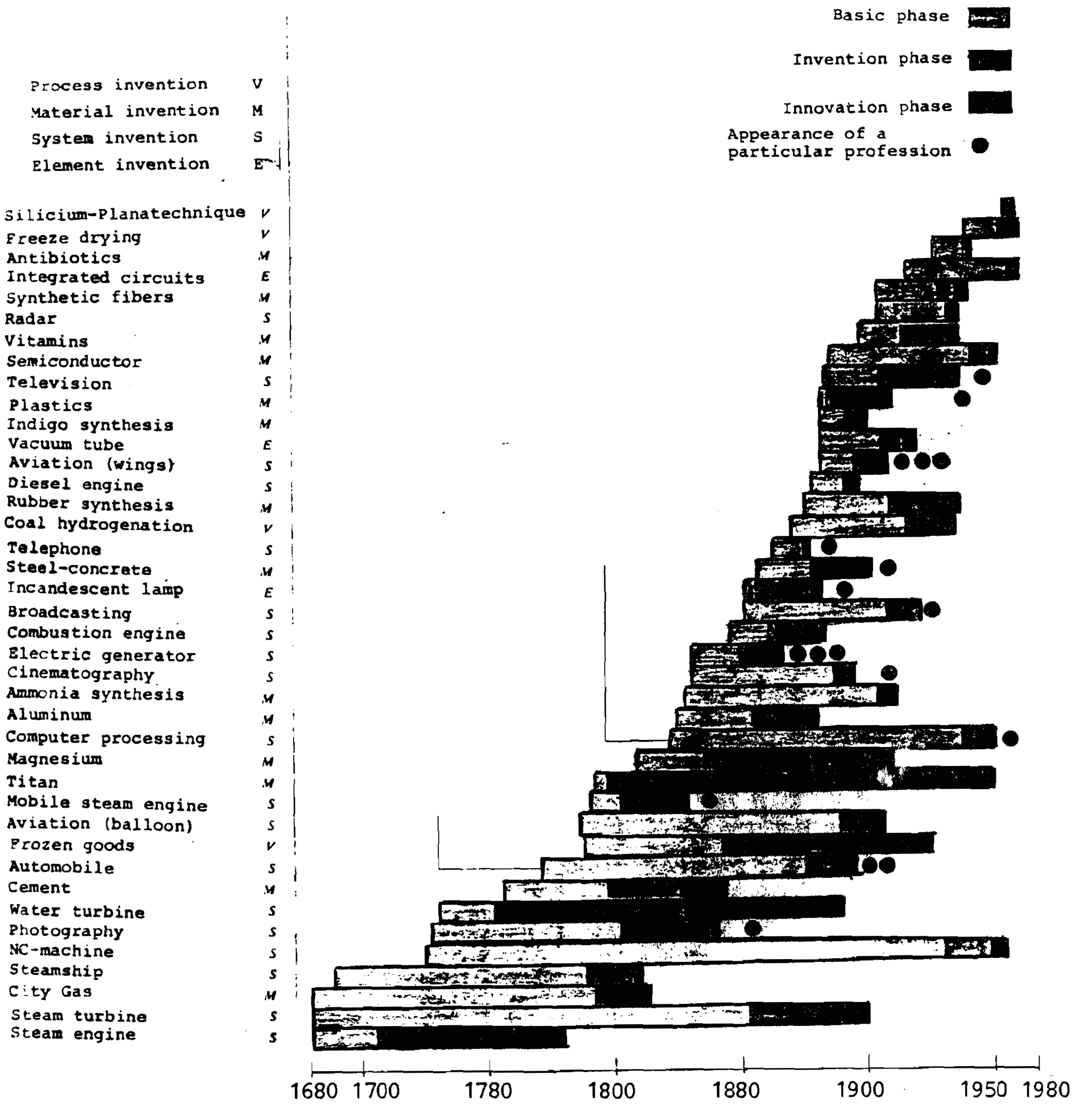
