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UPGRADING THROUGH INNOVATION: AN ECONOMIC CHALLENGE (INNOVATIVENESS AND KILO-PRICES OF EXPORT COMMODITIES)

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Heinz-Dieter Haustein

PREFACE

Innovation in its recent sense has existed for more than seventy years during which time there has been a bulk of literature on its management and impact. And yet it is not easy to relate innovation to economic and policy variables. Most economic theories provide no direct tools for easily determining the impact of innovative activity. For this reason the Innovation Management Task of the IIASA's Management and Technology Area set out from its very beginning to explore the possibility of better relating innovativeness to economic variables in order to enhance our knowledge of these important economic and technological processes. The impact of recent disturbances in pricing and the availability of raw materials has made the study of the relation of material usage to innovation seem particularly rewarding.

Professor Haustein undertook this task and explored the relevance of product kilo-prices to innovativeness in production and patterns of external trade and the world markets of particular products. Moreover, together with his collaborators, he underwent the "torture" of analyzing a vast amount of real data in order to detect meaningful patterns. It required his long experience and skill to correctly interpret the messages delivered by the data analysis.

This working paper introduces several new views of market structure and the process of market penetration opened up by kilo-price metrics. The paper also analyzes the limitations of this interesting indicator and its sensitivity to other than innovative processes. The knowledge generated during the research that resulted in this paper will certainly lead to a better understanding of the economic processes related to innovation management.

Tibor Vasko
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1. THE PROBLEM OF UPGRADING

The upgrading of raw materials, semiproducts, and final products presents a major challenge to modern economies. A country's ability to compete on the world market and its domestic economic situation are both closely linked with its ability to upgrade its commodities. Even countries with a monopolistic position in natural resources sooner or later need upgrading in order to counteract the objective tendency toward downgrading or transition to lower grade minerals, etc. Basically, upgrading means adding to a product value that can be realized on the world and domestic markets. Because innovations are an important means of adding real value to products, they are closely linked with the upgrading of goods.

Upgrading has two sometimes conflicting components: the economic or labor value aspect and the technological or use value aspect. Normally we link upgrading with the recognition of the processing chain in which raw material is converted into more and more sophisticated semiproducts and finally finished products (see Fig. 1). In this respect upgrading means step by step adding value to the raw material, increasing the kilo-price as well as the difference between the price of the product and that of the raw materials. But if one looks at the upgrading history of a single product type such as the electronic typewriter, from its first market introduction, one sees that it has a mainly increasing, but later on a decreasing kilo-price.

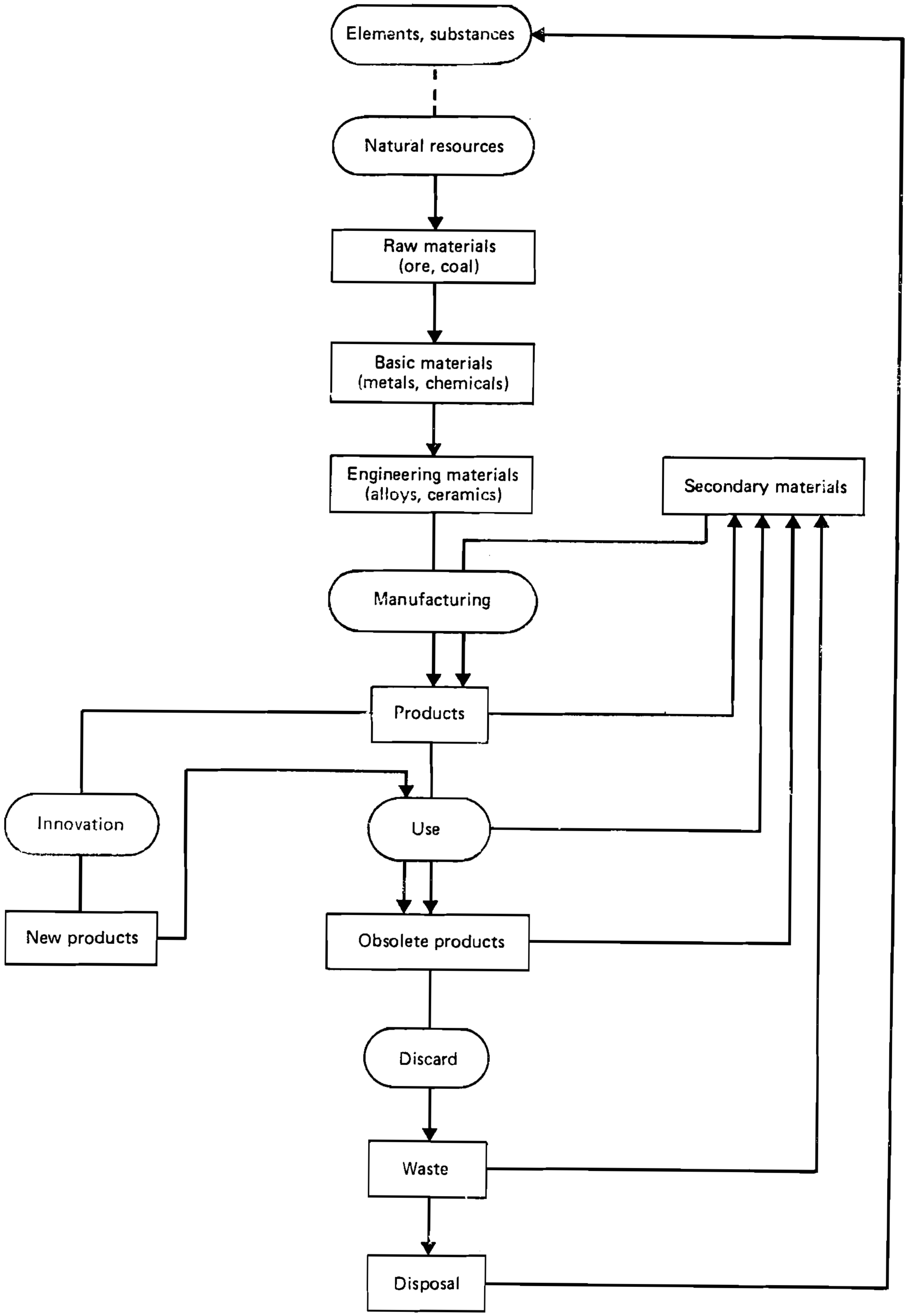


Figure 1. The processing chain of resources.

In this time-frame upgrading means not only adding value to the product, but also later on substracting value from the product. More and more R & D activities concentrate on the process by which the product is made, rationalizing it and reducing the value added per unit and also per kilogram.

Consequently the kilo-price, even on the net basis of value added per kilogram, is a necessary, but insufficient economic indicator of upgrading.

A comprehensive indicator of upgrading is the dimensionless coefficient of upgrading I

$$n(C) = \frac{\text{Value Added}}{\text{Material costs}} = \frac{N}{C} \qquad (1)$$

$$n(C) = \frac{p(M) \cdot n(P)}{c(M)}$$

where
$p(M)$ = Price P per kilogram M
$c(M)$ = Material costs C per kilogram M
$n(P)$ = Value added N per price unit P

If the kilo-price is already decreasing, the growth index of value added per price unit $n(P)$ has to be higher than the price index of materials in order to guarantee a higher upgrading coefficient $n(C)$.

Table 1 shows an example of this option. In practice, the rapidly growing prices for raw materials make it difficult to ensure an increasing $n(C)$. Upgrading by innovation is the most reliable option, but it represents a major challenge to the economy because of its intrinsic problems and trade-offs. Another economic indicator of upgrading is the relation between the price of the product and the material costs, or upgrading coefficient II

$$p(C) = \frac{\text{Price of the product}}{\text{Material cost}} = \frac{P}{C} \qquad (2)$$

$$p(C) = \frac{p(M)}{c(M)} \qquad (3)$$

This indicator is now used very often in the GDR for aggregate calculations of production output value per unit of materials value. In this case the indicator shows the upgrading performance of an enterprise or a firm or the industry as a whole (see Table 2).

But the coefficients of upgrading I and II are insufficient indicators if one wishes to reveal the upgrading effects of product and process innovations. Value added alone cannot explain the mechanism of upgrading in the capitalist economy. Microelectronics, for example, lead to an enormous reduction in value added in the products. In the case of telecommunications the coefficient of upgrading was 2.33 for electromechanical commutators, but 1.63 for electronic ones (first generation with analog display) and 1.04 for the second generation with digital display (Friedrichs, Schaff 1982). This results in a tendency toward falling average profit rates as well. At the same time new opportunities arise for a

Table 1. Indicators of upgrading product A (Example).

year	P	M	N	C	p(M)	n(P)	c(M)	n(C)	p(C)
1975	100	100	40	40	1.00	0.40	0.40	1.00	2.50
1980	120	125	55	52	0.96	0.46	0.42	1.06	2.31
Index	1.20	1.25	1.38	1.30	0.96	1.15	1.05	1.06	0.92

P - Price of the product

M - Mass of the product in kilogram

N - Value added

C - Materials value

p(M) - Kilo-price

n(P) - Share of value added in the price of the product

c(M) - Price of materials per kilogram

n(C) - Value added per unit of materials value

p(C) - Price of the product per unit of materials value

Table 2. Coefficient of upgrading for GDR industry.

Year	Price basis	Value added N	Material costs C	Coefficient of upgrading I N/C	Gross product P	Coefficient of upgrading II P/C
(1)	(2)	(3)	(4)	(3)	(4)	
1968	1966	61034	98286	0.62	165437	1.68
1977	1975	94533	159750	0.59	266173	1.67
1978	1975	98921	166690	0.59	278081	1.67
1979	1975	103622	172631	0.60	290325	1.68
1980	1975	109360	181800	0.60	304870	1.68

higher individual profit share in value added from technological monopolies in products and processes. We are witnessing a gigantic struggle for profit shares between producers of final goods and producers of electronic components.

Backward integration is hunting for monopoly profits by chip producers in order to compensate for losses caused by reduction in value added. Companies that produce final goods are taking over or creating capacities for producing electronic components.

Forward integration is hunting for extra profits in new final products, especially in the consumer goods industry and in the military sector, industries with fast turnover and model change, in order to fully exploit the advantage of high level chips. Companies that produce chips are taking over capacities for producing final products. For this they look for successful but too-small firms in their introductory stages.

The relative surplus value of new products and processes is the basis for the extra profits (Marx 1857, p. 312). Figure 2 shows value addition and opportunities for extra profits by product and process innovation. In economic reality the struggle for forward and backward integration is a "battle of dinasaurs," which leads to major imbalances. In 1979 there was a shortage of components because of too fast forward integration and in 1981/82 an oversupply of chips has arisen because of a prevailing backward integration. So we begin to understand that upgrading is a result of forces that counteract each other and that it should be measured in terms of profits.

The kilo-prices of commodities much better reflect the upgrading effects of innovations than the value coefficients mentioned. The current kilo-price of principally new product generations is much higher than the kilo-price of the older product generations. This will be shown later using as an example electronics.

But the kilo-price is also not a universal indicator of upgrading. If one looks at a single product type, such as electronic typewriters, which has a certain upgrading history from the beginning of its first market introduction, one sees that it has at first an increasing, but later on a decreasing kilo-price. Over a longer period the kilo-prices of certain products or product groups decrease mainly because of the effects of process innovation. The kilo-price of the first computer ENIAC 1949 was $333 per kilogram; the kilo-price of the microcomputer CBM 8032 (Commodore) in 1981 was $95 per kilogram. Also, kiloprices, like all economic indicators, are heavily influenced by price changes, which do not signify real upgrading. In order to offset this, a technological or use value indicator of upgrading should be used. We would like to propose a methodology for this purpose.

The information content of a product consists of two elements: scientific knowledge and know-how. The accumulated and available scientific knowledge refers to the product (S1) or to the process of making the product (S2). The know-how factor also has two components. One is the know-how of the first order K1, i.e., the learning factor or routine experience, which develops along with the production scale. The know-how of the second order K2 is the ability to introduce into practice incremental innovations, which occur over the whole life cycle of a technology.

