INNOVATION AND INDUSTRIAL STRATEGY

Heinz-Dieter Haustein

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PREFACE

The conditions and consequences of industrial development are currently being widely discussed. One reason for this attention is the marked decline in industrial growth rates in many countries of the world, including those with low levels of industrialization.

Aware that the successful management of innovation might be a cornerstone in solving the problem of industrial growth in both the market and planned economies, the members of IIASA's Innovation Management Task held a task force meeting on "Innovation and Industrial Strategy" in 1980. This paper is the completely revised version of my contribution to this meeting. It gives an overview of the problem of innovation and industrial growth at the global, national, and sectoral levels from the standpoint of our findings in innovation research.

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INTRODUCTION

The question of industrial policy and industrial strategy is not new. The economic growth of industrialized countries has been closely linked with industrial development for more than 200 years. These ties will endure, despite the increasing importance of the tertiary sector; policymakers in advanced countries do not think in terms of a post-industrialized society. What is sought is industrial policy that can ensure further growth in all sectors of the national economy.

Industrial growth is a combination of push processes that eliminate equilibria and compensatory processes that create them. Sometimes, however, imbalances become so severe that they can no longer be corrected with simple compensatory measures.

Several kinds of imbalance are impeding industrial growth at present:

1. the energy imbalance, caused by the depletion of valuable nonrenewable energy resources,
2. the material imbalance, caused by the depletion of valuable nonrenewable mineral resources,
3. the technological imbalance, caused by discontinuous technological progress,
4. the ecological imbalance, caused by intense commercial exploitation of our natural environment without regard to long-term consequences,
5. the social imbalance, caused by neglect of human resources through illiteracy, unemployment, and other factors, and
6. the political imbalance, caused by acceleration of the arms race and other factors.

These imbalances form a complicated picture that calls for a policy of compensation to reduce bottlenecks and ensure a new equilibrium.

But here we are faced with a major problem, for the present network of imbalances cannot be overcome with traditional policies of compensation or improvement. Without a major push toward basic innovations, growth rates will continue to decline as they have in the past decade (see Table 1). Thus industrial strategy has become a subject of international dimension.

In this paper the link between industrial strategy and policies on innovation is described. The paper is intended as a contribution to a future focal task at the International Institute for Applied Systems Analysis (IIASA). It was elaborated on the basis of a discussion with experts from IIASA, the United States, the United Kingdom, Hungary, the Federal Republic of Germany, Sweden, and the German Democratic Republic during the Task Force Meeting on Industrial Strategy and Innovation Policy. During this discussion, it was agreed that the problem should be analyzed at the global, regional, national, and sectoral levels.

Table 1. Industrial growth rates in 32 countries (1960-1978).

	Average annual industrial growth rates (in percent)		
	1960-1970	1970-1978	Difference
A. Developing Countries			
Low Income Countries			
1. Bangladesh	7.9	5.9	-2.0
2. Ethiopia	7.4	0.4	-7.0
3. Somalia	3.3	-2.6	-5.9
4. Mozambique	9.5	-5.1	-14.6
5. India	5.5	4.5	-1.0
6. Pakistan	10.0	4.8	-5.2
7. Angola	11.0	-4.1	-15.1
8. Indonesia	5.0	11.2	6.2
Middle Income Countries			
9. Egypt	5.4	7.2	1.8
10. Thailand	11.6	10.2	-1.4
11. Bolivia	6.2	5.1	-1.1
12. Syrian Arab Republic	6.3	11.6	5.3
13. Republic of Korea	17.2	16.5	-0.7
14. Turkey	9.6	8.8	-0.8
15. Mexico	9.1	6.2	-2.9
16. Argentina	6.0	2.2	-3.8
B. Planned Economies			
17. Bulgaria	11.3	8.1	-3.2
18. Czechoslovakia	6.0	6.2	0.2
19. German Democratic Rep.	6.1	6.0	-0.1
20. Hungary	6.8	6.0	-0.8
21. Mongolia	9.9	8.0	-1.9
22. Poland	8.4	10.2	1.8
23. Romania	12.8	12.0	-0.8
24. USSR	8.5	6.5	-2.0
C. Developed Market Economies			
25. United States	5.2	2.7	-2.5
26. Canada	6.8	3.7	-3.1
27. France	6.4	3.5	-2.9
28. Italy	6.2	2.7	-3.5
29. Federal Rep. of Germany	5.2	2.1	-3.1
30. Austria	4.9	3.4	-1.5
31. United Kingdom	3.1	1.3	-1.8
32. Japan	10.9	6.0	-3.1

Sources: World Development Report 1980. Statistical Yearbook of CMEA Countries 1979.

INDUSTRIAL POLICY, INDUSTRIAL STRATEGY, AND POLICY ON INNOVATION

Industrial strategy, a part of industrial policy, comprises the set of goals, tools, and measures designed to meet long-term national requirements for industrial development. Industrial policy is embedded in national economic and social policy.

Policy on innovation has a direct but historically changing link with industrial strategy, as (1) dynamic industrial development is impossible without innovation and (2) industrial cycles and structural changes are closely linked with the innovation cycle. It is difficult to characterize generally innovation policy and innovation policy, as they have been treated very differently in international literature.

Types of Industrial Policy and the Stages of Industrial Development

There are at present at least seven kinds of industrial policy:

1. Industrial policy as the policy of the enterprise without direct state involvement. Denmark has this kind of policy.
2. Industrial policy as sectoral policy. An example is the Dutch experience, where in the 1960s, certain industries were promoted through governmental aid.
3. Industrial policy as policy for nationalized industries. An example is Austria, where the steel and several other industries have been nationalized.
4. Industrial policy that promotes every type of enterprise except large corporations. The Netherlands launched such a program in 1975 (de Wolff 1980).

5. Industrial policy as corporate policy. In countries with large multinational corporations, industrial policy is made primarily by the corporations themselves rather than by the government. This is typical for the US. However, there is some question as to the limits of this approach (Hirschhorn 1980).
6. Industrial policy in newly industrialized countries as a set of measures that include direct government involvement. Examples are Mexico and Brazil.
7. Industrial policy as part of national economic policy and planning in the socialist countries (Čsikos-Nagy 1980). The USSR has the longest history of the type of policy.

Each of these kinds of policy is linked to a particular industrial stage. In the course of its history, industry has passed through a number of stages:

-- During the pre-industrial stage, primary production dominated, and agriculture and trade were the only industries.
-- The industrial revolution was a transitory stage during which rapid development of textile production was followed by the introduction of the machine tools industry. The classical example for this is England from 1770 to 1840.
-- In the monocultural stage, one or more industries dominated and a large proportion of industry became extractive. This was the stage of primary mechanization. The monocultural stage flowed into a transition stage during which more and more industries were established: the so-called metal cycle moved from iron ore and metallurgy to mechanical engineering and the railroad industry. Industries in and around the textile and metal cycles dominated. This was also a stage of advancing mechanization.
-- The industrial-complex stage, characterized by rapid growth in chemical, automobiles, aircraft, and electrotechnology, was seen in the advanced industrialized countries from 1920 to 1970. The period also marked the beginning of automation.
-- The highly-specialized industrial complex stage stresses research and development. Industries have become very competitive on the world market. This stage is typical of the most advanced industrialized countries, such as the USA, Japan, and the FRG.
-- The next (future) stage of industrial growth might be characterized by an amalgamation of future industries with other sectors of the national economy. Thus the spiral is closing and industry is returning to the starting point, but at a higher level.

The stage a country has reached can be determined by various indicators (see Table 2). The gross domestic product (GDP) per capita, the per capita consumption of electric power, and industry's share of all employed persons are indicators of the economic level of the country as a result of industrialization.

Table 2. Some indicators reflecting historical stages of industry.

Stages \ Indicators	Typical industries	Manufacturing industry's share in GDP (in percent)	Group A's share in industry	Industry's share in total work force
1. Preindustrial		< 15	< 20	< 5
2. Transitional	Textiles	15-25	20-35	5-10
3. Monocultural	Extractive industry, metal cycle, railroads	25-35	30-40	10-25
4. Complete industrial complex	Chemicals, automobiles, aircraft, electrotechnology	30-55	60-75	25-50
5. Highly specialized industrial complex	Electronics	25-45	60-75	30-40
6. Future	Bioindustry?	25-40	60-75	25-35

Source: Own estimates according to various statistical sources

Growth of industrial productivity, industry's share of the GDP, the share of all industries producing the means of production, and the share of food and textile industry in all industry are indicators of industrial activity. The share of primary production (agriculture and mining) in the GDP is an indicator of a country's raw material resources. The share of the GNP spent on research and development and the number of patents registered annually indicate the level of its technology. Foreign trade activity is indicated by industrial export per capita.

Recently Keith Pavitt (1979, 1980) made a comparison of several countries who are in the two most recent stages of industrial development. He distinguishes among first division countries, such as the US, the FRG, Sweden, and Switzerland; second division countries, such as Japan, France, Belgium, the UK, and Canada; and third division countries, including Italy, Spain, and others. The indicators he used were productivity in manufacturing, US patents per capita, industrial spending on R & D (per capita and in absolute figures), exports per capita, and unit value of manufacturing exports. It should be noted here, however, that while these indicators show the general position of a country's industry, one must also look at the country's sensitivity to crucial world problems of industrial development.

The Main Components of Industrial Policy and Recent Problems

A country's industrial policy and industrial strategy depend on its socioeconomic system, its size, and the stage of its industrial development. The main components of industrial policy are:

- goals and targets,
- available means and resources,
- available measures,
- main areas of application,
- status and activities of industrial organizations, and
- interaction with economic policy as a whole.

Problems arise, primarily from trade-offs among these components, and from trade-offs between industrial development and the development of non-industrial sectors of the economy. At present, the whole network of industrial problems is centered around the productivity issue. The worldwide decline in the growth rate of productivity is both the cause and consequence of many other problems, including:

- increasing competition in the field of advanced technology and in other fields,
- shortages of energy and raw materials,
- saturation of the market in certain fields,
- substitution of materials,
- persistent inflation and unemployment,
- problems of social environment (public transport, education, health standards, working conditions),

-- damage to the natural environment, and
-- growing military expenditures (see, for example, Hamilton 1978, Roman 1979).

But how these issues are ranked in importance varies among countries, and among groups of countries. This is shown in Table 3 for 15 of the major problems.

In seeking solutions to problems of industrial policy, more and more countries are turning to their policies on innovation. Innovation policy in the context of industrial policy seeks solutions to the following questions:

1. What changes in technology can be expected and how can they help overcome major gaps and bottlenecks and thereby increase productivity? What should be improved here?
2. What contribution can industry make toward solving future problems of productivity? What structural changes are desirable and possible?
3. What kinds of innovation are desirable and at what rate should they be introduced?
4. What measures are available for assessing innovation policies? What could be done to improve the efficiency of these measures?

Innovation policy actually has the same main components as industrial policy as a whole. Its primary objective, however, is not industrial development as a whole, but rather its first derivative in time.

Push and Compensation Policies and Their Interaction

The question of economic equilibrium is there again of great interest. A paper by Gerhard Mensch, Klaus Kaasch, Alfred Kleinknecht, and Reinhard Schnapp (1980) on "Innovation Trends and Switching between Full- and Underdevelopment Equilibria, 1950-1978" links the innovation problems with the dynamic stability in industrial development. The authors believe that particularly the underemployment problem arises from a certain type of development in innovation and that this problem can be solved by a new wave of basic innovations. The authors distinguish between expansionary investments (E) and rationalizing investments (R), a distinction which has been used in West Germany for some time. They link the search for the laws or regularities that govern the developmental path of a national economy with the findings of innovation theory.

In our opinion it is necessary and useful to use innovation theory for economic modeling; this is true for market economies as well as for planned economies.

In planned economies the term "proportionality" is used to characterize a certain equilibrium, defined according to given political and economic objectives. An urgent practical task

Table 3. Strategic problems of industry and their importance in groups of countries.

	Problems																	
	Presently Recognized																	Future
	Productivity Decline	International Competition		Supply Problems		Demand		Economic	Environment	Social Environment				Natural Environment		International Cooperation		
		In Advanced Fields	In Other Fields	Raw Materials	Energy	Saturation in Certain Fields	Substitution	Persistant Inflation	Unemployment	Transport	Education	Health Standards	Working Conditions	Land	Water Air	Closing the gap to LDC	Disarmament	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	
1. Market Economies																		
1.1 US	5	5	5	3	4	5	5	4	5	4	4	4	3	3	3			
1.2 FRG	5	5	4	4	5	5	5	3	4	4	5	4	3	4	4			
1.3 Japan	3	5	3	5	5	5	5	5	2	3	4	3	3	5	4			
1.4 UK	5	5	4	4	3	4	4	5	5	4	5	4	3	4	4			
1.5 France	5	4	4	4	4	4	4	4	4	4	4	4	3	4	4			
1.6 Canada	5	4	4	3	3	3	3	4	5	4	4	4	3	2	3			
1.7 Italy	5	4	4	4	4	3	3	5	5	4	4	4	3	3	3			
Sum	33	32	28	27	28	29	29	30	30	27	30	27	21	25	25			
2. Planned Economies																		
2.1 USSR	5	3	2	2	3	2	2	1	1	5	3	5	4	2	3			
2.2 CSSR	4	4	4	5	4	3	3	1	1	4	3	4	4	4	4			
2.3 GDR	4	4	4	5	5	3	3	1	1	4	3	4	4	4	5			
2.4 Poland	5	4	4	4	3	1	2	3	1	4	3	4	4	3	3			
2.5 Hungary	4	4	4	5	5	3	3	3	1	4	3	4	4	4	4			
2.6 Bulgaria	5	4	4	4	4	2	2	1	1	4	3	4	4	3	3			
2.7 Romania	4	3	4	4	3	1	2	1	1	4	3	3	4	3	3			
Sum	31	26	26	29	27	15	17	11	7	29	21	28	28	23	25			

5 - Very high importance
4 - High importance
3 - Medium importance
2 - Low importance
1 - Very low or no importance

in planned economies is to determine how to allocate investments between push processes and compensating processes so that a dynamic equilibrium between supply and demand, and between capital and labor is ensured.

Compensating processes lead to a static equilibrium by improving efficiency. In Figure 1 this is shown for innovations in processes. When looking at the stages of a production system, we generally find certain bottlenecks in productivity or in equipment per worker. By easing these bottlenecks against the average or maximum, we can increase the productivity of the whole system. If this is not done, then in a rapidly expanding system, the bottleneck will draw labor from other areas of production. Sometimes this is accounted for in calculations of an enterprise's efficiency; sometimes it is not.

Optimal efficiency can also be estimated from the standpoint of the national economy, by using, for example, a normative payback period. A similar feature is typical of compensating processes in the supply and demand of goods (Figure 2). Here compensating processes are used to meet demand better. This is done by increasing supply, promoting demand, and (later) reducing overcapacities.

It is widely recognized that compensating processes, while necessary, eventually lead to a static equilibrium with diminishing returns. In the short run, however, they result in higher absolute and relative efficiency than push processes; by reducing variances in the production and supply systems, efficiency is improved.

Push processes, on the other hand, introduce a qualitatively new technology into the production system, and thereby completely change the state of the art. Certain bottlenecks are relieved, and in the process, a new variance with new bottlenecks is created. In the long run, push processes result in higher efficiency than compensating processes. Static equilibrium vanishes and new possibilities for improvements arise.

Thus four types of investment can be distinguished: compensation investments involving processes and those involving products, and push investments involving processes and those involving products.

According to Mensch et al (1980), the present decline in productivity growth rates is due to a stalemate in technology, or the lack of basic innovations. This would mean that there have been heavy investments in compensation or improvement and a diminishing proportion of push investments. Table 4 shows the frequency distribution of 35,945 technological changes in four industries. Distribution of these changes in percent (Table 5) shows that more than two-thirds of the technological changes were of a compensatory nature and involved the development of processes; only 5 percent involved new products.