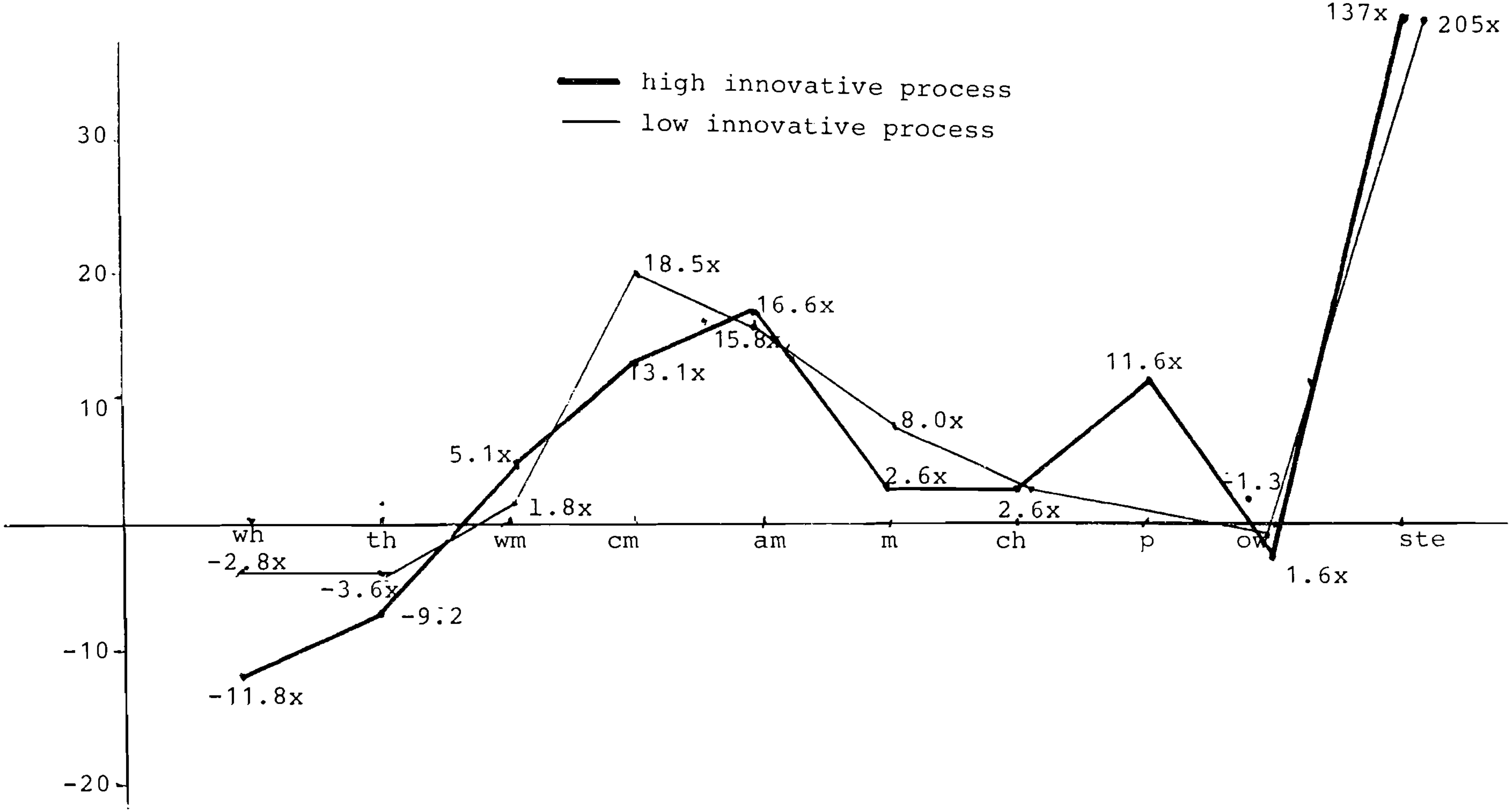