The scientific knowledge that is incorporated into the product could be measured separately for the product and the process in terms of patent intensity. Know-how of the first order could be measured by the inverse rejection rate and know-how of the second order by the speed of incremental innovations.

The four components S1, S2, K1,and K2 could be evaluated by a relative scale between 0 and 4; the cumulative sum of the evaluations is the gross information content of a product at the time t or I(t).

$$I(t) = \sum_t S1(t) + \sum_t S2(t) + \sum_t K1(t) + \sum_t K2(t) \tag{3}$$

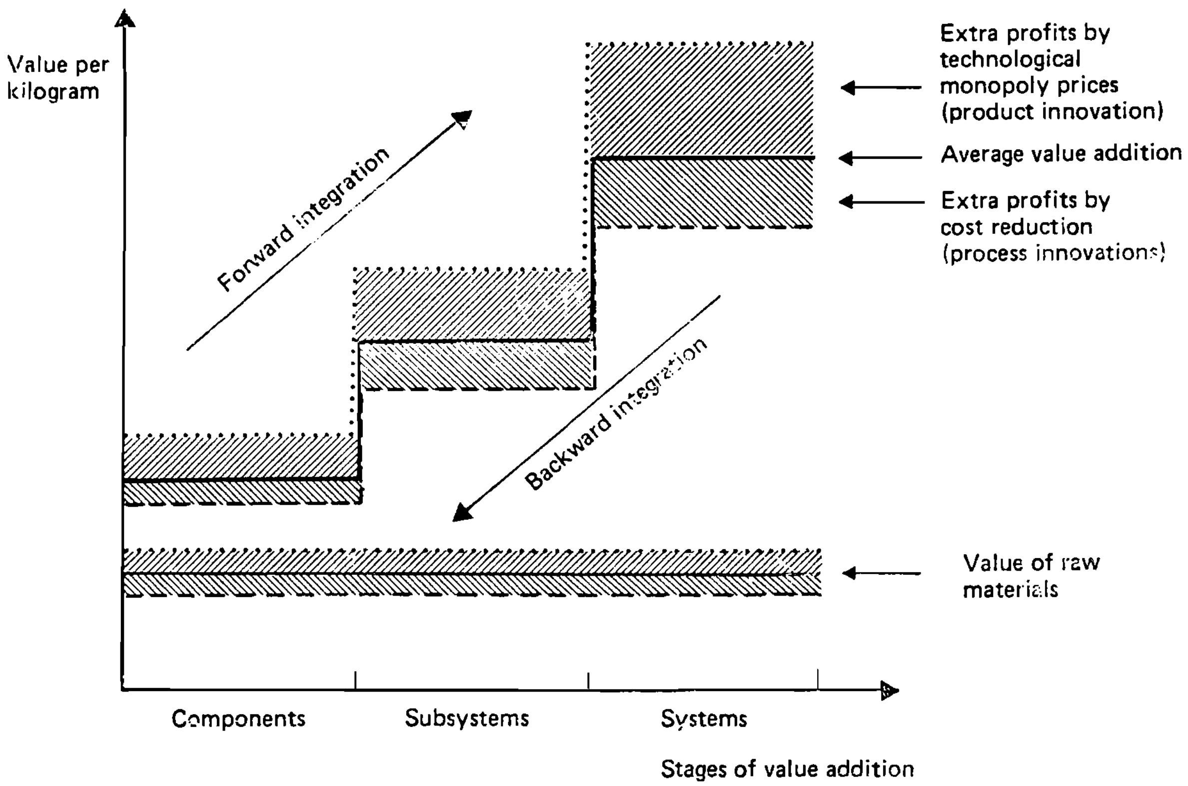


Figure 2. Forward and backward interaction in the microelectronics industry.

Knowing that in the given field of technology a principally new generation comes after Δt years, a net information content can be calculated

$$I^*(t) = I(t) - I(t - \Delta t) \qquad (4)$$

This information content $I^*(t)$ per kilogram is a technological indicator of upgrading (see Table 3).

Table 3. Information content of product A--a methodological example.

	Life cycle in years													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
S1	2	3	4	4	3	3	3	2	0	1	2	3	4	4
S1	2	5	9	13	16	19	22	24	24	25	27	30	34	38
S2	1	2	2	3	3	4	4	4	3	1	0	4	3	4
S2	1	3	5	8	11	15	19	23	26	27	27	31	34	38
K1	1	1	2	4	4	4	3	2	4	3	3	2	2	4
K1	1	2	4	8	12	16	19	21	25	28	31	33	35	39
K2	3	4	4	3	3	4	4	2	0	3	3	2	2	2
K2	3	7	11	14	17	21	25	27	27	30	33	35	37	39
I(t)	7	17	29	43	56	71	85	95	102	110	118	129	140	154
I(t)-I(t-8)	7	17	29	43	56	71	85	95	95	93	89	86	84	83
Kilo-price	100	110	120	105	100	90	95	95	95	90	80	82	75	78
Weight kg	1.5	1.4	1.4	1.4	1.0	1.0	1.0	0.9	0.9	0.7	0.7	0.7	0.7	0.7
I*(t)/kg	4.7	12.1	20.7	30.7	56.0	71.0	85.0	105.6	105.6	132.9	127.1	122.9	120.0	118.8

S1 - Patent intensity (Product)

S2 - Patent intensity (Process)

K1 - Know-how of the first order

K2 - Know-how of the second order

Evaluation

4 very high intensity

3 high intensity

2 medium intensity

1. 1 low intensity

0 no intensity

We now understand that upgrading is a complex phenomenon. Upgrading in the economy is ensured by a higher share of finished products, conservation of materials, a longer lifetime of consumer goods, substitution, and the introduction of new and improved products and processes. The opposite of upgrading is downgrading, for example by transition to lower grade minerals, by obsolescence, etc. Upgrading can be measured by special coefficients and to a certain extent by kilo-prices.

The value coefficients of upgrading are difficult to obtain for special products or product groups. Therefore we return now to the kilo-price, not as a universal measure of upgrading, but as a useful and necessary one.

2. THE IMPORTANCE OF KILO-PRICES

Innovation management is generally concerned with specific products rather than with average performance levels of industries or enterprices. For estimating the innovative performance of a country, an industry, or a firm, it is not enough to use traditional aggregate indicators like productivity, profitability, and capital intensity. Innovative performance is now widely recognized as a major factor in the competitiveness of a country or industry (Pavitt 1980).

A recent study by the Office of Technology Assessment analyzes US industrial competitiveness as exemplified by the steel, electronics, and automobile industries (U.S. Industrial Competitiveness 1981). The authors link competitiveness with the concept of comparative advantage, well-known since Ricardo, and consider it a rather complex phenomenon. This analysis (especially the comparison with Japan) would appear to be of great topical importance for the US in view of declining labor productivity growth rates and severe economic troubles in several industries. The OTA study employs such indicators as relative trends in labor productivity, relative wage rate trends, relative profitabiliy trends, import penetration ratios, and the share of modern process and product technologies. Most are rather general economic indicators with all their shortcomings and advantages.

More specific indicators, like the share of modern technologies, cannot be aggregated; others represent only input variables, like R & D expenditures, or too weak output measures, like the number of patent applications or patents granted. The OTA-study employs no indicators of upgrading of raw materials and manufactured goods and thus it gives only a very limited assessment of the innovative potential.

The innovative potential of a country is its ability to develop, introduce, and diffuse new and highly effective products and processes on its domestic market and on foreign markets. Innovativeness is the realization of this potential. But how can innovativeness be measured? The necessary unit of reference cannot be an enterprise, an industry, or a national economy. Innovation has to do with concrete products and not directly with general performance levels of economic units. And such indicators as product profitability include not only the innovative performance but many other economic factors as well. Moreover, it should be noted that facts about the profitability of products are regarded by most companies as strategic data, and normally are not published. So one has to look for other indicators.

We have found what in our opinion is an excellent one, having all the advantages of a clear-cut output measure: this is the kilo-price of manufactured export goods. Kilo-Prices (or prices per ton or per pound) have been used for many decades in the practice of foreign trade and in the comparison of product performance. Kilo-price indexes as such have been calculated as long as price indexes have existed. Kilo-prices have been used also for special comparisons and investigations of product groups (Amann and Slama 1976, Hufbauer and O'Neill 1972, Slama and Vogel 1971). But the literature on this topic is very scarce.

In this study we will try to show that the relative kilo-price of exported manufactured commodities and its growth rate reflect clearly enough the results of the upgrading of commodities and provide a good measure for the innovative performance of an industry or of a country. Innovativeness can be measured by the share of export commodities with high and rapidly growing kilo-prices, measured over a period of about five years.

While it is true that innovative export goods have a relatively high and rapidly-increasing kilo-price (what is meant by "high" and "fast" will be explained in greater detail) the reverse is not always true: not all export commodities with a high and fast increasing relative kilo- price are technologically *innovative*. We must exclude money and all money substitutes, such as gold, precious metals, jewelry, and furs. But other goods also have high and rapidly-increasing kilo prices and are not innovative at all. Furthermore, many less innovative countries place non-innovative commodities at the top of their lists of export goods. Price changes and changes in supply and demand, which are not connected with innovations, can have an important influence on our two indicators: the relative level and growth rate of kilo-prices.

But nevertheless we propose to use these indicators and to improve them for the purpose of innovation management. We see their importance in the following directions:

1. Theoretically we associate kilo-price indicators with the labor value theory. Innovations realize higher labor values. They give a push to the whole value system, which can be analyzed by reducing the price oscillations with moving averages and deflation procedures. An important tendency is the reduction of labor time needed per unit and the reduction in the unit values of goods, brought about through process innovations and rationalization measures. But there are counter-tendencies that increase the variance in unit values: qualitative changes in social needs and demand, qualitative changes in the *system* of economic resources, and last but not least innovations, which cause the foregoing changes or react to them. Without innovations we would have an increasing "entropy" of the economy and a lower and lower variance of kilo-prices. At the same time all possibilities for rationalization would be exhausted. The economic mechanism of innovations cannot be explained simply by the relative cost reduction phenomenon. Karl Marx (1857, p. 312) knew about another tendency. He called it production of relative surplus value, which is ensured by new products or

expanded production of existing products, either for new needs or markets or for the old ones.

2. The kilo-price relates social and a natural measures: it links the socio-economic cycle with the natural one. It is not possible to increase endlessly the masses of substance taken from nature to meet human wants and needs. On the contrary: it is necessary to better use natural potential by upgrading it through human creativity and human labor. It would be very difficult to describe this process using historical measures. For historical comparisons the consumption of primary commodities, energy, and labor time can be estimated. But the kilo-price itself is not a historical measure. However, it is possible to estimate the relation between the labor time needed for manufacturing goods and the labor time needed for obtaining the necessary primary commodities. In the hunting and gathering period this ratio might have been about 1, in accordance with the ratio of the sexes. In the present period it might be about 3 or 5. The ratio between human labor time per capita and the amount of natural substance per capita has decreased considerably, not only because of higher labor productivity, but also because much more natural substance is needed for each person. And this is the problem we see now when we look at the future population growth of mankind and the economic limits to the supply of primary commodities.

3. The kilo-price is closely connected with the mass-volume relationship. The satisfaction of human needs is a process that has real limits in space and time. Overcoming these limits is only possible by changing the mass-volume relationship. This seems to be a fundamental tendency in the development of productive forces; it is realized technically by miniaturization. There is a close correlation between miniaturization and upgrading of goods. This can be seen, for example, in microelectronics.

4. Practically, the kilo-price is a well-known measure in foreign trade and sometimes also in international comparisons of goods at the firm level. It can be linked with other indicators like performance or patent applications. In many developed countries of the world the upgrading of materials has been given first priority in economic policy. It is, for example, a clearly expressed social goal of the GDR, whose own material resources are very limited. The CSSR has a long tradition and much experience in economic analysis by kilo-price. So-called small open economies like to measure their performance and competitiveness using kilo-price.