An innovation structure of this nature is bound to lead to a decline in productivity; those making policy and setting priori-

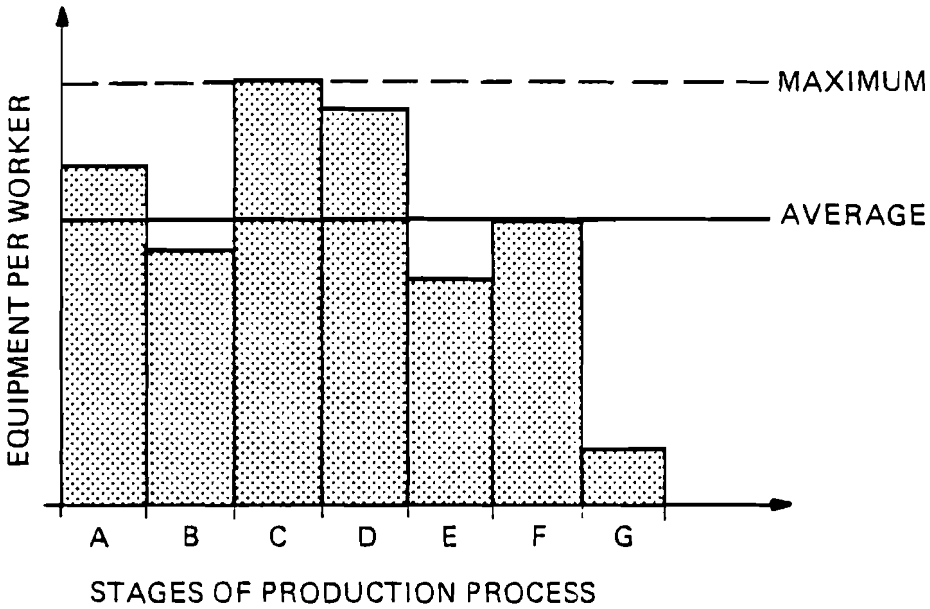

Figure 1. Technological profile of a production process.

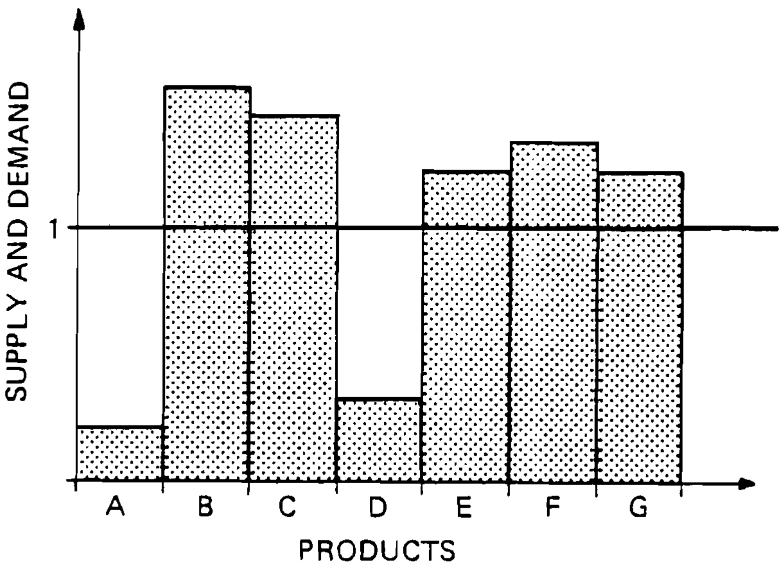

Figure 2. Supply and demand profile for a product group.

Table 4. Distribution of 35,945 technological changes in the plastics industry (1970), wood industry (1971), food industry (1972), and metal industry (1973) according to type of change (in percent).

Type of changes \ Reasons for changes		Higher capacity	Replacement	Shortage of work	Business outlook	Rationalization	Saving of labor costs	Shortage of workers	Low efficiency	Reduction of production	New products, etc.	Improvement in quality	Shortage of space	Improvement of working conditions	Others	Total
		AG	BT	BG	BG	BT	BT	BT	BT	CG	AG	BG	BT	BO	CO	
1. New shops (additional)	AT	1	0	1	0	1	0	0	0	0	2	0	0	0	1	5
2. New shops (replacement)	AT	2	0	0	0	1	0	0	0	0	0	0	2	0	0	7
3. Shutdown of shops	CT	0	0	1	0	1	0	0	0	0	0	0	0	0	0	3
4. Displacement of shops	BT	0	0	0	0	1	0	0	0	0	0	0	1	0	0	4
5. New plants, new equipment	AT	2	0	0	0	4	1	0	0	0	2	1	0	1	0	11
6. Replacement of machines	BT	5	4	0	0	10	1	0	0	0	1	1	0	1	0	23
7. Implementation of electronic data processing	AO	1	0	0	0	3	0	0	0	0	0	1	0	0	1	5
8. Shutdown of equipment	CT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9. Implementation of other processes	AT	1	0	0	0	2	0	0	0	0	0	1	0	0	0	4
10. Mechanization and rationalisation by additional devices	BT	2	0	0	0	8	2	0	0	0	0	0	0	1	0	14
11. Organizational change	BO	1	0	0	0	2	0	0	0	0	0	0	0	0	0	5
12. Introduction of new materials and intermediate products	BM	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
13. Introduction of other forms of energy	AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14. Use of additional equipment of the same type	BT	11	0	0	0	2	0	0	0	0	0	0	0	1	0	16
15. Others	CO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		26	5	2	0	38	4	2	2	0	5	6	3	4	3	100

Source: Dostal et al (1977).

Table 5. Distribution of 35,945 technological changes according to type of innovation and area affected (in percent).

		Product G	Process Equipment T	Materials Energy M	Organization and others O	Total
A	Push	5	16	o	5	26
B	Compensation	8	53	2	5	68
C	Others	o	3	o	3	6
	Total	13	72	2	13	100

ties on innovation must take this fact into account. But as seen in Table 6, showing the results of an enquiry of the ECE into policies on innovation in 16 countries, in only a few cases is the orientation toward basic innovations and push investments.

Differing Attitudes Toward Innovation Policy in Various Countries

Innovation policy differs in market and planned economies. The means and resources available to policymakers also differ.

In market economies the primary objectives of policy on innovation include

- mobilization and channeling of financial resources,
- support for smaller enterprises,
- the balance between R & D in the public sector and the developmental efforts of industry, and
- procurement activities.

In planned economies, on the other hand, innovation policy seeks to

- see that innovations contribute to plan targets;
- promote interaction between the central level and industrial organizations in the development of innovations;
- coordinate planning of research and development, investments, production, and efficiency; and
- aid in organizing programs for innovation in industrial planning.

The policy measures used to promote innovation also vary from one country to another. Table 7 shows a systematic overview of these innovation policy measures and their areas of application. Table 8 shows more specific measures, their area and type, the phase of the innovation process in which they are generally applied, the importance of their implementation, their stages of rapid growth and maturation, and the extent to which they are used in groups of countries.

It would be useful to evaluate the complexity of a country's policy for innovations by analyzing the presence and importance of all 32 measures. Table 9 is a first attempt at such an analysis.

The complexity of innovation policy also depends on the areas of greatest technological change. Table 10 shows this, using industry in the GDR as an example.

National policy for innovation in the context of industrial policy must take into account industrial development at the global level and its trends, objectives, and structural changes in light of the global interdependence of national economies. For multinational corporations this reflects the dimension of their strategic thinking and strategic action.

Table 6. Various countries formulate their policies on innovation and identify their priorities.

1. The identification of needs and the formulation of long-term research strategy is based on social and economic requirements and resources (Austria).

2. Research must be oriented towards development of society, organization of production, and management and control (Norway).

3. We need to identify those critical areas in which investment of scientific and technological resources leads to the greatest effect (Canada).

4. Practical and applied research should comply with current production needs (Poland).

5. Research projects should be chosen seriously and carefully on the basis of criteria, taking into account equipment of enterprises and development of the country (Spain).

6. Identification of priorities should take into account possibility of national economic potential (Belgium).

7. Stress is being laid both on immediate economic and strategic long-range usefulness (Federal Republic of Germany).

8. Priorities should reflect demands of local and international markets (Belgium).

9. Government policy should stimulate high standards of technological innovations (Czechoslovakia).

10. Survey of demand for new technology may provide a picture of future development (Netherlands).

11. Public influence should play a stronger and more active role in defining and implementing priorities (Belgium).

12. Scientific and technological work performed by various organizations, laboratories, institutions - both public and private - and also by individual researchers should be coordinated (Luxembourg).

13. It is necessary for scientific ideas and technological innovations to be disseminated to a number of areas of the national economy (Bulgaria).

14. In coming years, industry will need to base its investment plans on technology to a much greater extent than before (United Kingdom).

15. Economic and technological dependence on foreign countries is a constraint to research activities (Spain).

16. The economy must be adaptable to innovation (Poland).

17. We need to strengthen the national economy's ability to create, absorb, and adopt contemporaty technology (Turkey).

18. Newly selected R and D projects must be effective (Poland).

19. Innovations should contribute to the completion of the investment program (Romania).

20. Innovation should help solve problems of environment, working conditions, health, and other social problems (Czechoslovakia).

21. The need is to maintain and protect environmental quality (Canada).

22. Innovations should not be abused and undesirable side-effects should be prevented (Sweden).

Source: Structure and Change in European Industry (1977).

Table 7. A systematic approach to policy on innovation.

Type of measure / Area	Administrative and other direct measures				Economic stimulation				Mental and ideological factors Social organization				Complex measures			
	Legislative	Planning	Information	Others	Financing	Taxes	Credit	Others	Education	Popularization	Participation	Others	Plans	Programs	Projects	Others
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1. Socioeconomic environment																
2. Performance of sectors or industries																
3. Demand and market																
4. R&D Technological progress																
5. Specific innovation																

Table 8. Measures used in innovation policy and their characteristics.

No.	Measure	Area*	Type**	Phase †	Importance during: Implementation	Importance during: Rapid Growth	Importance during: Maturation	Frequency of application in: Developed Market Economies	Frequency of application in: Developed Planned Economies	Frequency of application in: Developing Countries
1.	Grants & subsidies	2,4,5	5	9	high	high	low	high	high	high
2.	Loans	2,4,5	5	9	high	high	low	high	medium	high
3.	Joint ventures	5	5	5	high	high	low	high	low	high
4.	Financing of new enterprises	5	5	5	high	high	low	high	high	high
5.	Incentives for inventors	4	8	4	low	low	high	high	medium	low
6.	Incentives for organization	2	8	9	high	low	medium	high	high	high
7.	Central planning of state owned enterprises	1,2,3,4,5	13	9	high	high	high	none	high	medium
8.	Patents	4	1	4	high	high	medium	high	medium	low
9.	Environmental regulations	1	1	9	high	high	medium	high	medium	medium
10.	Monopoly laws	2	1	9	low	low	medium	high	low	low
11.	Technical assistance	2	4	9	medium	high	low	high	high	high
12.	Governmental progress	1,2,3,4,5	14	9	high	high	low	high	high	high
13.	Information network	4	3	9	high	high	medium	high	medium	low
14.	Information centers	4	3	9	high	high	medium	high	medium	low
15.	Exhibitions	4	3	7	medium	high	low	high	medium	low
16.	Advisory services	2,4,5	3	9	high	high	low	high	low	low
17.	Statistical services	2	3	9	low	medium	medium	high	low	low
18.	Information campaigns	2,3,4,5	3	7	high	high	medium	high	low	low
19.	Research association	4	12	2,3	high	low	low	high	medium	low
20.	Industrial participation	2	11	9	high	high	high	medium	high	low
21.	Higher education	1,2,4	9	9	high	high	medium	medium	high	low
22.	Procurement activities	2,3	4	9	high	high	medium	high	medium	medium
23.	Standardization	4	1	4	low	medium	high	medium	high	low
24.	"Small Firms" policy	2	14	9	high	medium	low	high	low	low
25.	Government projects	5	15	9	high	high	low	high	high	high
26.	Depreciation rules	1,2	8	9	high	high	medium	high	low	low
27.	Trade restrictions	1,2	4	7	low	high	high	high	high	high
28.	Impact on industrial organization	2	4	9	medium	high	medium	medium	high	medium
29.	R&D funding	4	5	2,3	high	medium	low	high	high	high
30.	Tax policy	1	6	9	high	high	medium	high	low	medium
31.	Cooperation between public institutes and industry	1,2	4	9	high	high	medium	medium	high	medium
32.	Work on innovation in public institues	1,2,4	4	9	high	high	medium			

* See Table 7.
** See Table 7.
† (1) creative preparation, (2) basic research, (3) applied research, (4) development, (5) investment and implementation, (6) production, (7) marketing, (8) application and improvement, (9) all phases

Table 9. Instruments used to implement governmental policies on innovation.

Country	Work on innovation by governmental (public) organizations	Cooperation between governmental (public) organizations and industry in the field of innovation	Government financing of innovative programs	Tax incentives to encourage industrial innovations	Legislature favoring industrial innovation
Austria	X	X	X		
Belgium	X	X	X		X
Bulgaria	X	X			X
Byelorussian SSR	X	X			X
Canada	X	X	X	X	
Czechoslovakia	X	X	X		X
Denmark		X	X		
Finland		X	X		
GDR	X	X	X		X
FRG	X	X	X	X	X
Greece	X				
Italy		X	X		
Netherlands		X	X		
Norway		X			
Poland	X	X			X
Portugal		X			
Romania	X	X	X		X
Spain		X	X		
Sweden		X	X		
Ukrainian SSR	X	X			X
USSR	X	X	X		X
UK	X	X	X		
USA	X	X	X		

Source: Current and Prospective Issues in Science and Technology Policies (1980).

Table 10. Main areas of technological change and innovation programs in industry in the GDR.

Application field / Type of innovation	PRODUCTION: MAIN PROCESSES	PRODUCTION: AUXILIARY PROCESSES	PRODUCTION: SECONDARY PROCESSES	PRODUCTION: WORKING CONDITIONS	SERVICES	ADMINISTRATION
1. Process	Intensification programs					
2. Machines equipment			Programs for production of means for rationalization			Programs for data processing
3. Tools components	Program micro-electronics					
4. Materials energy	Program for finishing metallurgy					
5. Organization						Rationalization program for management
6. Consumer goods						

INDUSTRIAL DEVELOPMENT AT THE GLOBAL LEVEL: TRENDS, OBJECTIVES, AND STRUCTURAL CHANGES

Innovation and Long-term Cycles in Industry

There is no doubt that in the course of history, industrial growth has experienced a number of upswings and downswings. The underlying mechanism of this cyclical growth is affected by the relation between the capital goods and consumer good industries. Recently Graham and Senge (1980) investigated this assumption, using a systems dynamics approach.

Looking at world industrial production from 1850 to 1979, we see that growth rates were rather unstable during this period. Using an exponential function to describe long-term trends, one obtains a path of industrial growth measured in deviations from the long-term average (see Figure 3). Here we see the major downswings and upswings in industrial production, among them the unprecedented downswing at the end of the 1920s.

Long-term cycles have been much discussed in the literature since Kondratieff. Some years ago Gerhard Mensch described these "long waves" in terms of clusters of innovations, using the frequency distribution of major technological changes over time (1975).

Figure 4 shows an innovation index for 182 innovations. In each case, the evaluation function is adjusted to the date of introduction into the market. Thus the curve does not show the diffusion process; diffusion is seen in the industrial production curve.