Figure 9.

(Source: Tecknik und Arbeitsmarkt, Nürnburg, 1977, page 5)



wh = work by hand.
cm = control of machine.
p = planning of process.

th = transportation by hand.
am = adjusting machines.
o = office work.

wm = work with/on machines.
ch = checking.
sta= steering, advisary.

Figure 10. Impact of high innovative and low innovative technological change on the work content.

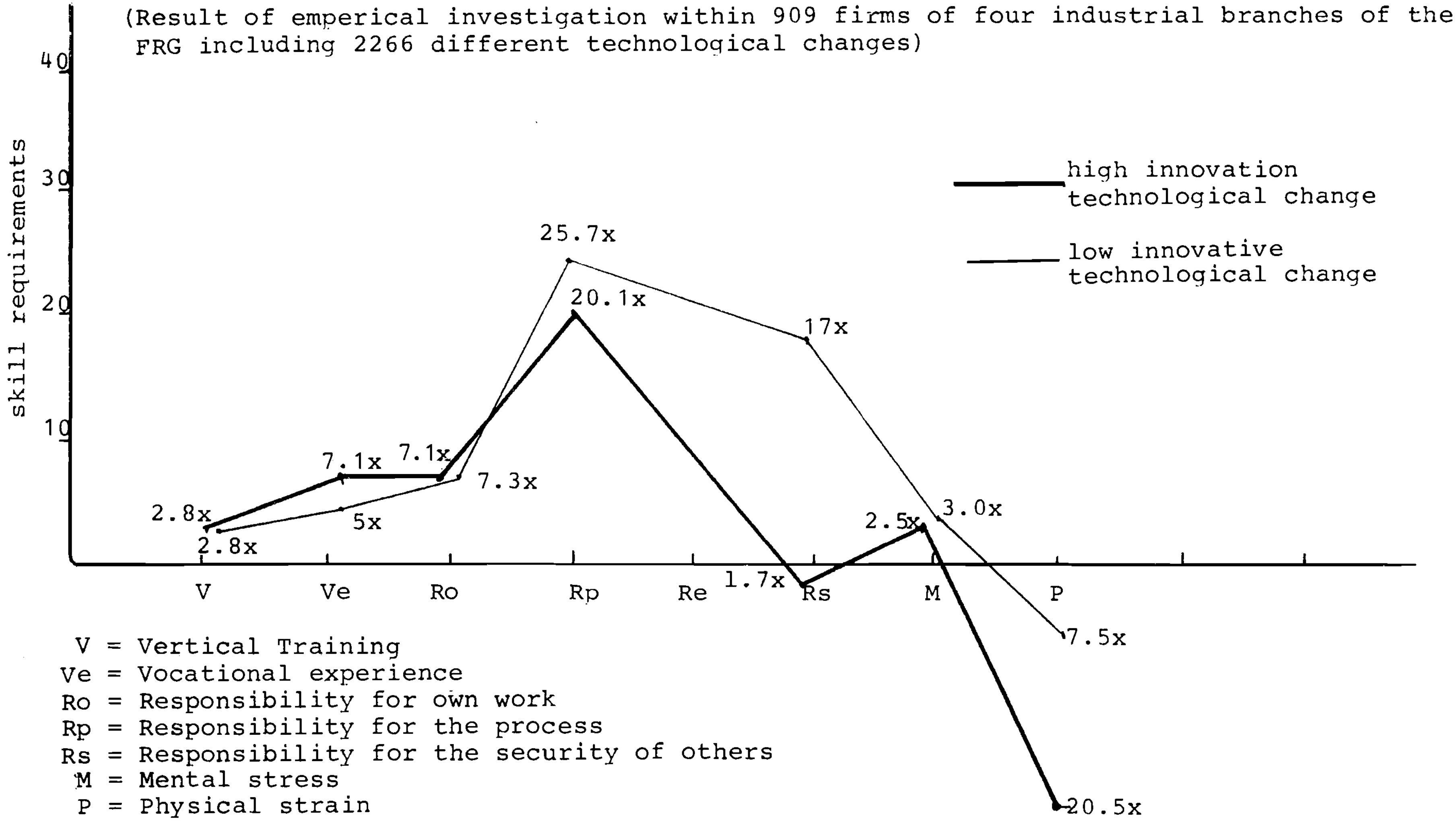


Figure 11. Impact of high innovotive technological change in the skill requirements of labor forces.

	IMPLEMENTATION	RAPID GROWTH	MATURATION	SATURATION
Highly Skilled Experts	xxxx	xxx	xx	-
Skilled Workers with Handicraft Experience	xxxx	xx	-	-
Skilled Workers	xxx	xxx	xxx	xxx
Semi-skilled Workers	xxx	xxx	xxxx	xxxx
Unskilled Workers	xx	xx	xx	x
Employment Effect	x	xxx	xxxx	o

xxxx - very high
xxx - high
xx - medium
x - low
\- - very low
o - negative

Figure 12.

Rapid Growth Stage

- o highly skilled experts maintain their importance to overcome the problems of extension of production and the implementation of product and process improvements.
- o the extension of production requires more specialized production equipment, through which we have a very high demand for skilled workers, semi-skilled workers and a high employment effect.
- o the demand for skilled workers with handicraft experience is decreasing.

Maturation Stage

- o high level of mechanization and automation.
- o very high demand for semi-skilled workers.
- o high demand for skilled workers
- o very low demand for highly skilled experts
- o low or negative employment effect.

Saturation Stage

- o automated and standardized production process.
- o high demand for skilled workers and semi-skilled workers.
- o low demand for unskilled workers
- o negative employment effect.

The lesson we can learn from our findings is that it is pointless to maintain a high share of skilled experts and experienced workers when production is shifting from rapid growth to the maturation and saturation stages. It is much better to use these skilled workers for the prepartion of new innovations, otherwise society will waste the most important resource: The creativeness of man. But this requires high flexibility in the organizational pattern and high mobility within the labor force.

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