5. The prices of primary commodities have grown faster since 1970 than they did in the decade before. Of course, this does not signify an upgrading of raw materials, but rather reflects inflation and changes in economic and political conditions.

The figures in Table 4 illustrate these changes. Important here are not the indexes, which reflect inflation, but the changing relations among the indexes, shown in C, E, G and J, which give an enormous stimulus to measures for conserving raw materials, i.e., to increasing the kilo-price of manufactured goods, but not at the expense of raw material prices.

Table 4. Development of world export prices* (1975 = 100).

	Primary commodities total	Manufactured goods	Relation A : B percent	Primary commodities except crude petroleum	Relation D : B percent	Crude petroleum	Relation F : B percent	Minerals	Relation H : B percent
	A	B	C	D	E	F	G	H	J
1970	33	55	60	47	86	15	27	.	.
1771	36	58	62	49	85	19	33	.	.
1972	39	62	63	55	89	22	36	.	.
1973	57	73	78	85	116	30	41	33	45
1974	104	89	117	107	120	100	112	96	108
1975	100	100	100	100	100	100	100	100	100
1976	106	100	106	106	106	106	106	105	105
1977	117	109	107	118	108	117	107	114	105
1978	119	125	95	121	97	117	94	115	92
1979	154	143	108	138	97	170	119	161	113
1980	225	158	142	157	99	295	187	271	172

* Excluding China, the USSR, and Eastern Europe

Source: UN Monthly Bulletin of Statistics (1981).

So actually the kilo-price should be measured on a net value basis, excluding the materials costs. Practically, this is only possible using special calculations.

6. The kilo-price of export goods is an empirical measure, available for many countries in the form of national and international statistics of foreign trade. It is given both in aggregate and in more detailed forms. For example the NIMEXE statistics of the European Economic Community contains figures for more than 6500 commodities. This represents an enormous amount of potentially useful empirical data.

7. At the level of the firm or enterprise, the question of kilo-price is connected with several fields of activity: with the development and design of new and improved products, with materials management, with incentives for saving of materials by rationalization measures, and with marketing and price calculations. The kilo-price can be used as a stragetic measure by corporations, as was done by the founder of the VOLVO-company (Goldberg 1981). A high and fast growing kilo-price of a commodity from the standpoint of the national economy is not necessarily

> the same from the viewpoint of the special commodity market. In certain markets an optimal kilo-price is the result of combining efforts in product innovation, quality improvement, and rationalization. This can be demonstrated clearly using the example of Japanese exports.

We are fully aware that stressing this indicator is a bit dangerous because of the simple fact that real economic life is multidimensional and thus should be analyzed multidimensionally. So we would like to make it clear that this investigation is only a limited contribution to the problem of measuring innovative output. And the measurement of output is only one component in the whole field of innovation management.

3. KILO-PRICE: CONTENT, MEANING, AND STRUCTURE

Mentioning the kilo-price of manufactured goods to anybody who is not familiar with this indicator usually causes confusion or surprise. Normally, consumers think of prices in terms of quantitative measures. "One kilogram of TV sets" seems nonsensical, as does the price of TV sets per kilogram. It is widely known, that in microelectronics the price per function has decreased with time. But its price per kilogram is much higher than the price of traditional electronics. So at first glance the kilo-price seems to be a paradoxical indicator.

The kilo-price is the relation between the price or sum of prices of goods and their mass or weight expressed in kilograms. Sometimes the term "unit value" is used, but is not necessarily a kilo-price. There can be other units like the number of goods, square meters and so on. The unit value index of statistical aggregates is normally made by using a mix of physical measures like kilogram, number of pieces, square meters and others. The point here is the value per kilogram. In the nominator we have export prices, given in f.o.b. (free on board) or in c.i.f. (costs, insurance, freight). The price basis has of course a big influence on the kilo-price. On the other hand, the density of goods (specific weight) or the mass-volume relation also has a major effect on the kilo-price.

The following goods have relatively high kilo-prices because of their relatively low densities:

- leather (0.90 g / cm3)
- alcohol (0.80 g / cm3)
- paper (0.92 g / cm3)
- cork (0.20 ... 0.35 g / cm3)
- calium (0.86 g / cm3)
- natrium (0.97 g / cm3)
- wood (0.4 ... 1.3 g / cm3)
- rubber (0.94 g / cm3)

- wax (0.95 g / cm3)
- paraffin (0.87 g / cm3)
- gasoline (0.68 ... 0.72 g / cm3)

The kilo-price depends on at least the following components

$$p(M) = \frac{P}{M} \tag{5}$$

$$p(M) = \frac{c(N)}{m(N) \cdot c(P)} \tag{6}$$

where
P = Export price in a monetary unit
M = Mass in kilograms
p(M) = Kilo-price
c(N) = Material costs C per unit (piece) N
m(N) = Mass M per unit N
c(P) = Material costs c per price unit P

Here we can see that the kilo-price of exports can be raised, when the weight per unit and the share of material costs in prices can be reduced faster than the material costs per unit decrease. Innovative goods very often have a higher share of labor costs and a lower share of material costs than less innovative goods. This is a major factor in their relatively high kilo-prices. But the decisive factor in the high kilo-price of innovative goods is their new or higher use value, which ensures a relative surplus value for the producer.

The kilo-prices of products with certain performance characteristics, like machines or consumer durables, have the following seven components:

$$p(M) = \frac{c(N) \cdot l(N) \cdot p(L)}{m(V) \cdot c(P) \cdot p(N) \cdot v(N)} \tag{7}$$

where
l(N) = Performance level L per unit N
p(L) = Price P per unit of performance L
m(V) = Mass M per unit of volume V
p(N) = Price P per unit N
v(N) = Volume V per unit N

In the long run one can expect the seven components to behave as follows:

	Growth	Impact on kilo-price
c(N)	-	-
l(N)	+	+
p(L)	-	-
m(V)	-	+
c(P)	+	-
p(N)	-	+

A simulation on the basis of these 7 components using for each of them an exponential function of the type

$$y = K - be^{-at} \tag{8}$$

will give an extremely wide range of possibilities from the starting point to the limits. We will return to this question in our empirical investigation in Chapter 3. Here we should make a special remark about the price in the nominator of our indicator. We are interested in the kilo-price as a measure of upgrading raw materials by adding value through innovations. Such a measure would be the relation

$$\frac{\text{value added by manufacturing in money terms}}{\text{raw materials in kilograms}}$$

But such an indicator is not easily available. The figures on kilo-prices actually represent a cumulative variable including the value added in mining and producing other primary commodities. All increases in value added in the course of the processing chain are represented in the price figures. The higher the kilo-price, the lower the share of value added in the gross product of the commodity group. For example in the US in 1977 the ratio of value added to value of shipments was 0.71 in the mineral industries and in 1976 it was 0.43 in the manufacturing industries (Statistical Abstract 1979).

At this point some remarks on the value structure of kilo-prices should be made. The price P consists of three components

$$P = c + v + m \tag{9}$$

where
c = costs of materials and amortisation
v = wages
m = profits
(v+m) = value added

Higher productivity leads to a lower share of wages per kilogram if the reduction of labor hours per kilogram is faster than the increase of wages per labor hour. It is difficult to filter out the inflation feedback on the kilo-price. Normally general price indexes are used as deflators. But this is a very rough measure.

A high and rapidly-increasing kilo-price is not always a sign of innovativeness. One has to filter out the following commodities from the range of products falling into the category mentioned.

1. Money and money substitutes like gold, other precious metals, jewelry, furs, and similar products.
2. Materials with a high and fast growing price because of the high value of the natural resources from which they are extracted.
3. Products with a specific weight below 1, which we mentioned before.

4. Products with a very high value of labor not connected with innovation, but with artwork, like paintings, sculptures, etc.

It is relatively easy to identify these four groups of products. However, there is another group of products that have rapidly-growing and relatively high kilo-prices due to temporary fluctuations in supply and demand. And other commodities are in reality much better than the price by which they are realized. This is a dark area in the kilo-price investigation. The only thing what we can do about it is to choose longer periods for analysis, say of about five years. For shorter periods the price oscillations can greatly mislead us.

Let us look now at the whole chain of kilo-prices from the lowest one, represented by such goods as stones and sand to the highest one, represented by such goods as computers, TV sets, jewelry and gold. This chain includes all processing chains of the production system of a country. One can see the enormous steepness of the kilo- price development over the stages. Cars have a kilo-price 236 times higher than that of iron ore.

Table 5 gives an overview of West German export and import kilo-prices for 1980. The exports of the FRG show an extremely favorable kilo-price relation to the imports. The high average figure is simply the result of the export and import structure. But what interests us here is the typical steep increase in kilo-prices from raw materials to final products. The growth of kilo-prices over the processing stages is obviously a super-exponential function, because of the increase in d ln p(M).

Table 5. Kilo-prices of exports and imports over the processing stages (FRG 1980).

	Export			Import			Export/Import ratio of the kilo-price (1):(4)
	DM/kg (1)	ln DM/kg (2)	d ln DM/kg (3)	DM/kg (4)	ln DM/kg (5)	d ln DM/kg (6)	coeff. (7)
Raw materials	0.133	-2.019	-	0.293	-1.228	-	0.45
Semiproducts	0.634	-0.456	1.564	0.587	-0.533	0.696	1.08
Preproducts	2.031	0.708	1.164	1.918	0.651	1.184	1.06
Final products	11.415	2.435	1.726	10.919	2.391	1.739	1.05
Average	2.192	-	-	0.867	-	-	2.53

Source: Statistical Yearbook for the FRG (1981).

In analytic form we can assume

$$\ln p(M) = \int_1^T (b + ct)dt \tag{10}$$

where t is the figure for the processing stage from t = 1 (raw materials) up to t = T (final product). T can be set arbitrarily at 10 to use a standardized measure of 10 stages. The result for the West German exports is

$$p(M) = e^{(0.3317t^2 - 1.254t - 1.0769)} \tag{11}$$

with
- t = 10 for final products
- t = 7 for preproducts
- t = 4.5 for semiproducts
- t = 1 for raw materials

This is of course not a growth law for the kilo-price of certain product groups over time, but a structural relation for the kilo-price over processing chains, which can be measured arbitrarily as we did or by real processing time.

Looking again at the whole chain of commodities from the lowest to the highest kilo-price, one can see not only product chains, but also various generations of products. For example vacuum tubes, transistors, and integrated circuits are grouped together. Table 6 shows their kilo-prices and their dates of innovation.

Table 6. Kilo-prices of product generations on the example of electronics.

	Euro-dollar per kg 1980	Date of innovation 1980	Age of product
Vacuum tubes	53	1913	67
Transistors	109	1951	29
Integrated circuits	265	1968	12

Source: Eurostat. NIMEXE. (1980).

This is a second explanation for the superexponential kilo-price structure in advanced countries. The younger the product generation, the higher the kilo-price. In the case of electronics, presented in Table 3, it seems strange that integrated circuits are more expensive than traditional elements. The price decreases in microelectronics have been exaggerated in the literature. But we are not analyzing the price per function. We are simply saying that the kilo-price of integrated circuits is higher than the kilo-price of vacuum tubes. The drop in kilo-prices over a longer time for a given generation of products is another question. Social progress would be impossible without this general trend. But the trend is ensured by an opposing trend: the invention and innovation of new commodities with a higher kilo-price.