In the past 200 years, several major technical revolutions have significantly affected industrial activities. Despite

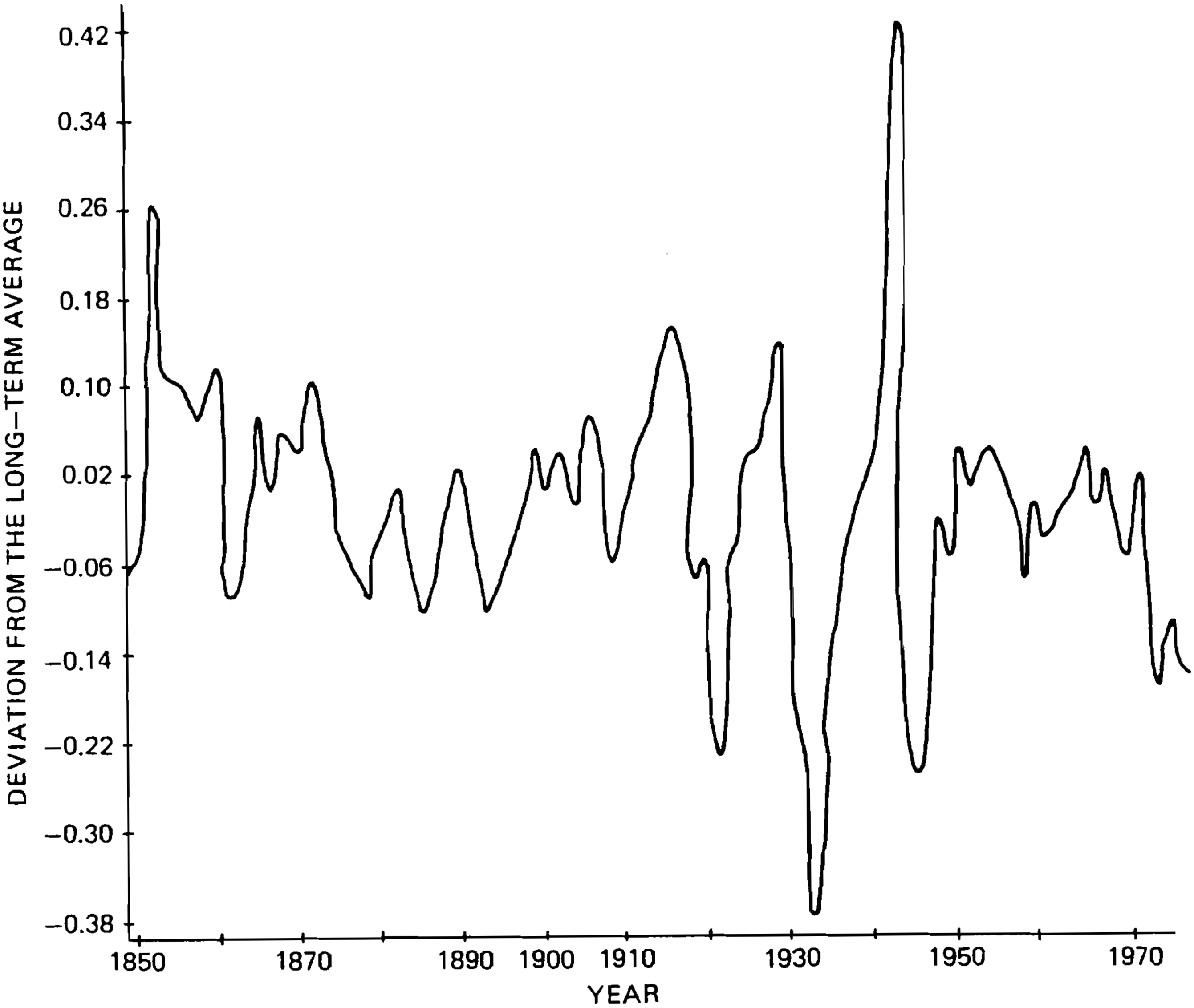

Figure 3. Industrial production logarithum
(World 1850-1979).

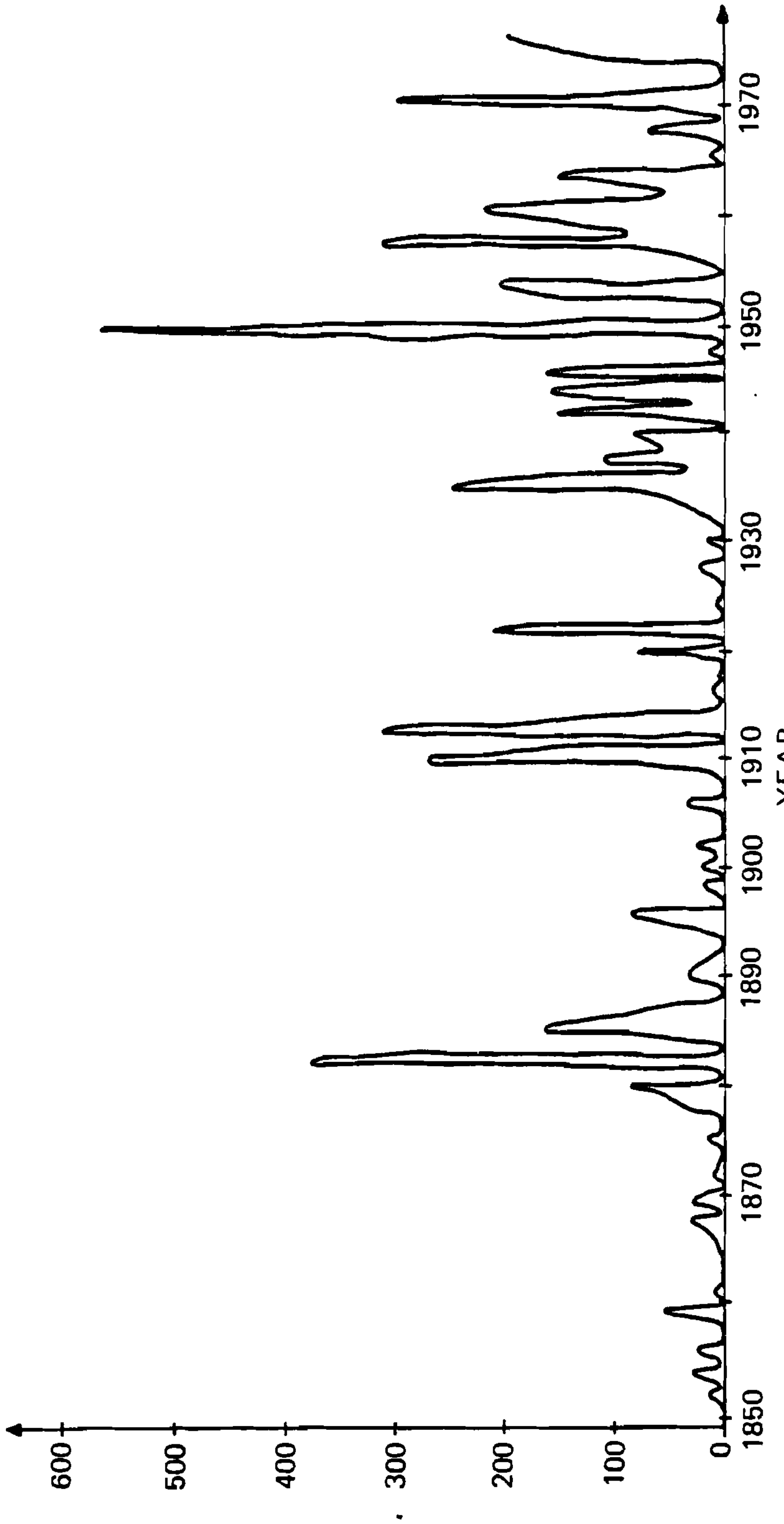

Figure 4. Innovation index based on 182 innovations (1850-1979).

differences in their technical character, they have two main features in common:

1. Each of them was caused by a bottleneck in the production system. The railroad, for example, became necessary during the industrial revolutions because of the enormous demand for transporting coal and cotton.
2. Each of them appeared in one area of the production system and then passed through a chain or network, step by step affecting the whole production system, and later (Figure 5) lifestyles and consumer patterns. For example, the spinning machine led to the mechanization of weaving, and later to the improvement of bleaching, textile printing, and dyeing. The steam engine proved to be the appropriate power source for these processes. Machinery soon developed to the point where machines could be produced with machines. As the demand for iron to produce machinery increased, more coal was needed to produce the iron, and so forth.

Tables 11 and 1 give comprehensive overviews of past industrial growth and present historical time series for industrial production, primary energy consumption, innovations, inventions, and patents. Qualitative and quantitative analyses of past cycles are necessary for developing a scenario of future industrial growth. Looking at the sequence of technical substitutions for functions of labor, one can see that present stress on the replacement of energetic and operational functions will soon be moving toward adaptive control and guidance, providing information, and performance of complex logical functions. There will be a major wave in industrial activity in telecommunications, computer linkages, communications, and machine systems. This could involve major changes in processes. The biotechnologies, automation equipment, telecommunications, bioindustry, and exploitation of the ocean are likely to be the growth industries of the next decades. Figure 6 shows the growth industries of the past and future in a hierarchical scheme with six levels of aggregation, the future industries being bioindustry, electronics, production of machines and equipment for production of machines and equipment, telecommunication, computers, protection of the environment, and exploitation of the ocean. (See also Business Week 50th Anniversary Issue).

There is an internal nucleus of industries where growth is accelerated: production means, machines and equipment, and machines and equipment for the production of machines and equipment (Fajnsilber 1980). Thus one can distinguish between two classes of industries:

- α industries which play a major role in all growth cycles, such as the engineering industry, and
- β industries responsible for one particular upswing in long-term development, such as the chemical and

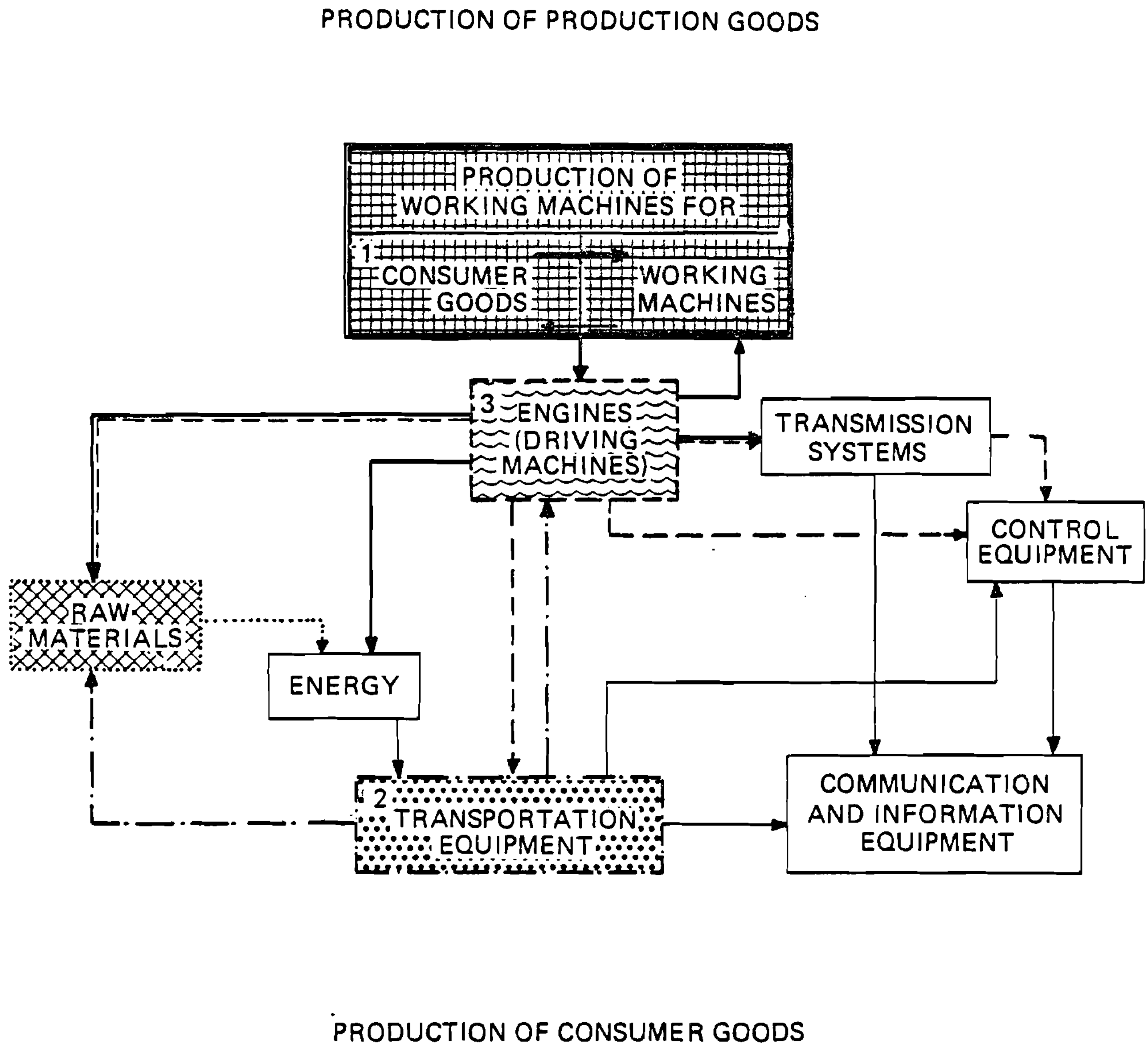

Figure 5. The two production sectors and their inner feedbacks.

Table 11a. Periods of industrial development since 1740 and their characteristics.

Periods	Social Characteristics	Changes in Resources	Changes in Demands	Change in Labor Functions: Substitution for	Change in Labor Functions: Extension of	Main Gaps in the Production System	Main Growth Industries
1740-1808	Early industrial capitalism	High growth of wood products and copper (Brass goods)	Increasing food demand	Manual (energetic)	Manual (energetic)	Spinning, Power source (driving machine), Fabrication of working machines necessary	Textile industry (spinning)
1809-1865	Free competition system	High growth of pig iron	Increasing food demand	Manual (energetic)	Manual (energetic and executive)	Coal demand, iron demand, and need for transportation system	Textile industry (weaving), mining, coal, pig iron, shipbuilding
1866-1910	Transition to monopolies	Peak growth of coal (1880)	Increasing food demand	Manual (energetic)	Manual (energetic and executive)	Need for mass production of machines, Strampower exhausted in its possibilities	Railroad, iron, and steel
1911-1932	Expansion of monopolies	High growth of rubber products	Decreasing expenditures for food (relatively)	Manual (executive)	Manual (executive)	Exhaustion of raw material basis (natural fibres)	Electricity, automobiles, and mechanical engineering
1933-1953	Growing from state interference	High growth of aluminum	Increasing expenditures for housing	Manual (executive)	Manual (executive assembling)	Flexible transportation system	Automobiles, chemicals
1954-1974	Fast growth of postwar capitalism	Peak growth of synthetic fibres	Fast growing demand for durable goods	Transport, Manual transportation, Manual work	Supervision of machines, Operating machines, Maintenance, Quality control	Fast growth of control mechanisms, requiring space and materials	Chemicals, aircraft
1975-1988	Expansion of multinational corporations	Peak growth of oil consumption (1975)	Increasing travel expenditures	Machine operation, Assembling, Office work, Mediation	Maintenance, Installation, Health service, Education	Information handling	Electronics
after 1988				Scheduling, Office work, Information function	Guidence, Consultation, Education		Telecommunications

Table 11b. Observed periods, their peak years, and their lengths in years.

Basic Innovations	Industrial Production	Energy Consumption	Basic Inventions	Dominating Fields	Patents	
1740-1808 68* 1764**	1750-1808 58 1785		1700-1780 80 1745	Textile machinery		
1809-1857 48 1833	1809-1865 56 1855	1600-2000 400 1800 (wood)	1750-1819 70 1780	Textile machinery	1710-1819 110 1764	
1858-1896 38 1882	1866-1910 44 1898	1780-2050 270 1915(coal)	1790-1850 60 1820			England
1897-1924 27 1910	1911-1932 21 1922	1890-2060 170 1975 (oil)	1821-1867 46 1841		1820-1867 48 1845	
1925-1948 23 1936	1933-1953 20 1941		1845-1882 37 1860	Basic industries Mechanical engineering	1868-1892 35 1880	
1949-1965 16 1957	1954-1974 20 1966		1879-1911 32 1895		1893-1920 28 1908	
1966-1980 14 1971	1975-1988 13 1982		1894-1925 31 1906		1921-1945 25 1931	
1981-1994 13 1988	1989-2001 12 1995		1916-1945 29 1928	Chemicals	1946-1976 30 1959	US
			1926-1956 30 1940	Electrotechnique		
			1941-1970 29 1958	Electronics		