A third component of kilo-price growth is technological sophistication within a given product group. Two investigations in the past tried to show this by comparing the kilo-price levels among developed countries for engineering products (Slama and Vogel 1971) and for organic chemicals (Amann and Slama 1976). But they used only kilo-prices without comparing them with other indicators of technological sophistication. The technological level of a product and its performance characteristics seem to be correlated with kilo-prices. We tried to verify this using the example of 56 big vacuum cleaners on the Austrian domestic market. The price in Austrian schillings (AS) per kilogram was compared with the performance indicator

$$L = \frac{\mathrm{Bar} \cdot \mathrm{l}}{\mathrm{W} \cdot \mathrm{sec}} 1000 \tag{12}$$

where
L = performance figure
bar = atmospheric pressure
l = liters
W = Watts
sec = seconds

Fig. 1 shows the results, including the regression found.

$$\frac{p(M)}{p(MO)} = 288 + 15.03988L / L(o) \tag{13}$$

$$N = 56 \qquad R = 31.27 \qquad S = 47$$

$$L(o) = 0.01152 \frac{\mathrm{Bar} \cdot \mathrm{l}}{\mathrm{W\ sec}} \tag{14}$$

$$p(MO) = 223\mathrm{AS/kg}$$

The result is statistically significant at a level of 2.5 percent error probability. Obviously the interdependancy between technological sophistication and kilo-price is quite weak in the case of vacuum cleaners. One reason for this might be that the indicator L does not reflect all properties of the technological level.

But there might also be other reasons, like market conditions, service, product name and so on. Hufbauer and O'Neill (1972, p. 272) identified the market share as a factor that influences export kilo-prices. Now let us review all the factors that have an impact on kilo-price or that lead to higher versus lower kilo-prices of products. (See Table 7.) Innovation plays a major role in upgrading, although some process innovations have the opposite effect. The first two factors of upgrading are linked together. Product innovations appear to be more intensive in the later stages of the processing chain. The share of new products in total sales in the U.S. metallurgy industry between 1967 and 1978 was 1.84 percent and in the engineering industry, 5.52 percent (Hartmann and Haustein 1979).

Table 7. Overview of factors that tend to raise and lower kilo-prices.

	Higher relative kilo-price	Lower relative kilo-price
1.	Value added in processing chain	Losses fromfailures and quality problems
2.	Product innovation leading to higher demand and a higher value of commodities	Obsolescence and reduction in demand
3.	Technological sophistication a. Higher performance b. Lower weight	Stagnation and degradation a. Lower performance b. Higher weight
4.	Process innovation, leading to reduction in material costs	Process innovation, leading to reduction in labor value per kg
5.	Quality competition	Price competition
6.	Sufficient marketing (Advertising, service, delivery periods)	Unsufficient marketing
7.	Inflation	Higher productivity
8.	Favorable market position (high share)	Unfavorable market position
9.	Random factors	Random factors

The result of the influence of all of the factors mentioned is a log-normal distribution of commodity shares over the scale of kilo-prices. We have verified this on the example of Austrian exports (219 commodities) with the help of the Kolmogoroff-Smirnow-Test. The logarithms of kilo-prices of export commodities are normally distributed. This is the necessary result of influencing factors, which are coupled multiplicatively. A third quantitative result is the equation for 219 Austrian export commodities.

$$\lambda = 105 + 0.153y \tag{15}$$

Standard deviation of coefficient	t-value
1.349	77.74
0.0268	5.71

s 19.85 — 218 degrees of freedom

r^2 13 percent

λ growth rate of kilo-prices 1978-1980

y kilo-price 1978

But this equation is actually identical with

$$\frac{dy}{ydt} - 1 = a + by \tag{16}$$

and this leads to the equation

$$y = \frac{be^{bx - x}}{1 - ae^{bx - c}} \tag{17}$$

which contains many possibilities for exponential growth.

4. THE KILO-PRICE OF AN INDUSTRIAL PRODUCT AND ITS DEVELOPMENT THROUGH THE STAGES OF INNOVATION

In the first chapter we developed a model of factors that influence the kilo-price of a product. Now the question is: how does this work in reality? Histories of kilo-prices of manufactured goods can rarely be obtained. Long-time series for prices are normally only available for primary commodities. We could create one for a classical commodity, the automobile, using the example of Ford's smaller cars. Tables 8.1, 8.2, 8.3, and Figure 3 show the data. The passenger car was a product with an increasing weight and price, even discounting inflation. This is quite unlike many other products, which display decreasing weights and prices over their lifetimes. But even in the case of cars, the deflated kilo-price went down considerably after a short increase in the introductory period. Since the rapid growth phase, which ended around 1925, the kilo-price has oscillated due to model changes and resultant higher or lower weights and prices. Overall, the kilo-price went up between 1925 und 1981, mainly because of price growth.

Tables 9.1, 9.2, and 9.3 show another example: the changes in the electronic calculator technology, which differs considerably from the case of the automobile because of a sharp drop in weight per unit. But one can observe that the kilo-price--after a first growth phase from 1962 to 1972--also began to decline, while the profit rate have continued to grow. So the change in the direction of kilo-price development might be a good indicator for the end of the introduction period of innovations just as the profit rate is a similar indicator for the rapid growth phase. One can generally expect that over the lifetime of a product the kilo-price will show a hyperbolic decrease such as that seen in Fig. 4.

It is important for a firm to make use of every available opportunity to achieve a higher kilo-price during the introduction period. But kilo-price and profit rates are relative indicators. What counts is not only effectiveness, but also turnover and the sum of profits. These absolute figures are normally highest in the maturation and saturation stages of a product. We took this into account whan analyzing 25 commodities of export to the European community countries between 1975 and 1980.

Ammonia liquid	Pos. 2816.10 of NIMEXE
Polybutadien-Styrol	"
Plastic bags	"
Mink fur	" 4301.15 " "
Household china	" 6911.50 " "
Cars, max. 1500 cc	" 8702.21 " "
Bikes, 50 cc	" 8709.59 " "
Camping caravans	" 8714.22 " "
Combustion engines for boats	" 8406.50 " "
Automotives	" 8423.17 " "
Potato-harvesting machines	" 8425.71 " "
Printing machines	" 8435.33 " "
Other sewing machines	" 8331.14 " "
Milling machines	" 8445.58 " "
Mechanical typewriters	" 8451.13 " "
Injection casting machines	" 8459.57 " "
Vacuum cleaners	" 8506.10 " "
Grinding lathes	" 8445.52 " "
Accounting machines	" 8452.65 " "
Heating ventilators	" 8512.23 " "
Black-and-white TVs	" 8515.28 " "
Valves	" 8521.23 " "
Transistors	" 8521.51 " "
Integrated circuits, monolithic	" 8521.61 " "
Electronic microcircuits	" 8521.68 " "

Table 8.1. US Automobiles 1906 - 1974 (Ford, smaller cars).

Year	Model	Price		Performance		Weight		Kilo-Price	
		Dollar	Index	PS	Index	kg	Index	$/kg	Index
(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1906	Ford N	500	100	15	100	476	100	1.05	100
1909	Ford T(Touring)	850	170	20	133	544	114	1.56	149
1925	Ford T(Touring)	310	62	25	167	729	153	0.43	41
1929	Ford A(Touring)	460	92	40	267	975	205	0.47	45
1936	Ford 40 Sedan	580	116	110	733	1293	272	0.45	43
1939	Ford 922 A	665	133	95	633	1145	241	0.58	55
1941	Ford 11 a	840	168	90	600	1376	209	0.61	58
1947	Ford 6	1234	247	90	600	1457	306	0.85	81
1953	Ford	1400	280	100	667	1350	284	1.04	99
1964	Ford Falcon	1985	397	85	567	1070	225	1.86	177
1974	Ford Pinto	2295	457	80	553	1108	233	2.07	197
1979	Ford Mustang	6230	1246	92.5	617	1206	253	5.17	492
1981	Ford Escort	5158	1032	69	460	763	160	6.76	644

Table 8.2. US automobiles 1906-1974 (Ford, smaller cars).

Year	Model	Unit Performance PS/1000kg	Index	Price Index All commodities 1967=100	1906=100	Kilo-Price deflated $/kg	Index
(0)	(1)	(10)	(11)	(12)	(13)	(14)	(15)
1906	Ford N	31.50	100	32.0	100	1.05	100
1909	Ford T (Touring)	36.76	117	34.9	109	1.43	136
1925	Ford T (Touring)	34.29	109	53.3	167	0.26	25
1929	Ford A (Touring)	41.03	130	49.1	153	0.31	30
1936	Ford 40 Sedan	85.07	270	41.7	130	0.35	33
1939	Ford 922 A	82.97	263	39.8	124	0.47	45
1941	Ford 11a	65.41	208	45.1	141	0.43	41
1947	Ford 6 GA	66.77	196	76.5	239	0.36	34
1953	Ford	74.07	235	87.4	273	0.38	36
1964	Ford Falcon	79.33	252	94.7	296	0.63	60
1974	Ford Pinto	72.20	229	160.1	500	0.41	39
1979	Ford Mustang	76.70	243	232.0	725	0.71	68
1981	Ford Escort	90.43	287	290.0	906	0.75	71

Table 8.3. US Automobiles 1906 - 1974 (Ford, smaller cars).

Year	Model	Labor hours per car	$ Index	Market share of Ford	Patent applications by Ford(3-year moving average)	All patent applications 1000 in US	Share of Ford patents per 1000 patents in US
(0)	(1)	(16)	(17)	(18)	(19)	(20)	(21)
1906	Ford N	150	100		5	55	0.1
1909	Ford T (Touring)	120	80		10	64	0.2
1925	Ford T (Touring)	41	27	50	17	80	0.21
1929	Ford A (Touring)	29	19		11	90	0.12
1936	Ford 40 Sedan	29	19		10	63	0.16
1939	Ford 922 A	27	18		9	64	0.14
1941	Ford 11 a	28	19		12	52	0.23
1947	Ford 6 GA	29	19		12	75	0.16
1953	Ford	31	21		39	72	0.54
1964	Ford Falcon	29	19	25	149	88	1.70
1974	Ford Pinto	29	19	25	193	102	1.90
1979	Ford Mustang	28	19	23	94	100	0.94
1981	Ford Escort	27	18	23			

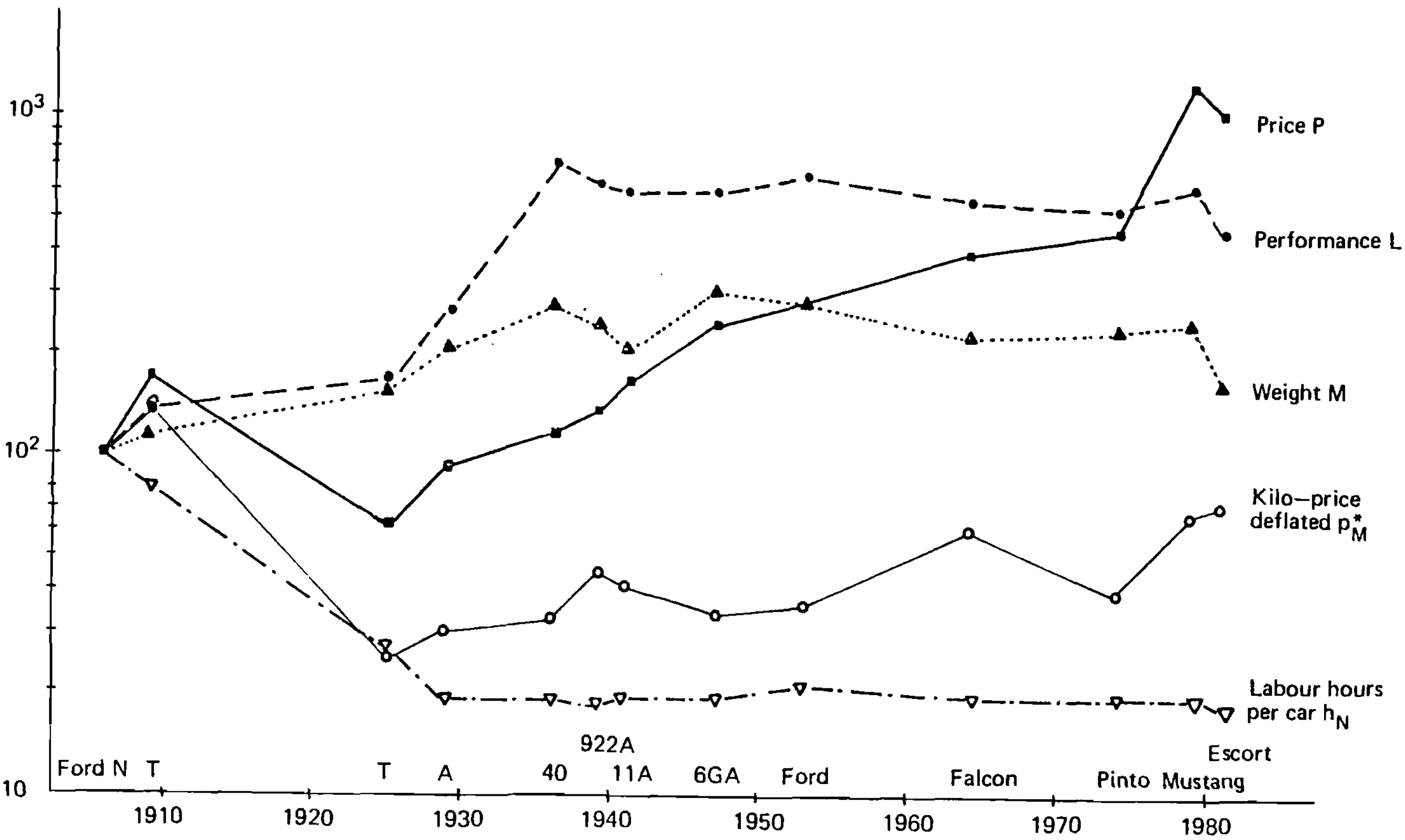


Figure 3. Development of kilo-prices and other indicators of the smaller Ford car.