*Length of period
**Peak year

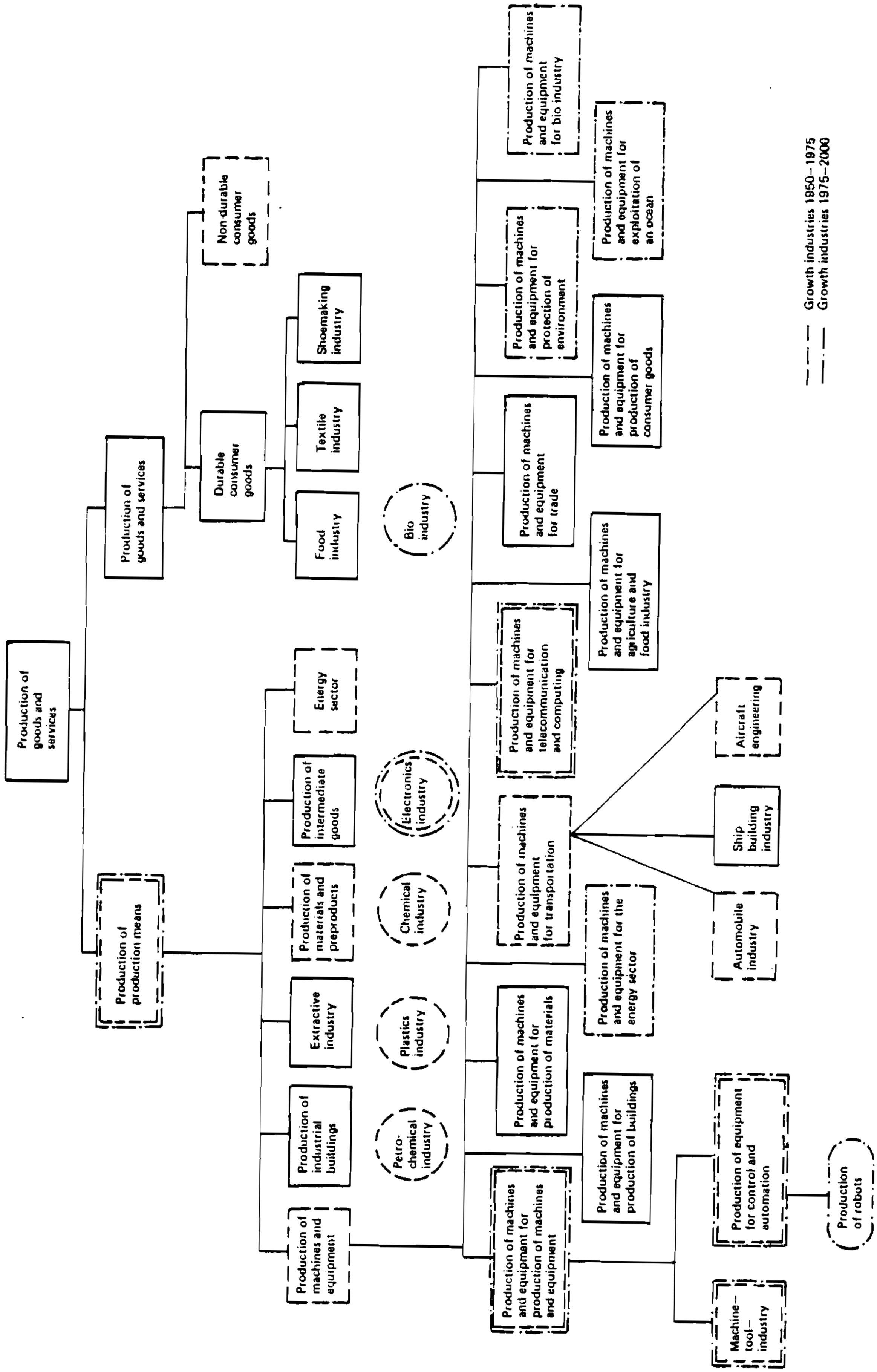

Figure 6. Growth industries in the advanced countries.

automobile industries (see Kleinknecht 1979; Kurenkov 1979).

The growth index and growth elasticity of Soviet industries are calculated in Table 12. The production of production means; the production of machines, tools, and equipment; the engineering industry; the production of machine tools industry; and the production of instruments show a growth elasticity greater than 1 for all cycles and countries during the industrialization period.

The areas of rapid growth in class β are shown in Table 13. The percentage of all employed persons engaged in the textile industry peaked around 1850; the absolute peak in numbers of textile employees was reached shortly before World War II. Metal production passed both of these points in 1965; the chemical industry, in 1979. The automobile industry may have now also peaked. In the future, new industries will be needed that can attract that part of the labor force that has been displaced from older industries and that cannot be absorbed by other sectors of the national economy (Heinze 1979).

Growth rates and other aspects of structural change depend, of course, not only on new technological possibilities, but also on socioeconomic environment.

Historical analyses give us useful insight into the possible directions of future changes. Nevertheless, it will be necessary to analyze the interaction between socioeconomic goals and the structure of industry when seeking solutions to present and future problems.

Interaction between Socioeconomic Goals and Industrial Structure in Groups of Countries

The structural development of industry is closely connected with national socioeconomic goals. Looking at the national goals of industrial strategy in the groups of countries seen in Table 14, we find major differences among the groups, due not only to their differing economic levels, but also to their differing socioeconomic systems.

The developed market economies are characterized by competition, transfer of production abroad, saturation in certain consumer areas, and an increasing divergence among the countries in this group. An important socioeconomic goal of industrial strategy in market-oriented countries is the reduction of unemployment. That competition plays a major role is seen in an investigation for West German industry (Scholz 1977), in which it was revealed that more than 50% of all technological changes in the manufacturing industry expected in the next decade will be linked to competition. A strong trend toward rationalization is also expected; this will result in additional unemployment.

We find quite a different situation in the planned economies. In these countries there is an urgent need for increased rationalization in production.

Table 12. Core of industrial growth in the USSR, 1913-1979. (Growth index for industrial output.)

Industry	Share 1979	1979 (1970=100)	Elasticity of growth 1970-1979	1940-1970	1913-1940
All industry	100	172	1.00	1.00	1.00
1. Group A	74	177	1.03	1.34	1.69
a. Production of machines, tools and equipment	14.9	222	1.29	n.a.	n.a.
b. Production of materials	59.1	167	0.97	n.a.	n.a.
c. Production of Group A for Department I*	53.1	179	1.04	n.a.	n.a.
d. Production of Group A for Department II*	20.9	170	0.99	n.a.	n.a.
2. Engineering	n.a.	252	1.47	4.00	5.79
a. Machine tools	n.a.	225	1.31	n.a.	n.a.
b. Production of instruments and apparatus	n.a.	404	2.35	n.a.	n.a.
Computers	n.a.	819	4.76	n.a.	n.a.
3. Chemicals and petro-chemicals	6.9	207	1.20	2.25	2.27

SOURCE: Statistical Yearbook of the USSR (1975,1979).
*Department I encompasses the production of production means and Department II the production of consumer goods. Groups A and B have the same meanings applied only to the manufacturing and extractive industries, excluding construction.

Table 13. Employment in selected industries in absolute figures and percent of all employed persons for Germany (and later) the FRG, 1846-1979.

	1846		1875		1900		1925		1939		1950		1965		1979	
	1000s	%	1000s	%	1000s	%	1000s	%	1000s	%	1000s	%	1000s	%	1000s	%
Building materials	146	4.4	333	6.5	784	8.8	704	6.0	821	5.3	414	5.2	266	2.6	183	2.0
Metal production	43	1.3	150	2.9	314	3.5	657	5.6			415	5.2	689	6.7	533	6.0
Metalworking	296	9.0	601	11.7	1394	15.6	2201	18.8	4544	29.4	1853	23.1	3629	35.2	3724	41.7
Chemicals	18	0.5	65	1.3	177	2.0	380	3.2	576	3.7	365	4.5	531	5.1	594	6.7
Textiles	734	22.2	926	18.0	1030	11.5	1212	10.4	1420	9.2	622	7.7	547	5.3	310	3.5
Clothing and leather manufacturing	817	24.7	1078	20.9	1522	17.0	1536	13.1	1642	10.6	847	10.5	440	4.3	330	3.7
Timber manufacture	361	10.9	522	10.1	811	9.1	1003	8.6	1061	6.9	634	7.9	219	2.1	238	2.7
Paper and board manufacture	20	0.6	84	1.6	195	2.2	290	2.5	383	2.5	147	1.8	77	0.7	108	1.2
Printing	15	0.5	46	0.9	146	1.6	286	2.4	238	1.5	136	1.7	211	2.0	162	1.8
Food, tobacco and beverages	455	13.8	676	13.1	1092	12.2	1387	11.8	1736	11.2	867	10.8	520	5.0	512	5.7
Gas, Water, Electricity	1	0	15	0.3	43	0.5	152	1.3	249	1.6	146	1.8	215	2.1	249	2.8
Construction	338	10.2	530	10.3	1239	13.8	1584	13.5	2524	16.3	913	11.4	1643	15.9	1111	12.4
Automobiles											329	4.1	514	5.0	787	8.8
Electrotechnology											319	4.0	975	9.4	1005	11.3
Computer industry															72	0.8
Industry total	3305	100	5153	100	8950	100	11708	100	15454	100	8035	100	10318	100	8930	100
National economy total											21960		27300		25500	
Industry's share in in total employment												36.6		37.8		35.0

Sources: Hoffman, W.G. (1965).
Statistical Yearbook of the FRG (1953, 1967, 1980).

Table 14. Groups of countries.

1. DEVELOPED MARKET ECONOMIES
   - 1.1 USA
   - 1.2 Western Europe
   - 1.3 Japan
   - 1.4 Others

2. PLANNED ECONOMIES
   - 2.1 CMEA (COMECON) member countries
   - 2.2 Other planned economies

3. DEVELOPING COUNTRIES
   - 3.1 Major developing countries with market orientation and middle income
   - 3.2 Developing countries with low income

We find still another situation in the developing countries. In Brazil, Mexico, Argentina, South Korea, and India, which account for more than 58% of value added in manufacturing in the developing countries, a number of societal problems have arisen as a result of fast and uneven industrialization. Many of the countries with the lowest per capita GDP (less than $265) also have the lowest growth rates for production.

Over the past 15 years, there has been rapid change in world shares of value added among the groups of countries (see Table 15) and there has been much speculation about the relative shares of value added that can be expected by these groups of countries in the years to come. For developing countries, a share of 14-18% by 1990 seems plausible. The Lima target of 25% by the year 2000, however, will be difficult to attain. The centrally planned economies might increase their share to 32-35% by 1990, due to their rapid growth rates.

To some extent, the goals of industrial strategy conflict among the groups of countries. A systems analysis of these goals would be very useful.

While it is difficult to estimate and compare the progressiveness of industrial structures, such an assessment is essential for industrial strategy, as only a progressive structure can meet the goals set forth. Sometimes a given structure must be radically altered. The following are indicators of industrial structure at the national level:

-- growth rate of production
-- level of productivity P
-- variance of elasticities S_E (elasticity $E = \lambda_i/\lambda$,

   where λ_i = growth rate of the i-th industry
   λ = growth rate of the whole industry)

-- coefficient for satisfaction of social and economic goals G

Table 15. Shares of groups of countries in world total of value added (based on 85 developing and 35 developed countries).

	DEVELOPED MARKET ECONOMIES	CENTRALLY PLANNED ECONOMIES	DEVELOPING COUNTRIES
1960	73.3	18.1	6.9
1975	61.9	27.7	8.6
Δ 1960-1975	-11.4	+10.4	+1.7
1990	47...54	32...35	14...18
Δ 1975-1990	-8..-15	+4...7	+5...9

SOURCE: World Industry Since 1960 (1979).
Own estimates for 1990.

The variance of elasticities has not yet been thoroughly analyzed, but is an important indicator for the order state of the process. My hypothesis is that the variance of elasticities has a nonlinear influence on growth rates. A high variance of elasticities indicates a high share of push processes; a low variance of elasticities, on the other hand, indicates a high share of compensatory processes. As I have shown in another study (Haustein 1974), there should be an optimal or at least satisfying relationship between push and compensatory processes.

But none of these indicators answers the central question: How well does a given or desired industrial structure suit a network of national social and economic goals?

The 30 goals for industrial policy seen in Table 16 were formulated from a broad range of information, including a recent ECE investigation (Current and Prospective Issues 1980) where the following objectives of national policy were named:

- -- solution of the developmental needs of the country (Greece, Italy),
- -- industrial innovation as a key factor for overcoming major economic problems: unemployment, inflation, and the imbalance between exports of raw materials and imports of manufactured goods (Canada),
- -- combining the technical aspects of innovation with the economic and social aspects (Czechoslovakia),
- -- maintenance and development of efficiency and competitiveness of the economy (Federal Republic of Germany),
- -- increasing the competitiveness of national technology and products on the world market (Romania, Turkey, Belgium),
- -- increasing production of new materials and products for export; increasing export capacity (Romania, Poland, German Democratic Republic),
- -- introduction of new products to the domestic market that are reliable, aesthetic, and of high quality (Poland),
- -- promotion of productivity and industrial technology (Portugal),
- -- development of industrial technology and modern technology (Greece),
- -- encouragement and development of scientific and technological research, survey, engineering, and other industrial studies (Greece, Turkey),
- -- increasing the effectiveness of science and technology (Bulgaria),
- -- raising of technical, qualitative, and aesthetic standards of goods (Poland),
- -- technical assistance to smaller enterprises (Italy).

These diverse social, economic, and ecological goals, both final and intermediate, are of varying importance among the groups of countries. We can weight their importance for the following groups of countries: developed market economies, planned economies, semideveloped countries (Brazil, Mexico,

Table 16. Goals for industrial strategy in groups of countries with their weights and the contribution coefficient of selected industries.

		(1) Satisfaction of high-level needs	(2) Satisfaction of basic needs	(3) Increasing exports	(4) Satisfaction of domestic demand	(5) Competing with other branches	(6) Competing with developing countries	(7) Competing with developed countries	(8) Increasing knowledge and skills	(9) Contribution to national economic complex	(10) Contribution to infrastructure	(11) Utilization of national resources	(12) Closing the gap with leading countries	(13) Contribution to regional division of labor	(14) Contribution to faster growth of developing countries	(15) Selective protection of national industry
Weights	1 Developed market economies	4	2	4	3	3	2	3	3	1	2	2	3	1	2	3
	2 Planned economies	3	2	4	3	3	2	3	4	2	3	4	4	4	3	3
	3 Semideveloped c. with market oriented	2	3	4	2	1	3	3	2	2	1	4	4	2	4	2
	4 Developing c with planning orientation	1	4	4	2	0	2	2	3	4	1	4	4	3	4	3
	5 Other developing countries	0	4	3	4	0	0	0	1	2	0	4	3	3	2	2
Industries	1 Mining	0	1	2	2	1	2	2	1	1	0	3	0	1	1	1
	2 Energy and fuel	2	2	2	2	2	2	2	1	3	2	3	3	2	3	2
	3 Basic materials	1	2	2	2	1	1	1	1	2	1	3	0	1	1	1
	4 Chemicals	2	2	2	2	3	2	3	3	3	1	2	2	2	2	2
	5 Engineering	3	2	3	3	3	2	3	3	3	2	2	3	3	3	3
	6 Automobiles	3	0	1	3	2	0	3	3	1	2	1	3	1	2	2
	7 Manufactured metal goods	1	2	1	2	2	2	1	1	2	2	2	1	1	1	1
	8 Electrotechnology	3	2	3	2	3	0	3	3	3	2	1	3	2	2	1
	9 Household applicances	3	1	3	2	2	1	3	1	2	2	1	1	1	1	1
	10 Electronics	3	1	3	2	3	0	3	3	3	3	1	3	1	3	2
	11 Textile, clothing, shoes	1	3	2	3	0	2	0	0	2	1	3	1	2	3	3
	12 Food	2	3	3	3	0	2	2	4	3	2	3	2	2	2	2

		(16) Increase in productivity	(17) Increase of profits	(18) Increase of net product	(19) Reduction of imports	(20) Increasing R&D	(21) Creation of jobs	(22) Environmental protection	(23) Improvement of working conditions	(24) Product development	(25) Process development	(26) Contribution to services	(27) Conservation of energy	(28) Increasing fexibility and adaption	(29) Reducing costs, fighting inflation	(30) Improving quality
Weights	1 Developed market economies	3	4	1	2	3	3	4	3	4	1	4	4	3	4	4
	2 Planned economies	4	2	4	3	4	0	3	4	3	4	3	4	4	4	4
	3 Semideveloped c. with market oriented	2	4	3	3	2	3	2	3	4	3	3	3	3	4	3
	4 Developing c with planning orientation	3	2	4	2	1	3	1	4	3	4	2	3	2	3	2
	5 Other developing countries	3	2	4	2	1	4	0	1	1	3	1	3	2	3	1
Industries	1 Mining	1	1	1	1	0	2	-1	-2	0	1	0	-1	-3	-3	0
	2 Energy and fuel	3	1	2	2	1	2	-2	0	0	3	2	3	3	-3	0
	3 Basic materials	2	1	1	1	1	1	-2	0	1	2	0	-2	0	-2	2
	4 Chemicals	3	3	3	3	3	1	-2	0	3	3	2	-1	2	1	3
	5 Engineering	3	3	3	3	3	1	0	1	3	3	2	1	3	2	3
	6 Automobiles	3	3	3	3	2	2	-2	0	2	2	3	-2	-1	1	2
	7 Manufactured metal goods	2	2	2	1	0	2	0	1	2	1	2	1	1	0	1
	8 Electrotechnology	3	3	3	3	3	3	2	1	3	3	3	3	3	3	3
	9 Household applicances	2	2	2	2	0	2	2	1	3	1	3	1	1	0	1
	10 Electronics	3	3	3	3	3	1	3	2	3	3	3	3	3	3	3
	11 Textile, clothing, shoes	2	2	2	2	0	2	0	1	1	1	2	0	0	-1	2
	12 Food	2	2	2	3	0	2	0	1	2	1	2	-1	0	1	1

		Weighted sum for developed market economies	Weighted sum for planned economies	Weighted sum for semi developed countries with market orientation	Weighted sum for developing countries with planning orientation	Weighted sum for other developing countries	Standardized weights for developed market economies	Standardized weights for planned economies	Standardized weights for semi developed countries with market orientation	Standardized weights for developing countries with planning orientation	Standardized weights for other developing countries
Weights	1 Developed market economies										
	2 Planned economies										
	3 Semideveloped c. with market oriented										
	4 Developing c with planning orientation										
	5 Other developing countries										
Industries	1 Mining	32	46	35	43	42	1.8	2.3	2.1	2.5	3.3
	2 Energy and fuel	136	159	129	129	115	7.7	7.9	7.6	7.6	9.1
	3 Basic materials	64	80	63	78	62	3.6	4.0	3.7	4.6	4.9
	4 Chemicals	174	183	174	168	120	9.9	9.1	10.2	9.8	9.5
	5 Engineering	219	244	216	201	149	12.5	12.1	12.7	11.8	11.8
	6 Automobiles	143	147	133	123	98	8.1	7.3	7.8	7.2	7.8
	7 Manufactured metal goods	114	121	110	109	84	6.5	6.0	6.5	6.4	6.7
	8 Electrotechnology	231	245	220	198	150	13.1	12.2	1.3	11.6	11.9
	9 Household applicances	154	251	139	211	86	8.8	12.5	8.2	12.4	6.8
	10 Electronics	248	255	130	122	140	14.1	12.7	7.6	7.2	11.1
	11 Textile, clothing, shoes	117	132	206	197	103	6.7	6.6	12.1	11.5	8.2
	12 Food	125	152	146	127	113	7.1	7.5	8.6	7.4	9.0
		1757	2015	1701	1706	1262	100	100	100	100	100

Argentina, South Korea, India, and Turkey), developing countries with planning orientation, and other developing countries.