Table 9.1. Changes in electronic calculator technology.

No.	Phases	Product type	Process/ Component type	Number of total components		Initial costs		Price per unit	
				Number	Index	Dollar	Index	Dollar	Index
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	1962-1966	Deck-Top	Discrete compont.	5000	100	170	100	602	100
2.	1967-1968	Portable	Integrat. circuits	840	17	125	74	439	73
3.	1969-1970	Handheld	MOS/LSI (chips)	57	1.14	60	35	255	42
4.	1971-1972	Pocket	1 chip MOS/LSI	40	0.80	20	12	193	32
5.	1973-1975	Pocket	COS	39	0.78	5	2.94	62	10
6.	1976-	Pocket	1 chip	35	0.70			10	1.66

Table 9.2. Changes in electronic calculator technology.

No.	Phases	Labor Intensity		Weight		Volume		Mass-Volume relation	
		Percent	Index	g	Index	cm(3)	Index	g/cm(3)	Index
(1)	(2)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1.	1962-1966	30	100	23000	100	66000	100.00	0.35	100
2.	1967-1968	28	93	2000	8.70	1800	2.73	1.11	317
3.	1969-1970	24	80	500	2.17	500	0.76	1.00	286
4.	1971-1972	10	33	300	1.30	300	0.45	1.00	286
5.	1973-1975	8	27	150	0.65	100	0.15	1.50	429
6.	1976-			50	0.22	50	0.08	2.50	714

Table 9.3. Changes in electronic calculator technology.

No.	Phases	Kilo-Price		Profitrate		Origin
		$/kg	Index	Percent	Index	
(1)	(2)	(19)	(20)	(21)	(22)	(23)
1.	1962-1966	26.2	100	2.54	100	US/UK
2.	1967-1968	220	840	3.14	124	Japan
3.	1969-1970	510	1947	3.25	128	Japan
4.	1971-1972	643	2454	8.65	341	US
5.	1973-1975	413	1576	11.40	449	Japan
6.	1976	200	763			Japan

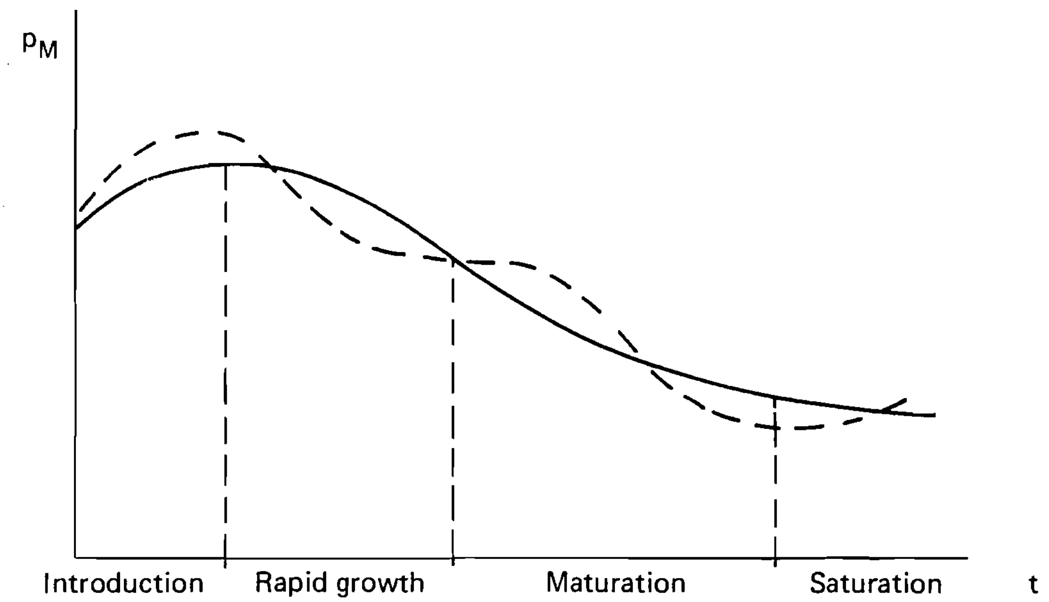


Figure 4. Typical development of the kilo-price over the innovation stages.

In comparing the kilo-prices and market shares of all competing countries in the export of a given product we discovered three types of market structure for the range of 25 commodities (see Fig. 5). Eight commodities--microcircuits, integrated circuits, injection casting machines, sewing machines, accounting machines, harvesting machines, bikes, and household china--showed a structure in which one or two countries dominate the market, the other countries competing on a wide spectrum of kilo-prices and having only small market shares. Countries with higher kilo-prices have not yet been able to gain market shares through mass production and lower costs and kilo-prices. Fig. 6 shows this for potato-harvesting machines, where FRG industry dominates.

The reason for this type of market structure can be a technological monopoly, an advanced position in process technology, or a good comparative advantage. While it is not easy to attack the position of a monopoly, attempts to do so are of course possible and sometimes successful. In the case of accounting machines Italy managed to overtake the market position of the FRG without lowering its own kilo-price (Fig. 7).

Type I seems to have a rather instable pattern. In contrast, Type II is more stable. For many traditional products (13 from our sample), such as vacuum cleaners, mechanical typewriters, and black-and-white TV sets, competition leads to a more normal distribution of countries over the kilo-price. Fig. 8 shows this for vacuum cleaners, a market area where marginal gains in product level and rationalization can be observed. Type II can suddenly change to Type I if one competitor can establish a monopoly. This happened in the case of combustion engines for boats between 1975 and 1980 (Fig. 9).

Type III is represented by only four products: milling machines, grinding lathes, furriery mink, and bags. Fig. 10 shows for grinding lathes a situation in which kilo-price and market share are positively correlated, or simply: the higher the kilo-price, the higher the market share. In this case the factor quality and quality tradition plays an important role. Many products of the engineering industry seem to have this pattern.

Looking at all the products within the three types of market structure, it becomes clear that an optimal kilo-price is the result of a combination of technological progress, comparative advantages in costs, and quality standard and tradition. This combination makes it possible to achieve a leading or even dominant position in the market. Not necessarily a maximal kilo-price, but a maximal turnover or a maximal sum of profits are the result.

The Japanese in particular are an example of a country whose efforts to achieve higher market shares are not based on high or rapidly increasing kilo-prices. Between 1975 and 1980 the Japanese were most successful in three West European markets: film, cars, and musical instruments. In all three cases the growth of kilo-prices was lower than that of the average of the total Japanese export to the same countries. Japanese industry is obviously able to combine product and process innovation.

Lennart Ohlsson (Ohlsson 1974) found that in the Swedish engineering industry, price per ton is negatively correlated with the physical capital intensity of production (capacity of motive power per employee) and positively correlated with human capital intensity (ratio of technical personnel to the total number of employees). This confirms our finding that kilo-prices decline in the maturation and saturation stage when capital intensity has been relatively high in the early innovation stages (i.e., in the most innovative branches).

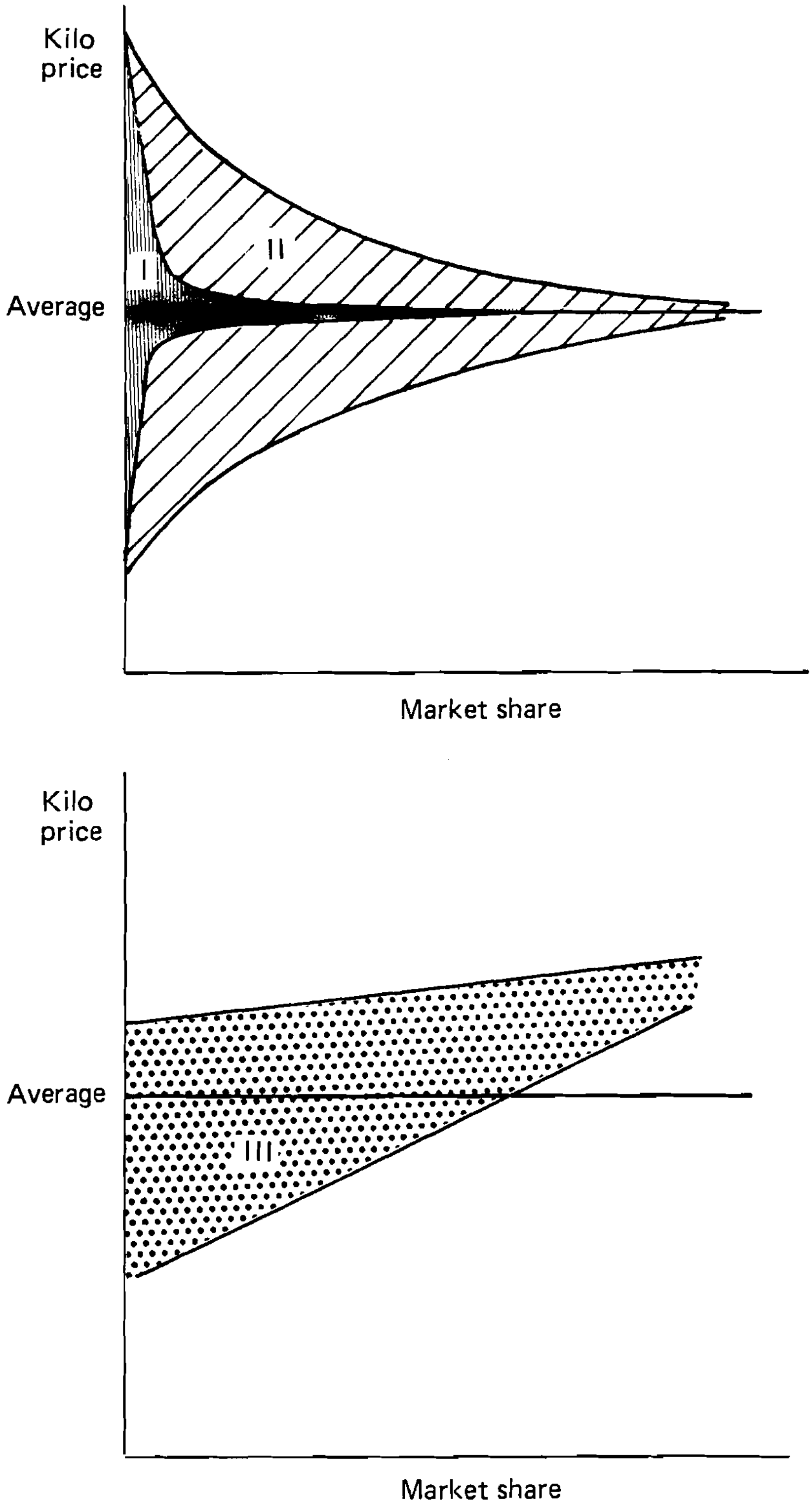


Figure 5. The three types of market structure seen for the 25 commodities under study.