These weights, reflecting the present situation, are affected by current world trends, including:

-- competition from newly industrialized countries,
-- saturation of areas of demand in developed countries,
-- changes in human behavior and tastes,
-- energy shortages,
-- increasing divergence among developed market economies,
-- growing environmental problems.

We see also that individual countries have conflicting goals, as each country seeks to protect its own economy. A current example of this is the "high technology war" between the US and Japan. As its older industries decline, the US is being faced with growing competition from Japan for dominance of the worldwide electronics industry. The object of this struggle is not a single branch of industry; it is all industry. For electronics will affect all areas of industry in this decade. The US fears the loss of its control over the content, direction, and pace of industrial development in a high-technology world, as industry becomes increasingly dependent on these technologies.

Having established the matrix of weights for the importance of industrial policy goals, we must assess the contribution of each industry to these goals on a scale. This is accomplished as follows:

For a given industry,

$$j = 1,2...m$$

For all goals,

$$i = 1,2...n$$

For one of the groups of countries, one obtains

$$k = 1,2...5$$ (a scalar product or goal satisfaction coefficient)

$$g_{j,k} = \sum_i w_{i,k} f_{ij}$$

where

$w_{i,k}$ is the weight of the i-th goal in the k-th country groups. ($w = 0,1,2,3,4$: very low or no priority, low, medium, high, very high priority, and $f = 0, \pm 1, \pm 2, \pm 3$: low or no contribution, medium, high, very high contribution.)

We can thus assess a given industrial structure by multiplying the shares of industries with the goal satisfaction coefficient. And so we obtain a vector

$$h_j = v_j \cdot g_{j,k}$$

which can be standardized and compared among countries. We also obtain the sum

$$G = \sum_j h_j$$

which indicates the progressiveness of the structure from the standpoint of goal satisfaction.

We see from this rough evaluation that the capital goods industry, including engineering and electrotechnology, receives the highest standardized weight in all groups of countries.

Between 1950 and 1975, the major growth industries were petrochemicals, chemicals, plastics, automobiles, electronics, aircraft engineering, machine tools, and production of machines and equipment for production control and automation.

An internal nucleus of technological progress is invariant over time. This comprises the increasing share of capital goods in value added, the increasing share of machines and equipment in capital goods and in total exports, and the rapid growth of production of machines and equipment for the production of machines and equipment.

Table 17 shows the increasing share of capital goods in industrial production for several countries.

Rapid industrialization is generally linked with a marked increase in the share of capital goods in production. Japan, Italy, Poland, and Romania are typical cases where this has occurred. The capital goods sector (especially the production of machines and equipment) plays an important role in industrial growth and in the innovation process for the following reasons:

1. The capital goods sector is an important expansion area for exports. Table 18 shows exports and imports of engineering products in 1977. Those countries with high innovative performance have favorable export/import ratios for engineering.
2. As Keith Pavitt (1979) and Karl-Heinz Oppenlaender (1980) have shown, spending for research and development, patent activity, innovative performance, and export results have become more closely interlinked since the 1960s, although this relationship has been mediated by strengths in the capital goods and machinery sectors.
3. The capital goods sector (and the engineering industry in particular) is less capital-intensive that the average industry, largely because of the emergence of new branches, such as the semiconductor industry,

Table 17. Share of capital goods in industrial production.

Country	Market Economies			Country	Planned Economies		
	Proportion of capital goods in value added manufacturing industry				Proportion of capital goods in gross product of all industries (including extractive industry)		
	1960	1974	Δ per annum		1960	1978	Δ per annum
USA	38.1	42.7	0.3	USSR	72.5	74.1	0.1
Japan	31.7	48.5	1.2	CSSR	61.5	67.8	0.4
FRG	38.2	39.0	0.1	GDR	60.8	66.0	0.3
France	37.3	39.2	0.1	Hungary	66.0	64.7	-0.1
UK	41.1	40.5	0	Romania	62.8	73.1	0.6
Italy	29.9	36.5	0.5	Poland	57.5	65.1	0.4
Brazil	9.2	14.5	0.4	Mongolia	51.6	51.8	0

SOURCE: Interfutures (1979).
Statistical Yearbook of CMEA Countries (1979).

Table 18. World exports and imports of engineering products (1977).

	Exports (mill.US$)	%	Imports (mill.US$)	%	Export/Import Ratio
Developed Market Economy Countries	273,585.5	87.5	183,844.6	58.8	1.49
U.S.A.	51,036.5	16.3	36,125.9	11.6	1.41
E.E.C.	137,658.0	44.0	82,356.1	26.3	1.67
Japan	44,737.5	14.3	3,372.1	1.1	13.27
Other Countries	40,153.5	12.8	61,990.5	19.8	0.65
Developed Planned Economy Countries	31,132.5	10.0	32,558.3	10.4	0.96
U.S.S.R.	8,473.3	2.7	14,886.9	4.8	0.57
Developing Countries	7,782.0	2.5	93,178.0	29.8	0.08
Brazil	1,396.0	0.4	3,289.7	1.1	0.42
Hong Kong	1,205.2	0.4	1,683.0	0.5	0.72
Korea, Rep. of	1,727.8	0.5	2,990.6	1.0	0.58
Singapore	2,017.1	0.6	2,405.0	0.8	0.84
Non-effected Imports			(2,919.1)	0.9	
WORLD TOTAL	312,500.0	100.0	312,500	100.0	

Source: Monthly Bulletin of Statistics (1980).

which begin at low levels of capital intensity. This explains the contribution by the capital goods sector to the growth of industrial employment. Capital intensity is higher than the industrial average in the petroleum and petroleum derivative industry, and in the paper, steel products, rubber, and food industries.

4. The capital goods sector (and especially the engineering industry) acts as an outstanding training ground for other industries. The advancements in technology that are incorporated into the design and functions of capital good and the kind of worker training induced and supported by this sector help extend innovations to older industrial sectors, where they often contribute substantially to rises in productivity.

Comparative studies of national industrial development should be complemented by detailed national studies.

INNOVATION AND INDUSTRIAL DEVELOPMENT AT THE NATIONAL LEVEL

An analysis of industrial goals of individual countries is more complicated than one of groups of countries, because of the need to consider specific historical situations when looking at the national level.

An important topic in a discussion of national industrial development is the industrial strategy of small countries, such as the Netherlands, Finland, the GDR, Switzerland, and Hungary (Roman 1979; Honko 1980; de Wolff 1980; Technical Capability 1979; Schenk 1979; Blattner 1977; Hinterhuber 1978). Small nations cannot simply model their industrial structures after those of larger nations. They are better advised to take advantage of their smallness by concentrating their efforts in the directions which will best enable them to take advantage of domestic resources and experiences. For example, Sweden and Hungary are rapidly developing their drug industries. Because the selling price of pharmaceutical products is many times the cost of manufacturing them, the drug industry is ideal for high-wage economies.

There are certain principal gauges by which we can measure the qualitative industrial performance of a country. Figures 7 and 8 show a profile of the industrial structure of the FRG in 1950 and 1976. Figure 9 shows the patent structure in 1972, which is very progressive, except for the high share of environmentally intensive production. The patent structure of 1972 predicts a future progressive pattern of industrial structure which had not yet been realized in 1976 (Figure 8). But we must bear in mind that gauges are subject to historical change. The high-demand industries of one period may not be the high-demand industries of another.

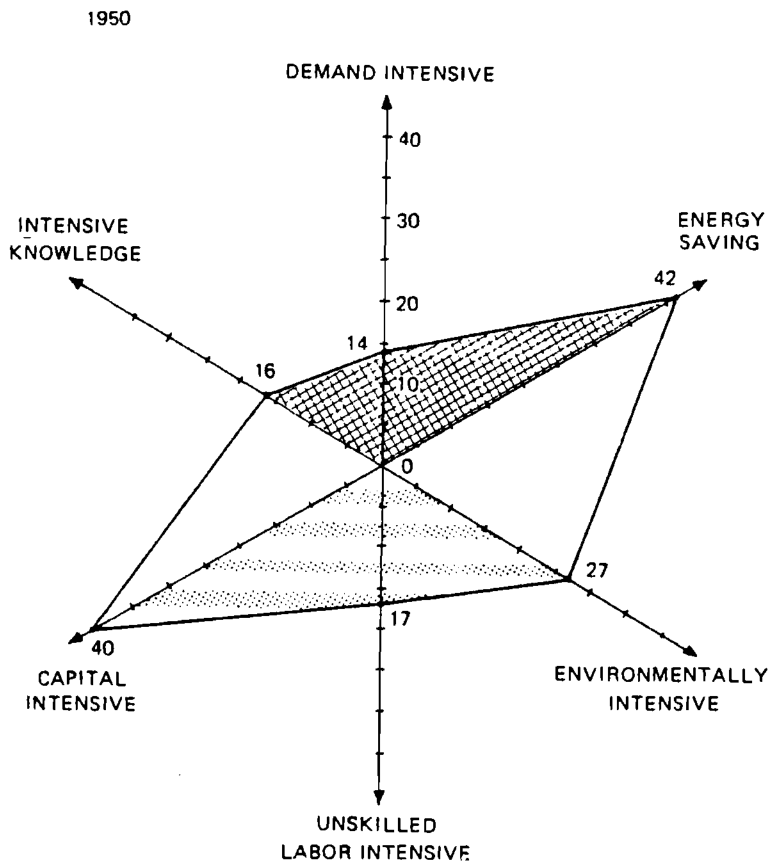

Figure 7. Industrial structure of the FRG in 1950.

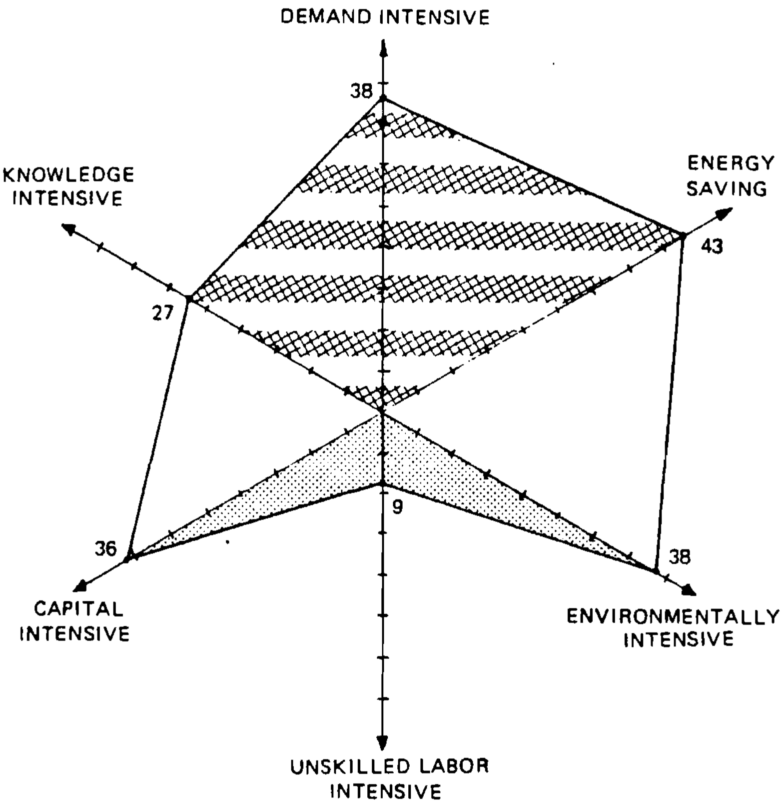

Figure 8. Industrial structure of the FRG in 1976.

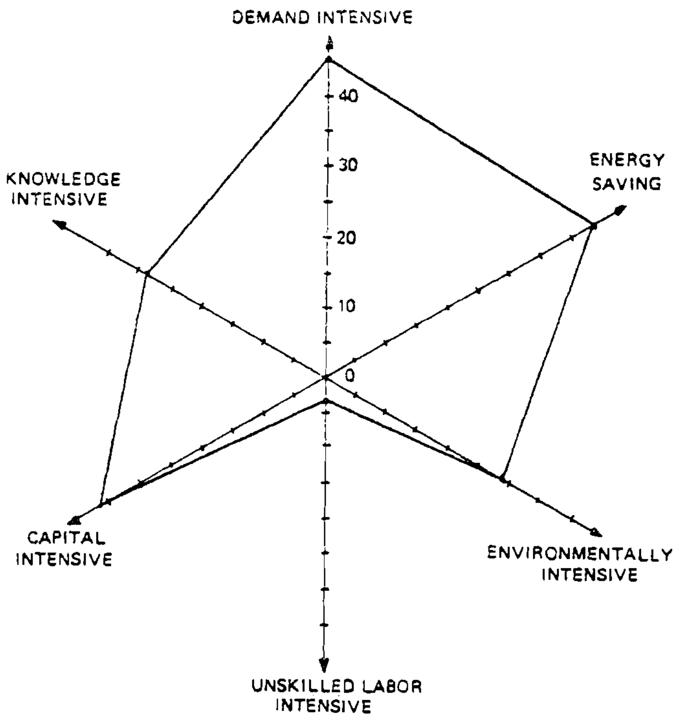

Figure 9. Patent structure of the FRG in 1972.

An analysis of individual goals is also necessary when examining the main opportunities and directions of a policy for innovation (see Scholz 1977). Table 19 shows the result of a 1977 investigation of 37 industries in the Federal Republic of Germany. This table indicates that the greatest problems arise from the need to compete with imports from both developed and developing countries. The major directives of technological change in the FRG are toward improvements in products and new products. In the GDR, industrial objectives are ranked in a different order and technological policy thus takes a different direction (see Table 20). A major objective is to reduce the amount of manpower needed. The economic system and its concrete conditions play a decisive role in technological policy. Table 21 illustrates this.

In the FRG, automation in industry is aimed primarily at increasing profits. This can best be ensured through reduced spending on wages, reduced processing time, and increased flexibility in production. In the GDR, on the other hand, automation is used to close societal gaps, among them, shortages of labor, energy, and raw materials.

Figure 10 shows the relationship between labor (in number of hours worked) and investment (in real capital input) in FRG industry for the years 1955-1977. Figure 11 shows indexes for numbers of workers and amount of investments in the GDR for the years 1950-1977 where the year 1960 = 100. These indexes are useful for investigating policies for innovation under differing economic conditions. As in all EEC countries, labor substitution has accelerated in the FRG since 1970 (Rothwell 1979).