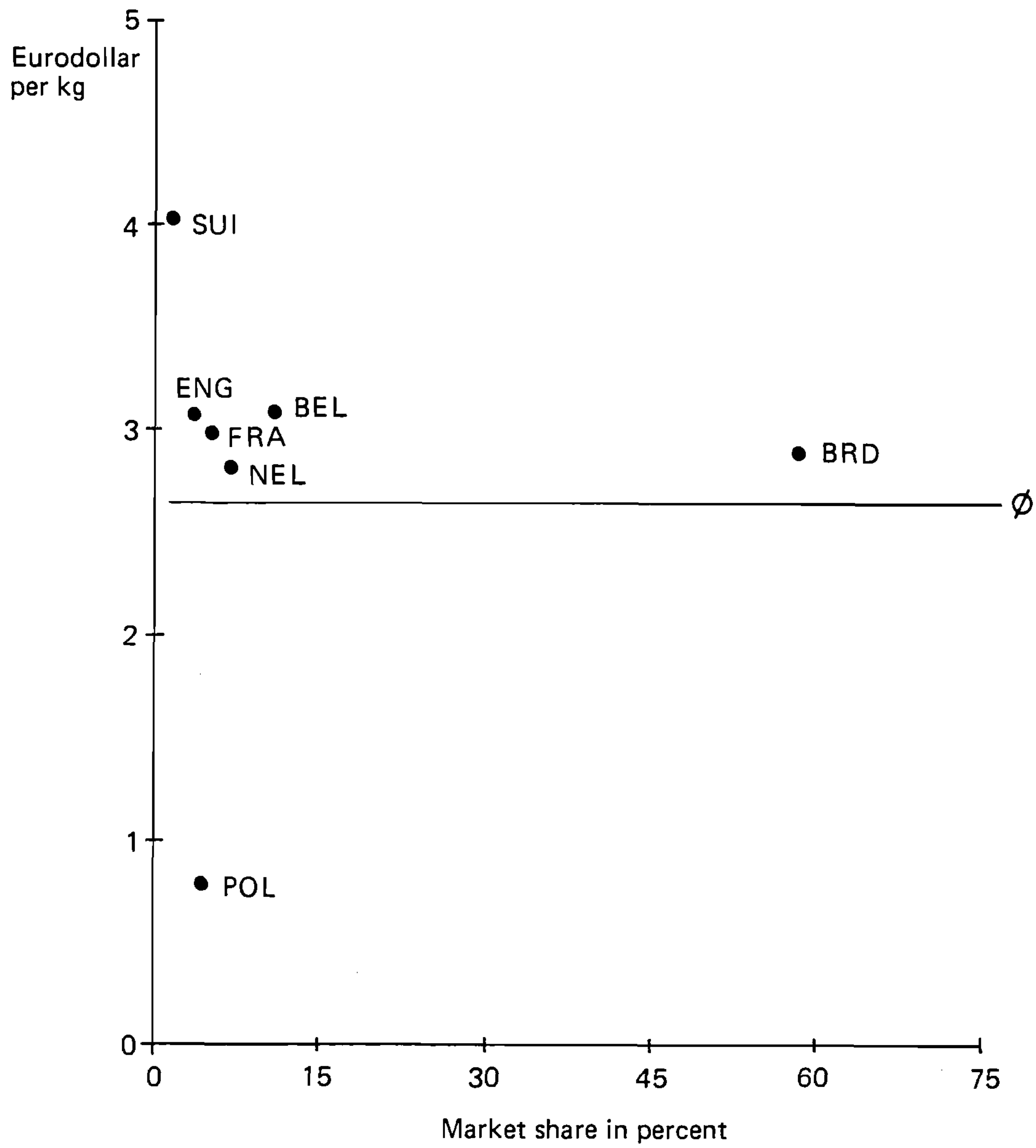


Figure 6. Potato harvesting machines--exports to the EC.

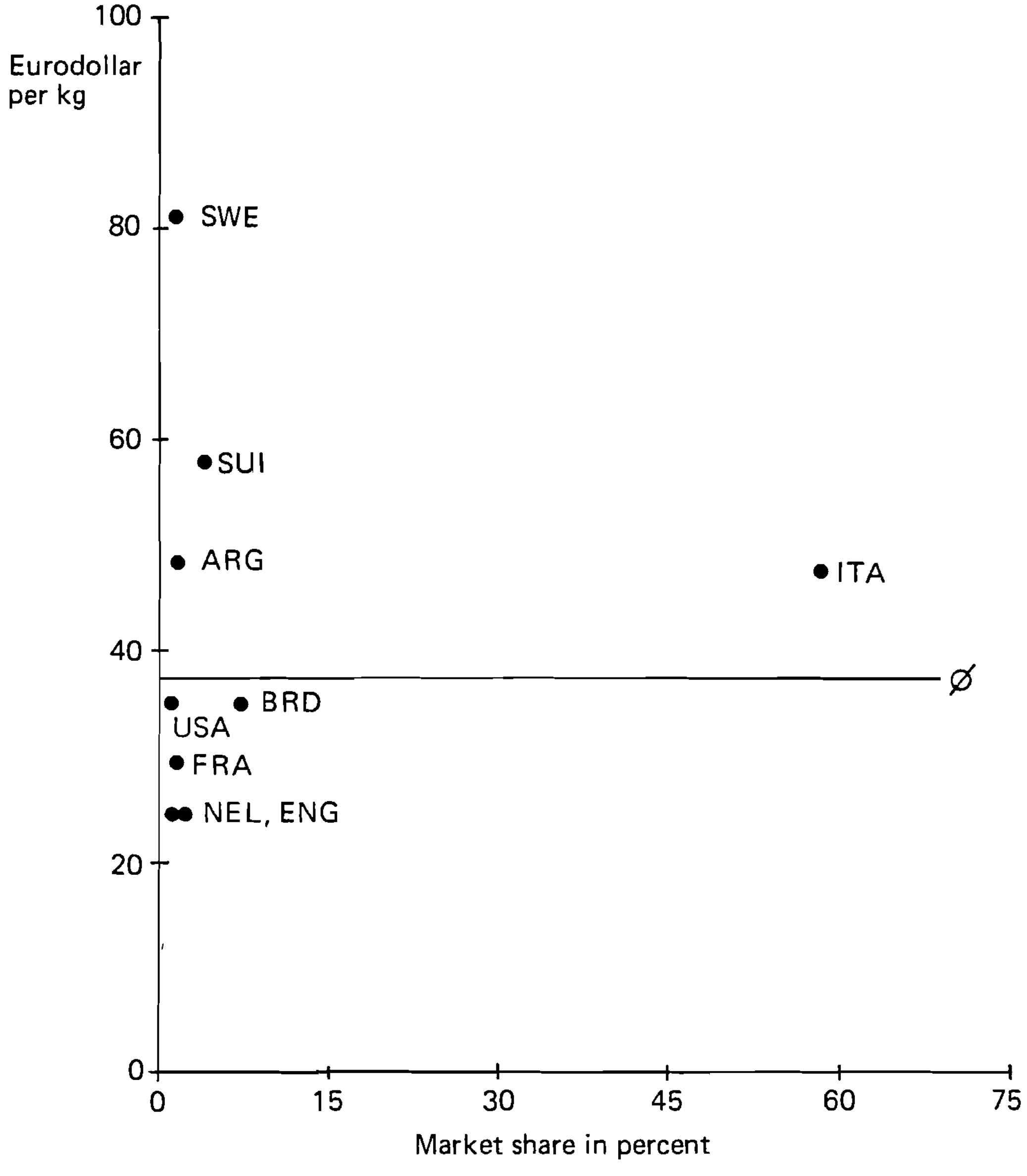


Figure 7. Accounting machines--exports to the EC.

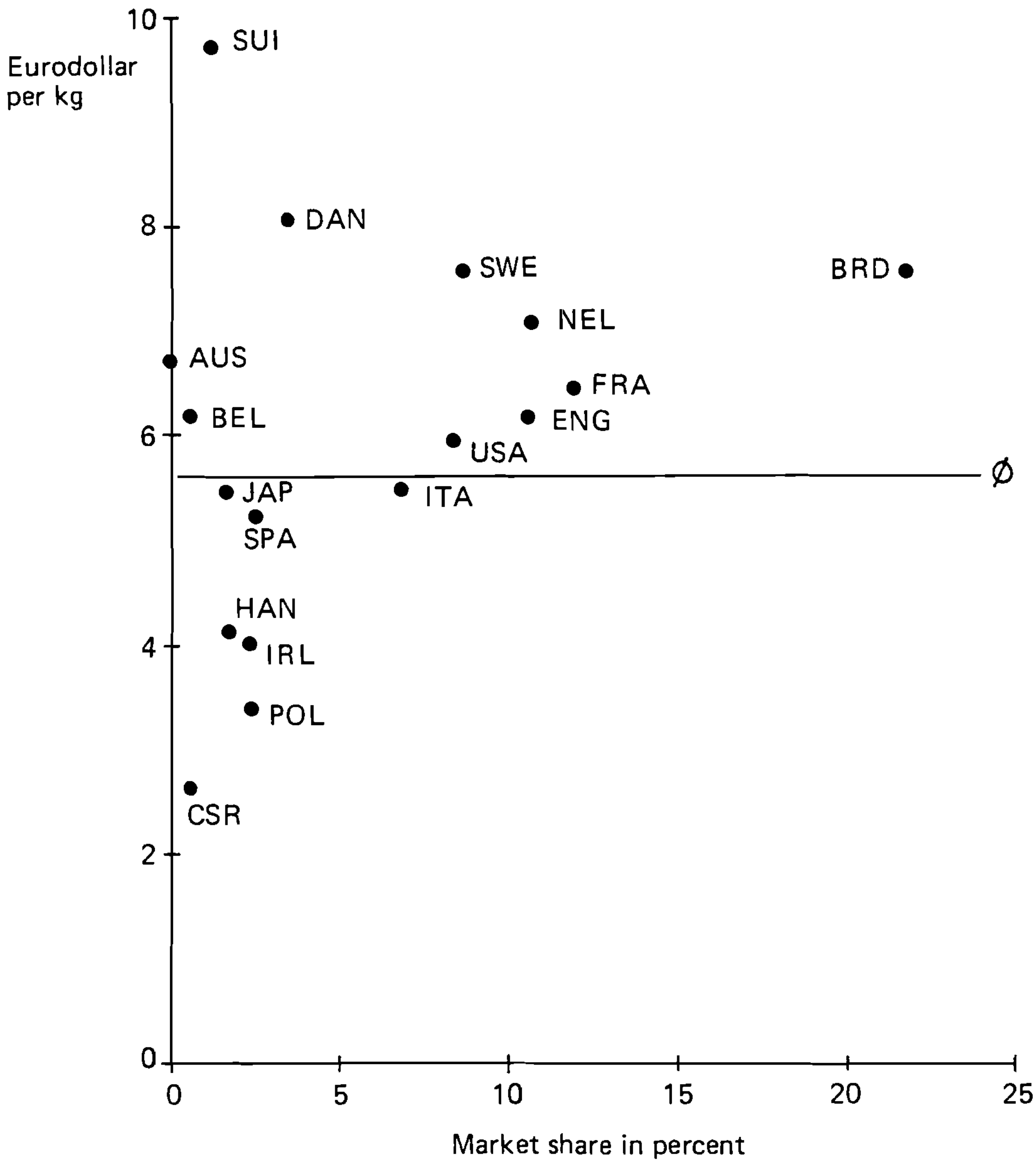


Figure 8. Vacuum cleaners--exports to the EC.

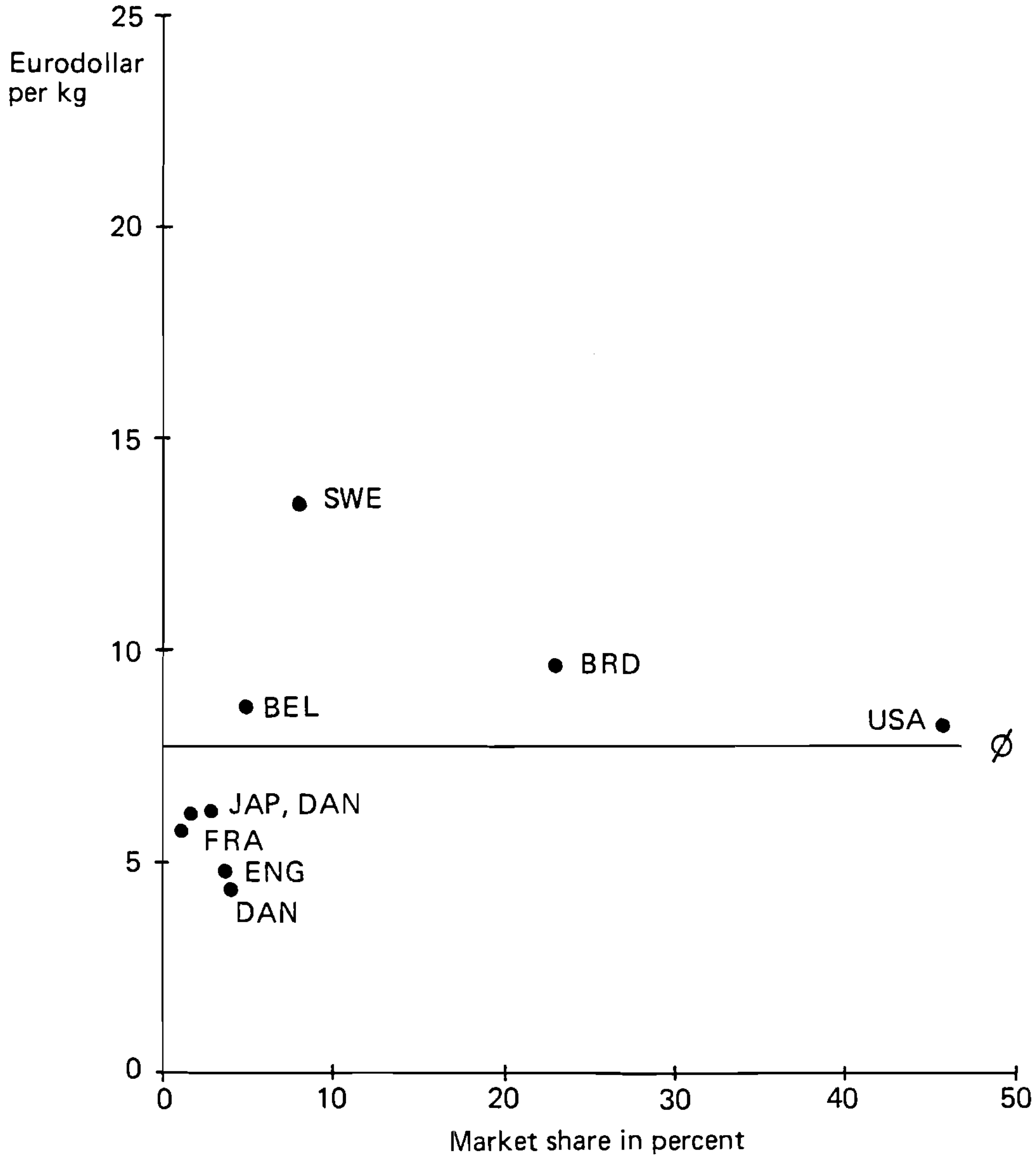


Figure 9. Combustion engines for boats--exports to the EC.

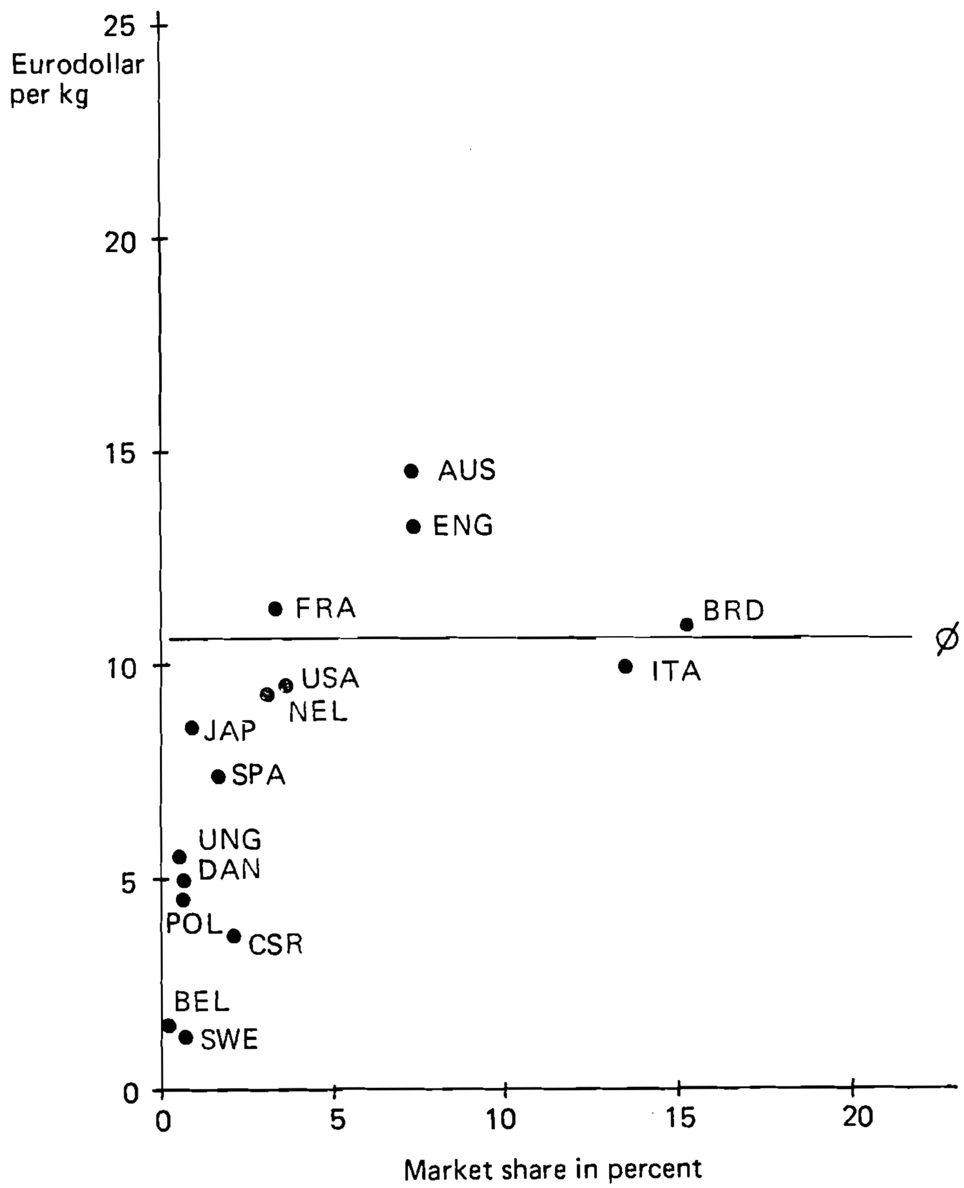


Figure 10. Grinding lathes--exports to the EC.

5. KILO-PRICES OF COMMODITY GROUPS AND CLASSES

Large industrial organizations in market as well as in planned economies tend to focus not on single products, but on whole ranges of product groups with both positive or negative prospects. In practice, commodities with higher and lower kilo-prices coexist in all industrial organizations; the main question is how to combine them in order to reach a certain vector of goals and targets.

We analyzed the development of kilo-prices of West German exports between 1969 and 1979 for 95 product groups. The average deflated growth index was 1.10 and its variance S = 0.54. The average kilo-price of the sample was 28.60 DM/kg in 1979 and its variance was 65.76 DM/kg.

Table 10 shows the distribution of commodity groups for different kilo-prices and growth indexes. Into groups A4, A5, and B5, with high and very high kilo-prices and growth indexes, fell such products as:

- computers, accounting machines
- electric measuring tools
- electro-medical equipment
- instruments, apparatus
- TV color receivers
- precious metal goods, gold and silver plated
- office machines
- telecommunication equipment and other leather goods

Most of these are highly innovative commodities.

We found the lowest growth index of kilo-prices, including one negative one, for

- knitting goods
- furriery (finished)
- movies, developed films

which are in the same line A of high kilo-prices.

We then determined the following additional indicators for each commodity group

e(M) primary energy consumption
h(M) working hours per 1000 kg 1979
s(E) share in total exports in percent 1979
r(E) share of exports in total trade for the given commodity in 1979 in percent
e(H) primary energy consumption per working hour Kwh/h 1979

Table 10. The number of 98 commodity groups for different kilo-prices and growth indexes in the FRG.

	Index of "kilo-price" deflated 1969-1979					
$\bar{p}^{\bullet}_{M}$=1.10 $\bar{p}_M$=28.6 *DM / Kg*	1 very low ≤0.82	2 low >0.82 ··· 1.01	3 medium >1.01 ··· 1.19	4 high >1.19 ··· 1.38	5 very high >1.38	Σ
A >61.49 very high	4	4	1	1	6	16
B >39.56... 61.49 high	0	3	2	1	2	8
C >17.64... 39.56 medium	4	3	3	5	4	19
D >6.68... 17.64 low	8	5	4	0	5	22
E ≤6.68 very low	8	7	7	4	7	33
Σ	24	22	17	11	24	98

p(S) share in total patent applications for the comparable patent groups 1968-1973 in percent

Then we analyzed the influence of these variables on the kilo-price and on the share in exports by regressions for each column and line in our 5 x 5 matrix.

Of 200 equations, only 26 were statistically satisfying. Only one of the regressions within the same growth index area but over different levels of kilo-prices was statistically significant. We concluded that similarities in the developmental and causal pattern can be identified mainly within a certain span of kilo-prices.

Let us look at the most interesting equations. Table 11 gives an overview of the regressions, expressing the influence of three factors on the kilo-price:

share in patents	p(S)
primary energy consumption per kg	e(M)
working hours per kg	h(M)

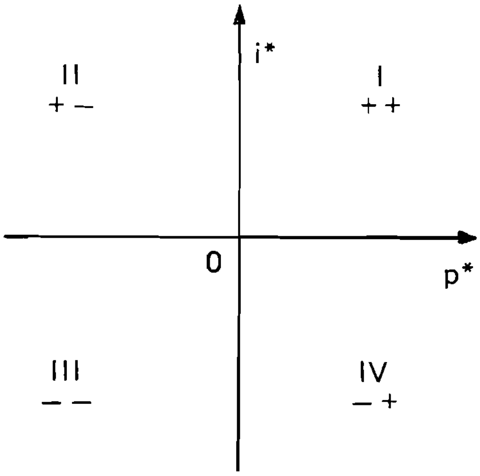
The number of working hours per kilogram has a clear-cut positive influence on the kilo-price. This is true only partially for the primary energy consumption and the share in patents has a positive influence only in the medium group. Also, when analyzing the share of the commodity group in total exports we could not find a clear-cut dependancy upon kilo-prices. So this regression trial was not very successful. More important is the level- and growth-matrix of kilo-prices as a tool for recognizing the innovative position of commodity groups. This is an element of a portfolio method for analyzing the innovative performance of a country, an industry, or a firm.