Table 19. Adaptation problems and the directions of technological change in industry in the Federal Republic of Germany (percentage of entries from 277 cases in 37 industries).

Adaptation problems / Directions of technological development	Transfer of production abroad to meet: domestic demand	Transfer of production abroad to meet: foreign demand	Competition problem with Imports from: developed countries	Competition problem with Imports from: developing countries	Competition problem with: products of other industries	Supply of resources: Raw materials	Supply of resources: Energy	Suitable environmental conditions	Total
1. Changes in the scale of equipment	0.7	0.7	1.8	1.4	0.7	-	1.4	1.1	7.9
2. Changes in the organization	1.4	1.8	3.2	2.9	1.8	0.7	2.2	1.4	15.5
3. Increasing automation	1.4	2.5	6.1	2.9	2.2	1.4	2.2	-	18.8
4. Change in processes	1.4	2.5	3.2	2.9	2.2	1.8	2.5	2.2	18.8
5. Change in materials	1.1	1.4	2.2	1.8	2.9	1.4	-	-	10.8
6. Improved products	1.4	3.6	6.9	2.2	3.2	1.1	1.4	1.4	21.3
7. New products	0.7	1.8	1.8	0.7	0.7	0.4	0.4	0.4	6.9
Total	8.3	14.4	25.3	14.8	13.7	6.9	10.1	6.5	100.0

SOURCE: Scholz (1978).

Table 20. Objectives and directions of technological development in GDR industry (1980).

Objectives / Kind of innovation	To conserve resources: Manpower	Materials	Energy	Imports	Environment	To increase exports	To improve working conditions	To satisfy domestic demand	Total	Percent
Weight for objectives	4	4	4	3	2	4	3	3	-	-
1. Changes in scale of equipment	2(8)	2(8)	2(8)	0(0)	0(0)	1(4)	1(3)	1(3)	(34)	11.4
2. Changes in organization	1(4)	0(0)	0(0)	0(0)	0(0)	0(0)	2(6)	1(3)	(13)	4.4
3. Increased automation	3(12)	1(4)	3(12)	1(3)	1(2)	1(4)	3(9)	2(6)	(52)	17.4
4. Change in processes	3(12)	3(12)	3(12)	3(9)	3(6)	2(8)	3(9)	2(6)	(74)	24.8
5. Change in materials	1(4)	3(12)	2(8)	3(9)	3(6)	1(4)	1(3)	1(3)	(49)	16.4
6. Improved products	-1(-4)	1(4)	1(4)	2(6)	1(2)	2(8)	1(3)	2(6)	(29)	9.7
7. New products	-3(-12)	2(8)	3(12)	3(9)	3(6)	3(12)	1(3)	3(9)	(47)	15.8
	6(24)	12(48)	14(56)	12(36)	11(32)	10(40)	12(36)	12(36)	(298)	100.0
	8.1	16.1	18.8	12.1	7.4	13.4	12.1	12.1	100.0	

Table 21. Reasons for automation in industry in the FRG and the GDR (1975-1980)

Reasons for automation	Rank in importance	
	FRG*	GDR**
1. To reduce the share of all costs spent on wages.	1	13
2. To reduce processing time.	2	2
3. To increase flexibility of production.	3	10
4. To reduce waste.	4	8
5. Shortage of qualified manpower.	5	9
6. To reduce material consumption.	6	4
7. To reduce energy consumption.	7	3
8. To increase safety of work.	8	5
9. To reduce heat, noise, etc.	9	6
10. To conform to technical changes necessary for changes in product.	10	11
11. To reduce monotony and stress on the job.	11	7
12. To decrease dependency on special knowledge.	12	14
13. Quantitative shortage of manpower.	13	1
14. To meet environmental regulations.	14	12

SOURCE: * Scholz (1978).
**Own estimates.

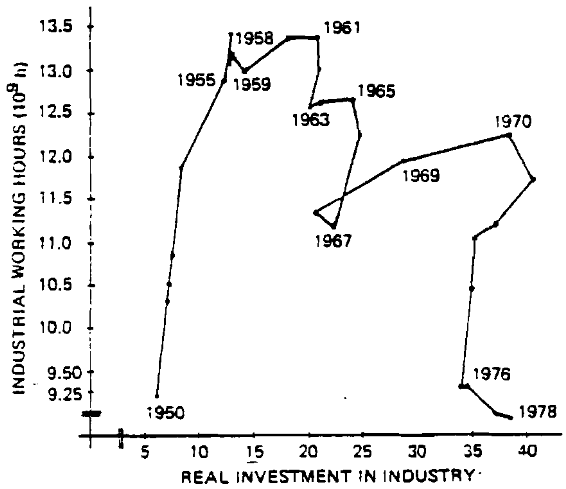

Figure 10. The relationship between labor hours and real investment capital input in FRG industry (1950-1978).

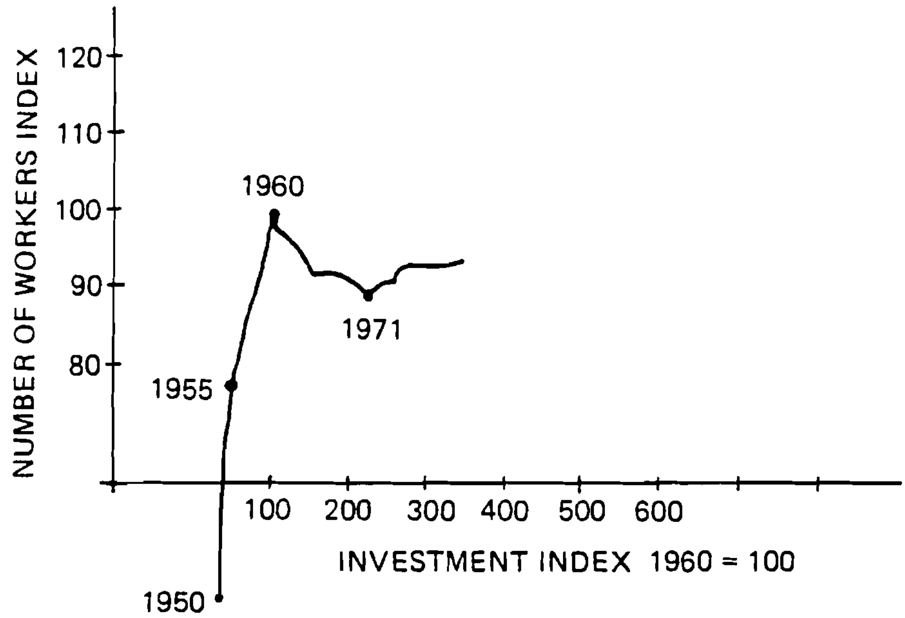

Figure 11. Index of numbers of workers and investments in GDR industry (1950-1977).
Source: Statistical Yearbook of the GDR (1955-1979).

The basic question here is whether innovation policy can help by providing opportunities to expand investments and by creating new jobs (Oppenlaender 1980; Mensch et al. 1980; Uhlmann 1979). In the GDR, where the scarcity of labor demands rapid rationalization, there has been extensive growth since 1971. To better understand the mechanisms of this development, it is necessary to drop down to at least the sectoral level.

INNOVATION AND RELATIVE EFFICIENCY AT THE SECTORAL LEVEL: THE CASE OF THE CHEMICAL INDUSTRY IN THE GERMAN DEMOCRATIC REPUBLIC

The chemical industry in the GDR, chosen for an analysis at the sectoral level, has traditionally been an important sector of the economy. In 1979, chemical output exceeded 33 billion marks. With a share of 14%, this makes it the second largest single industrial branch, outranked only by mechanical engineering. More than 335,000 workers are employed in 474 enterprises in the major chemical complexes shown in Table 22.

Table 22. Major chemical complexes in the GDR.

Chemical complexes founded before 1973	Location	Number of employees
VEB Leuna-Werke "Walter Ulbricht"	Leuna	31,000
VEB Petrolchemisches Kombinat	Schwedt	30,000
VEB Chemiefaserkombinat "Wilhelm Pieck"	Schwarza	29,000
VEB Chemiekombinat Bitterfeld	Bitterfeld	32,000
VEB Chemische Werke Buna	Schkopau	29,000
VEB Farbenfabrik	Wolfen	19,000
Chemical complexes founded since 1973		
VEB Kombinat Agrochemie	Piesterik	15,000
VEB Kombinat Plast- u. Elastverarbeitung	Berlin	32,000
VEB Kombinat Lacke und Farben	Berlin	8,000
VEB Chemieanlagenbaukombinat	Leipzig/Grimma	32,000
VEB Reifenkombinat	Fürstenwalde	10,000
VEB Kombinat Synthesewerk	Schwarzheide	12,000

In the chemical industry, innovation has been a matter of technical efficacy, economic efficiency, and social effectiveness. The main problems from the standpoint of planning authorities can be formulated as follows:

1. What potential for efficiency do present and planned innovations have?
2. Is this potential great enough to meet long-term planning targets?
3. If not, what other technological or organizational options are available?
4. What factors will be decisive for increasing efficiency in the future?
5. How can we change these factors in the future to improve the situation?

The nature of these questions leads us to conclude that in planned economies, efficiency is measured not only in terms of absolute efficiency, i.e., profitability or productivity. The proper allocation of resources requires relative efficiency, or efficiency in relation to potential or normative efficiency.

$$e(t) = \frac{e_A(t)}{e_A{}^*(t)}$$

where

$$0 \leq e(t) \leq 1$$

The assessment of normative efficiency is a key to practical planning (Haustein 1976).

A simple method for assessing relative efficiency involves the relation of the present efficiency of a system to the average efficiency of the next higher system.

$$e_M(t) = \frac{e_A(t)}{\bar{e}_A(t)}$$

For the chemical industry, we compared the efficiency figures of the chemical industry alone with the efficiency of all industries.

Relative efficiency can be measured against the average or against a normative figure (see Table 23). It can also be measured in absolute figures or in growth rates. Where growth rates are used, relative efficiency appears as an elasticity figure. For the analysis of relative efficiency in the chemical industry, six indicators were chosen:

-- benefits from inventions and proposals per unit of wages,
-- productivity,
-- profit per unit of gross product,
-- output per unit of material,
-- net product per unit of fixed captial, and
-- output per kilowatt hour.

Let us look at the development of these indicators (Figure 12). What causes the changes? First of all, such changes can

Table 23. Scheme for calculating relative efficiency.

Level	Absolute benefits or outputs	Absolute efficiency (current output/ input-relation)	Relative efficiency relative to the	
			Normative efficiency	Average efficiency of the next higher system
1. Single innovation				
2. Innovating system				
3. Industry as a whole				

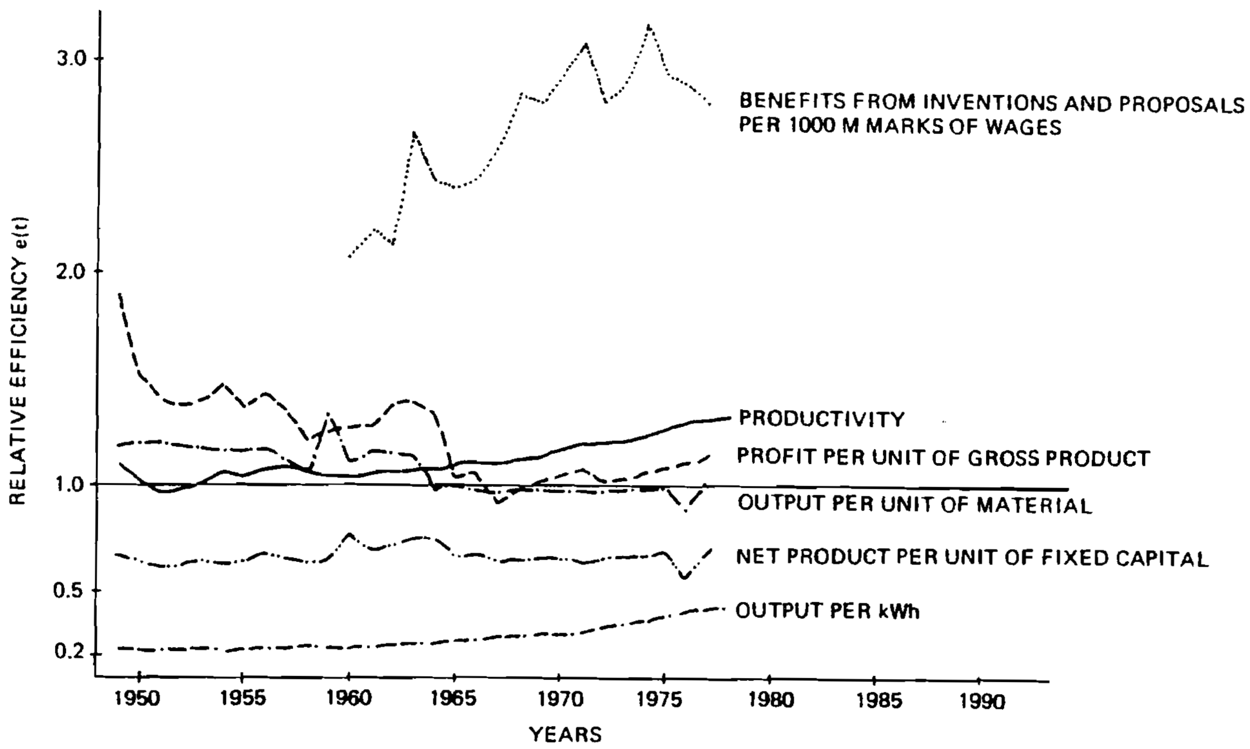

Figure 12. Relative efficiency of the GDR's chemical industry.

be traced to the levels of the six indicators. Every structure has a historical background. When looking at the chemical chemistry in the GDR, one must take into account coal chemistry and its high demand for energy. In 1965, only 7 percent of the carbon demand in the chemical industry was satisfied by oil. By 1970, this figure had reached 25 percent (see Figure 13). Since 1965, output per kwh has increased markedly. During the same period, productivity and profit per unit of gross production has also increased. The structural change in the petrochemical industry was accompanied by rapid expansion of two major chemical industries: synthetic fibers and plastics (Figure 14). These industries grew quickly between 1967 and 1978 as a result of heavy investments. Thus it is understandable that the rationalization effect of investments was not yet high enough to ensure a significant reduction of working hours (see Figure 15). There was rapid growth in automatic and semiautomatic equipment, but the growth of the automation coefficient of labor was slower (See Figure 16.) Thus

$$a_M = \frac{M_A}{M}$$

$$a_W = \frac{W_A}{W}$$

where

M_A = automatic and semiautomatic equipment

M = all classifiable equipment

W_A = workers using automatic and semiautomatic equipment

W = all workers

The relationship between a_M and a_W is

$$k = \frac{a_M}{a_W} = \frac{M_A/M}{W_A/W} = \frac{M_A/W_A}{M/W}$$

where k is an indicator for relative machine intensity. Mathematically, this is the relation of two logistic functions having different parameters (Haustein 1975).

$$k = \frac{1 + ae^{-bt}}{1 + ce^{-dt}}$$

where

a,b = parameters for the logistic function of the automation coefficient of labor, and

c,d = parameters for the logistic function of the automation coefficient of equipment.

In

$$t = t_{max} = \frac{1}{d} \ln \frac{c[de^{bt} + a(d-b)]}{ab}$$

k reaches a maximum.

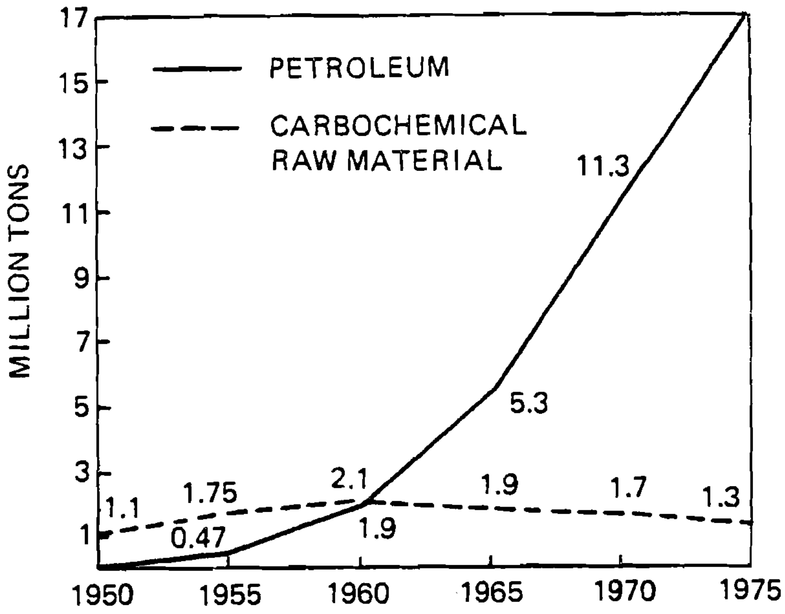

Figure 13. Development of petroleum processing and the utilization of carbochemical raw materials in the GDR.
Source: The Chemical Industry of Eastern Europe, 1975-1980 (1976).

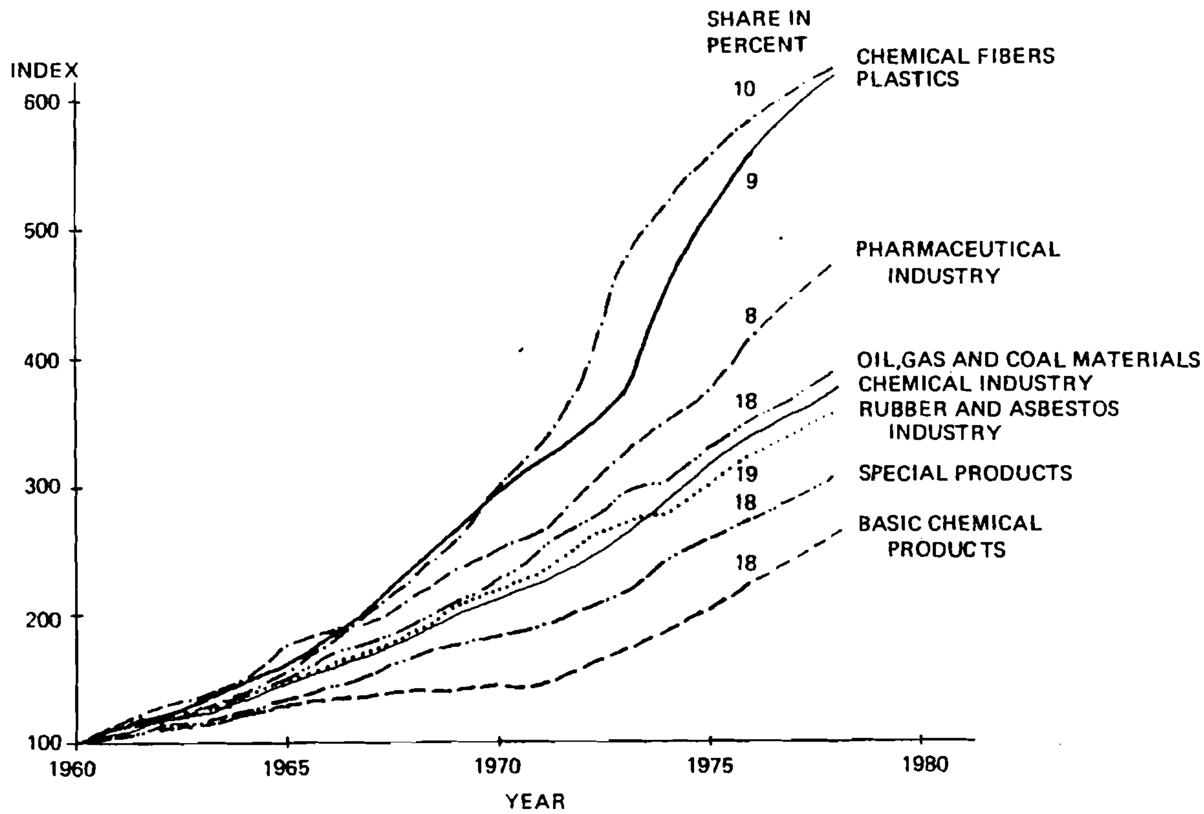

Figure 14. Development of branches of the chemical industry in the GDR.

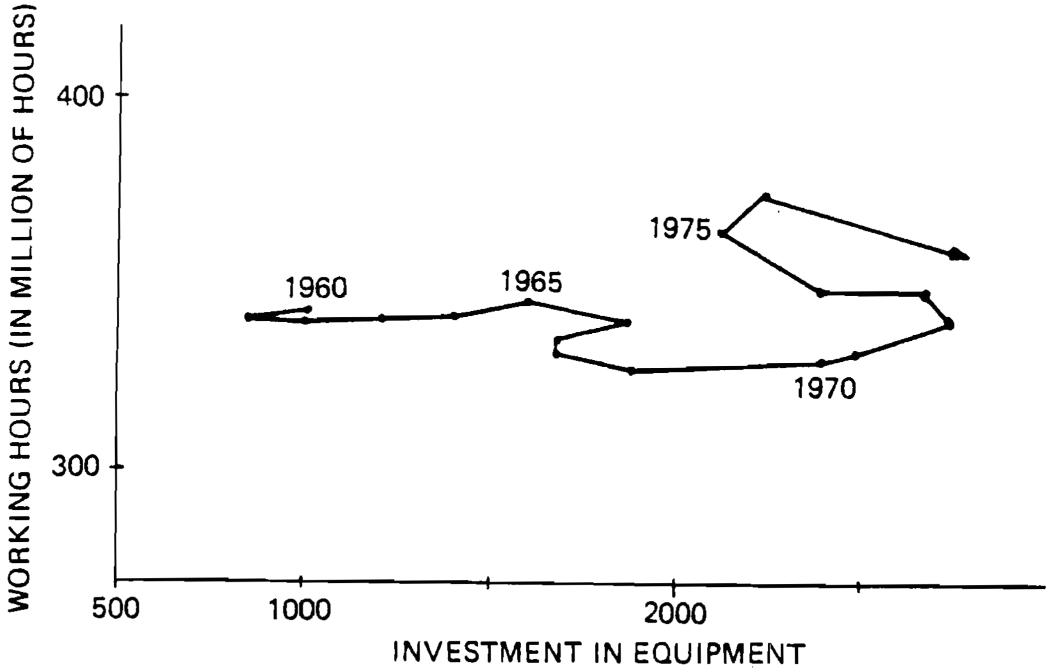

Figure 15. Development of working hours and investment in the GDR's chemical industry.

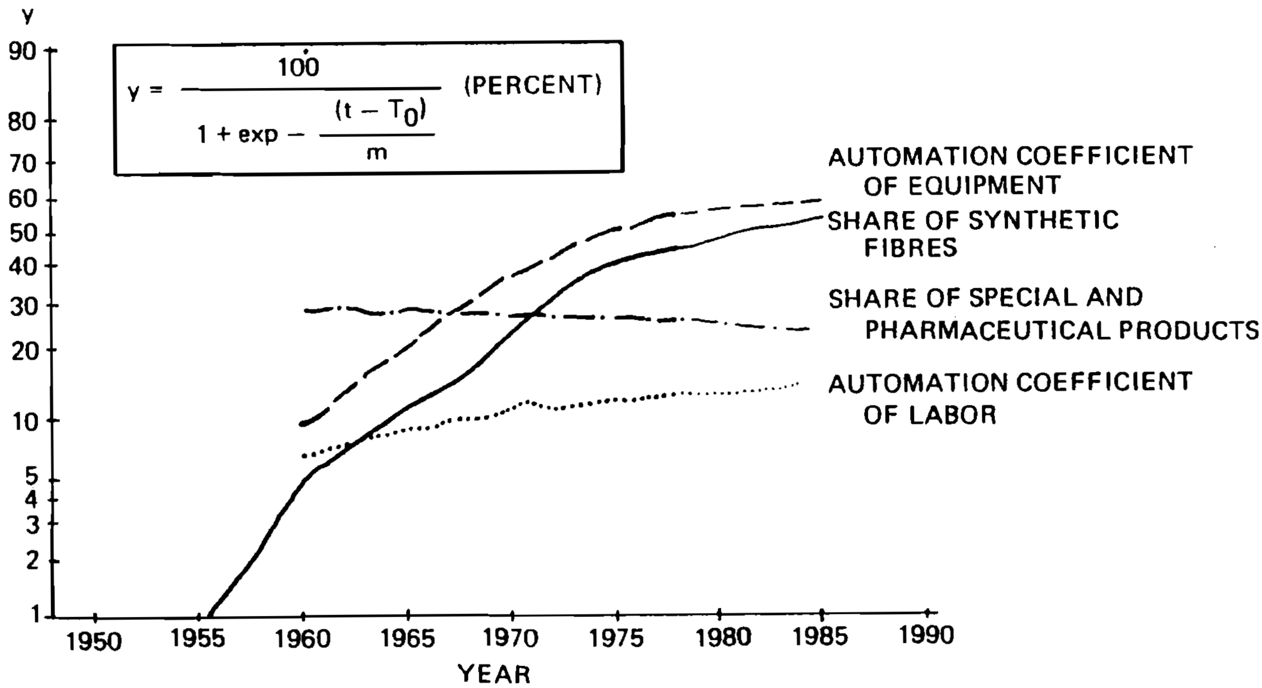

Figure 16. Indicators of the GDR's chemical industry.

If the parameters a,b,c, and d are known, a forecast of k is possible. t_{max} can be estimated by iteration.

In the chemical industry in the GDR, k was 1.23 in 1960 and reached a maximum of 4.63 in 1974. This indicator increases in the expansive stage of automation and decreases in the intensive stage. The chemical industry must reach a higher level of automation to obtain the desired rationization effect and with it, the desired growth in productivity.

The next decisive factor is product development, where we find the same trend. Since 1970 the trend toward a declining share of chemicals in all exports and in the export volume per unit (gross product) has been reversed through innovations in products and processes.

Thus the transition to petrochemistry was very successful. But the likelihood of an oil price in excess of 38 dollars per barrel by the mid-1980s has drastically altered the situation with regard to raw materials and energy and has made it imperitive that we seek innovations and/or improvements in the processing system (see Figure 17 and Table 24).

Coal chemistry has again become of great interest: the two carbide-producing plants in the VEB Chemische Werka Buna, for instance, substitute coal for more than 5,000,000 tons of crude oil annually. Production of carbide reached a peak of 1,335,000 tons in 1973 and then slowed down. In 1977, it began to rise again. New and improved processes for coal-chemistry are now being sought. The oil equivalent of all coal chemistry was 7,000,000 tons in 1980 and is expected to reach 11,000,000 tons by 1990.

There is a rapidly growing demand for synthetic natural gas (SNG). In 1979, 25% of this demand was covered through the processing of coal. (SNG production in 1980 was five billion cubic meters; this is expected to reach seven billion cubic meters by 1990.)

What are the key problems for improving efficiency in the chemical industry?

Due to a scarcity of resources, it will be necessary to increase output per unit of material. This must be accomplished without creating the demand for additional energy or other resources.

We will have to increase investment in rationalization. At the beginning of 1980, more than 20,000 investment projects in the GDR were analyzed using certain criteria, among them rationalization.

And because of the diminishing benefits in certain production fields, we must improve the potential of innovation in the chemical industry. Generally, there seems to have been an increase in innovation potential in the past 10-12 years, correlating to investment activity.

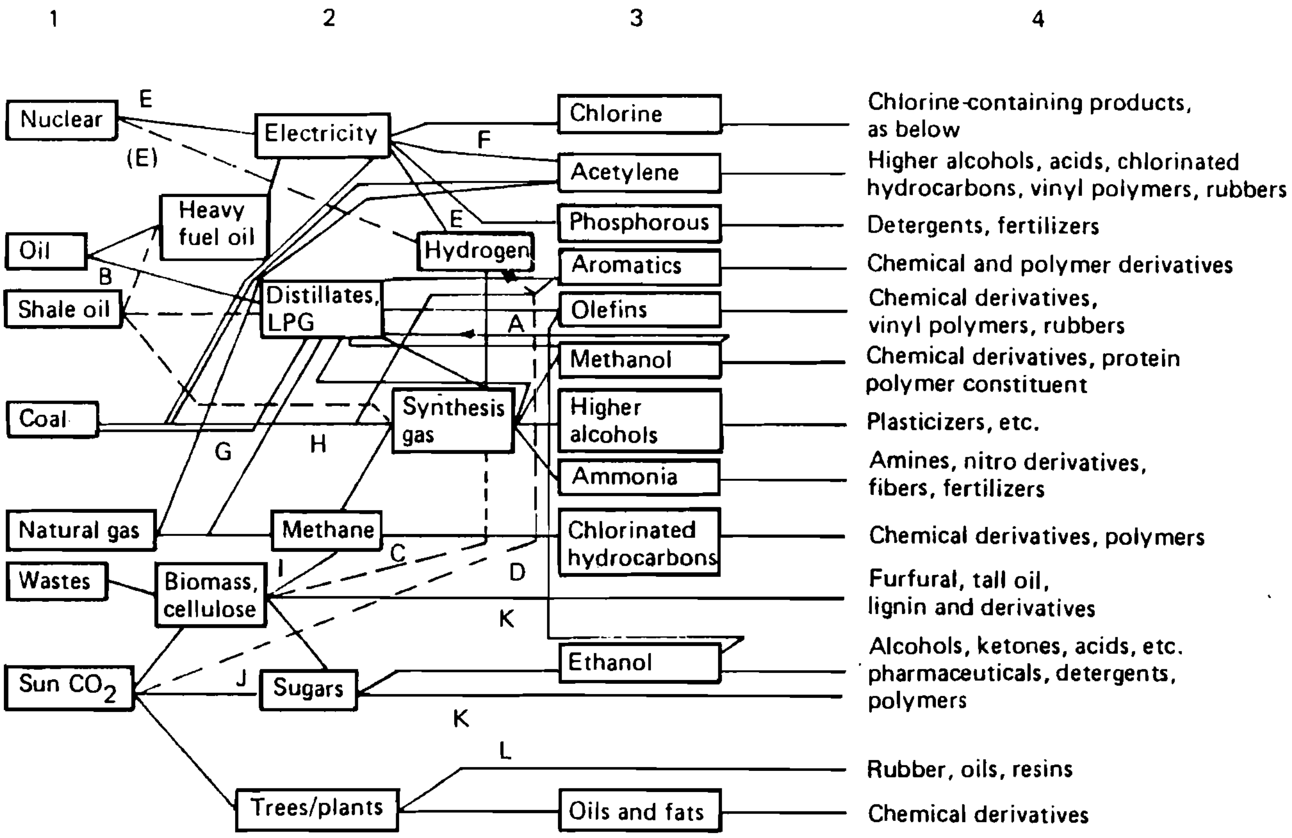

Figure 17. Potential new pathways and their relations to present and previous practice. Source: Caudle (1978).

Table 24. Likely routes for the post-petrochemical era.

New routes

A. The conversion of methanol to liquid and gaseous hydrocarbons.
B. Substituting shale oil in routes presently using crude oil and/or coal.
C. The aerobic conversion of biomass to sythetic gas.
D. The phototropic production of hydrogen in biological systems.

Old routes with new potential

E. Production of hydrogen by electrolysis. (Use of direct nuclear heat is also being researched.)
F. Production of ecetylene, possibly via carbide, but more likely through a plasma reactor.
G. Coal hudrogenation (which also requires hydrogen or synthetic gas).
H. Fischer-Tropsch type synthesis yielding both hydrocarbons and oxygenated products.
I. Anaerobic fermentation of natural and/or waste materials.
J. Increased production of sugars either naturally, or by acidic or enzymatic hydrolysis of cellulose; and subsequent fermentation or conversion.
K. New products (e.g., lignin) from existing natural materials.
L. Increased yields from existing species, and/or new or modified species.

Source: Caudle (1978).

Resuming our analysis of a case sector, we can now list the main factors that influence the development of a major industry in a planned economy. These are

-- historically-given structures,
-- national targets,
-- type of process development,
-- type of product development,
-- type of investments,
-- changes in the resource situation,
-- organized structural change,
-- potential for innovation in industry,
-- competition from abroad,
-- division of labor with other planned economies.

An essential question for future industrial development is the impact of innovations on efficiency and the impact of social and economic goals on innovation. Applied systems analysis is challenged with developing a methodology that can forecast this interdependence.

A PROPOSED METHODOLOGY FOR STUDYING THE EFFECT OF INNOVATIONS ON INDUSTRIAL GROWTH AND EFFICIENCY

I propose that future studies at IIASA of industrial development concentrate on three topics:

1. global resources and industrial development,
2. global needs and industrial development, and
3. innovations and industrial development.

We must find an appropriate methodological approach for studying the last topic and determine opportunities for sectoral development in industry that are consistent not only with social and economic needs, but also with existing constraints and objective possibilities for technological progress (see Figure 18). The complex interaction between social goals, technological opportunities, resources, and the production system should be dealt with step by step. Figure 19 shows a flow diagram of this procedure.

The first step is to collect, analyze, and categorize technological opportunities (TO). These can be grouped as shown in Table 25.

Table 26 shows a rough evaluation of technical opportunities according to their interaction. This allows us to order the fields for technological opportunities (FTO) by rank. One could also examine patent statistics to identify fast-growing technological fields.

A major assumption of such an approach is that growth in productivity will be guaranteed over the next 10 to 20 years by technological opportunities that are already in the developmental stage or are already being applied. An assessment of future growth of productivity can be made by using the scheme of factors shown in Table 27. Statistical data on the share of these factors in growth of productivity are available for planned economies.

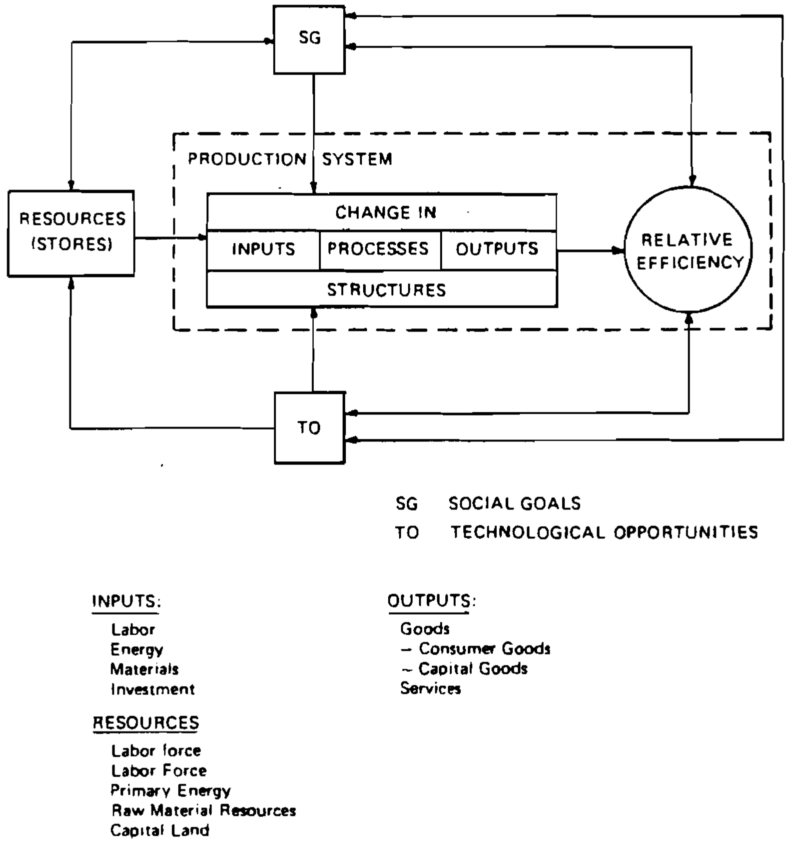

Figure 18. Main components of a methodology for studying the effect of innovations on industrial growth and efficiency.

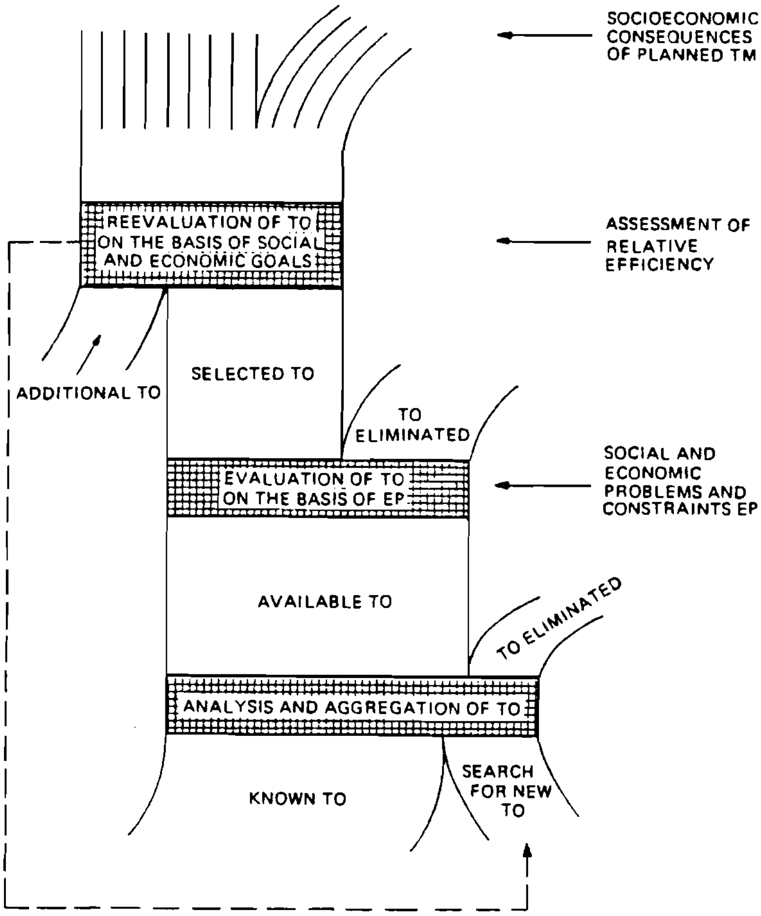

Figure 19. Flow chart of technological options (TO).

Table 25. Scheme for categorizing technological opportunities (TO).

1. Production process
    1.1. Automation
        1.1.1. Production systems
        1.1.2. Robots
        1.1.3. Measurement and quality control
        1.1.4. Technology for transportation and storage
    1.2. Energy Technology
    1.3. Other processes
        1.3.1. Changes in the form of objects (dividing or connecting)
        1.3.2. Chemical processes
        1.3.3. Biological processes

2. Materials and inputs
    2.1. Integration and use of electronic compounds
    2.2. Substitution

3. Communication and organization
    3.1. Communication technology
    3.2. Office automation

Table 28 shows the influences of all fields of technological opportunities (FTO) on factors of productivity growth (PF). These affect economic problems (EP). This rough estimate gives some indication of major patterns of productivity and future opportunities. We can thus recognize possible future structures of technological policy.

But can the technological opportunities available ensure the growth in productivity necessary in the next period? This can only be answered by analyzing relative efficiency. An analysis of economic indicators (EJ), socioeconomic problems (EP), and socioeconomic goals (SG) is the basis for certain assumptions on total future growth.

The next step will be a more detailed calculation of the influence of technological opportunities on labor, energy, materials, and investment. If the goals are not met through planning measures, a next iteration begins.

Table 26. Fields for technological opportunities (FTO) until 1990 and their interaction.

From → to	A	B	C	D	E	F	G	H	I	J	K	L	Total
A Production systems	-	2	2	2	1	2	2		2	2	1	2	18
B Robots	2	-	1	2	1	3	2					1	12
C Measurement and quality control	3	3	-			2	2	2	3	2			17
D Transportation and storage	2			-								2	4
E Energy	2			2	-	1	2					2	9
F Changes in design	2	2	1	1	2	-			2	2			12
G Chemical processes	2	2			2		-		2	2			10
H Biological processes							1	-	2	2			5
I Integration of materials and inputs	3	2	2			3	3		-		2		15
J Substitution	2		2		2	2	2		2	-			12
K Communication technology				2	2					2	-	3	9
L Office automation	3	2	2	2							3	-	12
Total of vertical columns	21	13	10	11	10	13	14	2	13	12	6	10	
Total of columns, vertical and horizontal	39	25	27	15	19	25	24	7	28	24	15	22	

Legend: 3 high impact
2 medium impact
1 low impact

SOURCE: Technischer Fortschritt (1980).

Table 27. Scheme showing factors of productivity growth (PF).

1. Technological level
    1.1 Products
        1.1.1 New products
        1.1.2 Improved products
    1.2 Equipment (mechanization and automation)
    1.3 Processes
        1.3.1 New processes
        1.3.2 Improved processes
    1.4 Materials
    1.5 Materials

2. Labor force
    2.1 Working conditions and health
    2.2 Eduction, qualification, knowledge
    2.3 Working time

3. Organizational level
    3.1 Changes in scale
    3.2 Organization in the enterprise
    3.3 Organization in the industry

4. Structure
    4.1 Structure of output
    4.2 Structure of labor force
    4.3 Structure of fixed capital

5. Natural environment

Table 28. Fields for technological opportunities (FTO) and their impacts on factors of productivity growth (PF).

FTO (From → to PF)	Technological Level: Products – New	Products – Improved	Equipment	Processes – New	Processes – Improved	Materials	Energy	Labor Force: Working conditions Health	Education Qualification	Working time	Organizational Level: Changes in scale	Organization in the enterprise	Organization in the industry	Total
A Production systems			3		2	2	2	2	2	3	3	3		22
B Robots			3			1	1	3	2		2	2		14
C Measurement and quality control	2	3	2	3	3									13
D Transportation and storage					2		1	2			2			7
E Energy			2	2	2		3	2						11
F Changes in the form of objects			2	2	2	2	2	2						12
G Chemical processes	2	2	2	2	2	3	2	2						17
H Biological processes				2		2	2							6
I Integration in materials and inputs		2	2	2	3	3	2	2						16
J Substitution of materials	2	3	2	3	3	3	2	2						20
K Communication technology		3	2				2	2	3	3	2		2	19
L Office automation								3	3	3	3	3		15

Legend: 3 high impact
2 medium impact
1 low impact

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REFERENCES

Blattner, N. 1977. Industrial Policy: A Skeptical View. Paper presented at the Fourth European Conference on Industrial Structure in Berlin.

Business Week. September 3, 1979. 50th Anniversary Issue. New Growth Industries: How U.S. Business Will Change in the Next 50 Years.

Caudle, P. 1978. Chemicals and Energy: The Next 25 Years. Futures 10:361-379.

The Chemical Industry in Eastern Europe, 1975-1980. 1976. Fourth Edition. London: Chemical Data Services.

Csikos-Nagy, B. 1980. Industrial Policies and Strategies, 3: Hungary. CP-80-39. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Current and Prospective Issues in Science and Technology Policies. Developments in Science and Technology Policies. Review of National Policies in the Field of Technological Innovation. 1980. Paris: UN Economic Commission for Europe.

Dostal, W., M. Lahner, and E. Ulrich. 1977. Datensammlung zum Projekt Auswirkungen Technischer Änderungen auf Arbeitskräfte: Beiträge zur Argeitsmarkt- und Berufsforschung. (Data collection for the Project on the Effects of Technical Changes on the Labor Force: Contributions for the Labor Market and Vocational Research). Nürnberg: Institut für Arbeitsmarkt- und Berufsforschung der Bundesanstalt für Arbeit.

Fajnsilber, F. 1980. Industrialization, Capital Goods, and Labor in Advanced Economies. Paper presented at the Sixth World Congress of Economists in Mexico City.

Graham, A.K. and P.M. Senge. 1980. A long-wave hypothesis of innovation. Technological Forecasting and Social Change 17:283-311.

Hamilton, I., ed. 1978. Industrial Change: International Experience and Public Policy. New York and London: Longman Press.

Haustein, H.-D. 1975. Die Proportionalität der technischen Basis in Sozialismus (The Proportionality of the Technical Basis in Socialism). Berlin: Akademie Verlag.

Haustein, H.-D. 1976. Messung der Volkswirtschaftlichen Intensivierung (Measuring the Intensification of the National Economy). Berlin: Akademie Verlag.

Heinze, J. 1979. Strukturwandel in der Bundesrepublik: Eine Auseinandersetzung mit der Drei-Sektoren-Hypothese (Structural Change in the Federal Republic of Germany: A Debate on the 3-Sector Hypothesis). Munich: IFO Schnelldienst.

Hinterhuber, H., ed. 1978. Innovationspolitik in Österreich (Innovation Policy in Austria). Vienna: Federal Ministry of Science and Research.

Hirschhorn, J. 1980. Federal Industrial Policy. Washington: Office of Technology Assessment.

Hoffman, W.G. 1965. Das Wachstum der Deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts (Growth of the German Economy since the Middle of the Nineteenth Century). Berlin and Heidelberg: Springer Verlag.

Honko, J. 1980. Developing a Finnish industrial strategy. In Industrial Policies and Strategies 1. CP-80-4. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Interfutures. 1979. Facing the Future: Mastering the Probable and Managing the Unpredictable. Paris: Organization for Economic Cooperation and Development.

Kleinknecht, A. 1979. Basisinnovationen und Wachstumsschübe: das Beispiel der westdeutschen Industrie (Basic innovations and growth spurts: the example of West German industry). Konjunkturpolitik 25:5-6. Berlin: Duncker und Humblat.

Kurenkov, Y. 1979. Scientific and Technological Progress and Structural Change in World Industrial Production. Budapest: Industrial Development and Industrial Policy.

Mensch, G. 1975. Das Technologische Patt (The Technological Statemate). Frankfurt-am-Main: Umschau Verlag.

Mensch, G., K. Kaasch, A. Kleinknecht, and R. Schnopp. 1980. Innovation Trends and Switching Between Full- and Under-Employment Equilibria, 1950-1978. Discussion papers IIM/ dp 80-5. Berlin: International Institute of Management.

Monthly Bulletin of Statistics. 1980. Vol. 34, No. 10. New New York: United Nations.

Oppenländer, K.-H. 1980. The Impact of Technical and Structural Change on the Structure and Employment of Manpower. Munich: IFO-Institute.

Pavitt, K. 1980. Innovation in Western Europe: A Challenge and an Example. Sussex, England: University of Sussex.

Pavitt, K. 1979. Technical Innovation and Industrial Development in the 1980s: the Dangers of Divergence. Sussex, England: University of Sussex.

Roman, Z., ed. 1979. Industrial Development and Industrial Policy: Proceedings of the Second International Conference on Industrial Economics. Budapest: Akademai Kiado.

Rothwell, R. 1979. The Relationship Between Technical Change and Employment. Sussex, England: University of Sussex.

Schenk, W. 1979. Technologiebedingte Strukturschwächen in der österreichischen Wirtschaft (Technologically induced weaknesses in the Austrian economy). In: Perspektiven, Berichte, Analysen. Neue Technologien und Produkte für Österreichs Wirtschaft. Wien: Zentralsparkasse und Kommerzbank.

Scholz, L. 1978. Zukunftsinvestitionen zur Bewältigung des Beschäftingungs- und Strukturproblems (Future Investments for Solving Employment and Structural Problems). Munich: IFO-Schnelldienst.

Scholz, L. 1977. Ursachen und Ausmaß sektoraler Strukturwandlungen in der verarbeitenden Industrie bis 1985. (Causes and Dimensions of Sectoral Structural Changes in the Manufacturing Industry until 1985). Munich: IFO-Schnelldienst.

Statistical Yearbook of the CMEA Countries. 1979. Moscow: CMEA Secretariat.

Statistical Yearbook of the FRG. 1953, 1967, 1980. Wiesbaden: Federal Office of Statistics.

Statistical Yearbook of the GDR. 1955-1979. Berlin: Central State Office of Statistics.

Statistical Yearbook of the USSR. 1975, 1979. Moscow: Central Office of Statistics.

Structure and Change in European Industry. 1977. E77/IIE3. Geneva: Economic Commission of Europe. New York: United Nations.

Technical Capability and Industrial Competence: A Comparative Study of Sweden's Future Competitiveness. 1979. Stockholm: Royal Swedish Academy of Engineering Sciences.

Technischer Fortschritt: Auswirkungen auf Wirtschaft und Arbeitsmarkt (Technical Advancement: Consequences for the Economy and the Labor Market). Vienna and Düsseldorf: Econ Verlag.

Uhlmann, L. 1979. Was Kostet ein Arbeitsplatz? (What does a working place cost?) Munich: IFO Schnelldienst.

Wolff, P., de. 1980. The Netherlands Industrial Policies and Strategies 2. CP-80-33. Laxenburg, Austria: International Institute for Applied Systems Analysis.

World Development Report. 1980. Washington, D.C.: World Bank.

World Industry Since 1960: Progress and Prospects. 1979. Special Issue of the Industrial Development Survey for the Third General Conference of UNIDO. ID/Conf. 4/2 (ID/229). New York: United Nations Industrial Development Organization.