Table 12 compares the kilo-prices of commodity groups and their shares in total exports. It shows the very progressive structure of the West German exports.

A most interesting questions is how the movement of relative kilo-prices interacts with the change in relative patent applications of the product or product group. We analyzed this by using the four quadrants in Fig. 11 in order to identify the principal pattern in the behavior of these indicators. One could expect a certain dichotomy in the growth of kilo-prices and patent applications because diminishing kilo-prices result in efforts to upgrade products through model changes and to increase the number of patent applications. Let us look again at the Ford car. Table 13 and Figs. 12 and 13 show the historical pattern, which is clearly dominated by an oscillation between the second quadrant (growing patents, declining kilo-prices) and the fourth quadrant (declining patents, growing kilo-prices). For a highly innovative product we can expect a movement mainly in and between the first, second, and fourth quadrants. The first quadrant may be typical for the introduction and the rapid growth phase and the opposite third quadrant may be symptomatic of obsolete and declining goods.

Table 11. Kilo-price of commodity groups as a linear regression function of the share in patents p(S), primary energy consumption per kg e(M), and working hours per kg h(M).

Group of kilo prices	Equation	r^2	S	Degree of freedom (n-2)
A	$p(M)=-1.69-0.0002p(S)+0.0005e(M)+0.101h(M)$	99.99	0.004	14
B	$p(M)=-1.72-0.0005p(S)-0.0001e(M)+0.101h(M)$	99.99	0.003	6
C	$p(M)=13.8+0.223p(S)-0.219e(M)+0.044h(M)$	47.90	3.667	17
D	$p(M)=-1.69-0.00001p(S)+0.0005e(M)+0.101h(M)$	99.99	0.003	20
E	$p(M)=-1.69-0.0001p(S)+0.0008e(M)+0.101h(M)$	99.99	0.006	31



p* Growth rate of relative kilo–prices.
i* Growth rate of relative patent applications.

Figure 11. Four quadrants for analyzing the growth of relative kilo-prices and relative patent applications of products.

Table 12. Kilo-prices in DM and market shares in percent of FRG exports 1979.

"kilo price" 1979 (in DM/kg)	Share in total exports in percent very low < 0.2	low > 0.2...0.8	medium > 0.8...1.4	high > 1.4...2.0	very high > 2.0
> 61.49 very high	Furriery semiprod. Knitting goods from wool Furriery, finished goods Watches Clocks	Computers, accounting mach. Knitting goods from chem. fibres Other clothes Precious metals Electromedical equipment. Electric measuring tools	Office machines	Precision instruments Optical goods Instruments, apparat.	
>39.56.. 61.49 high	Knitting goods from Cutlery Other leather goods Music instruments	Leather shoes		Telecommunication equipment	
>17.64.. 39.56 medium	Woven materials from wool	Dye-stuff from tar Tools a. agricultural appliances Machines for food indust. Printing machines TV receivers	Spinning machines Paper and printing machines Textile machines	Pumps, compressors Pharmazeuticals equipment	Machine tools Electrotech[illegible] goo[illegible] Electrotechnology
>6.68.. 17.64 low	Leather Goods from copper Cosmetics Toys	Woven materials from chemical fibres Books etc.	Agricultural machines Conveyors Plastics		Automobiles (15.7=S(E))

	Bicycles	Photochemimical goods Mining equipment Ball, roller bearings	Electric power machines Domestic electric equipment	
≥6.68 very low	Timber Liquite Salt Raw potash Rubber Yarn from chem. fibres Lumber	Meat and preparations Beverages and tobacco Scrap iron Coke	Fuel Furniture Coal	Cereals

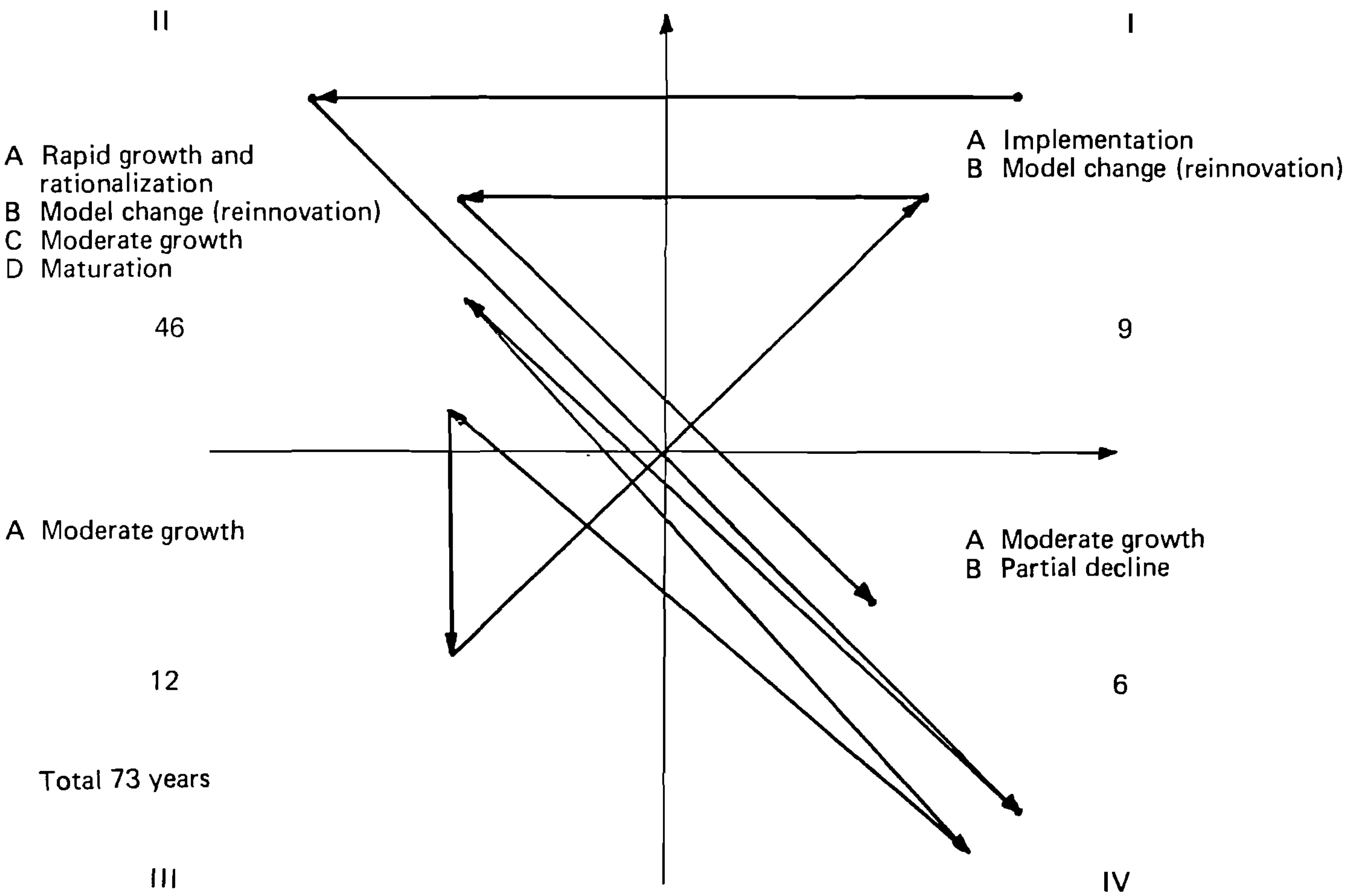


Figure 12. Movements between quadrants over the technological life-cycle of the Ford car.

Figure 13. Changes among quadrants over the technological life-cycle of Ford cars.

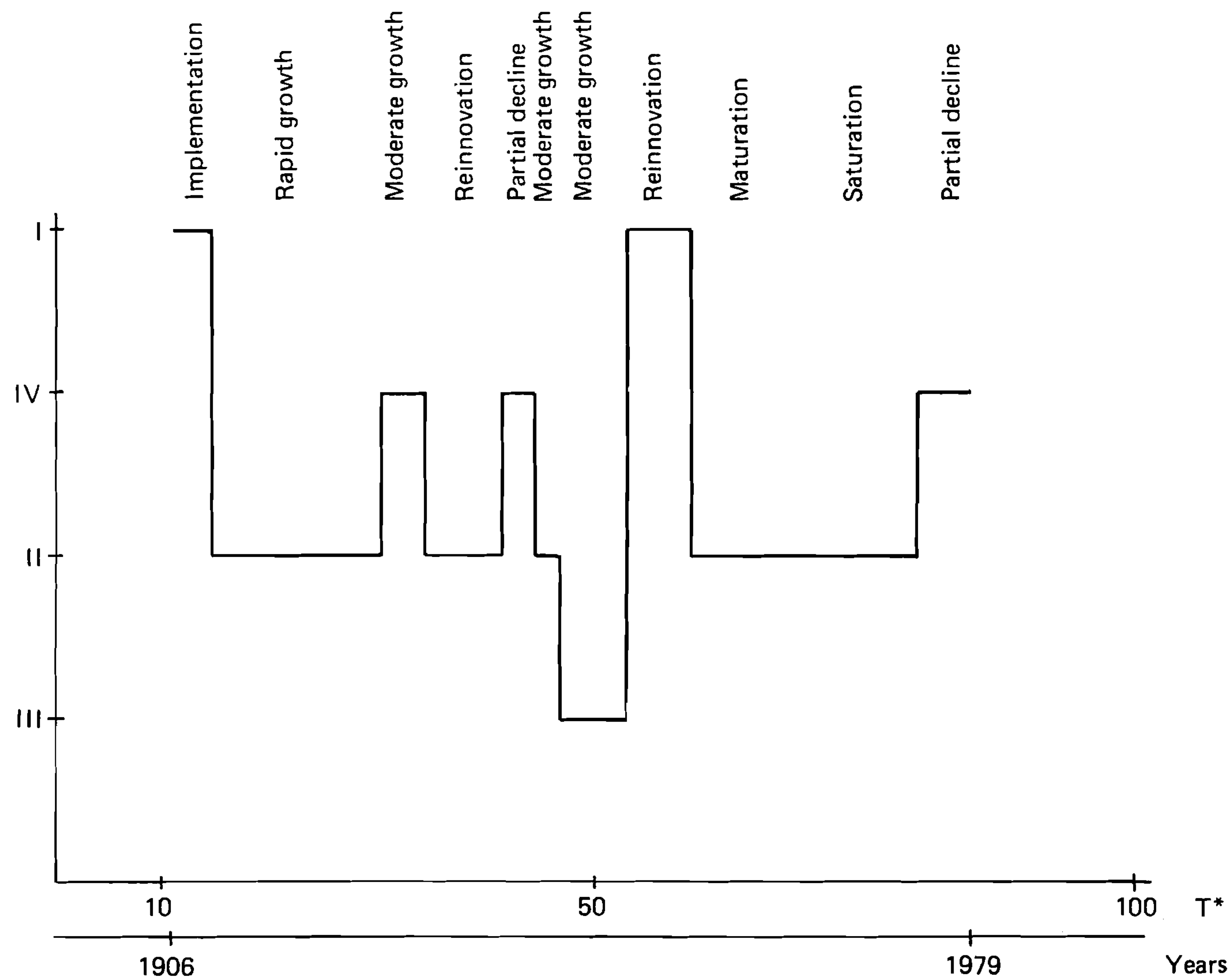


Table 13. Life cycle of the Ford car.

Periods	Number of years	Relative Kilo-price	Relative patent applications	Growth Phase	
1906-1909	3	+	+	I.	Implementation
1909-1925	16	-	+	II.	Rapid Growth
1925-1929	4	+	-	IV.	Moderate Growth
1929-1936	7	-	+	II.	Reinnovation (Modelchange)
1936-1939	3	+	-	IV.	Partial Decline
1939-1941	2	-	+	II.	Moderate Growth
1941-1947	6	-	-	III.	Moderate Growth
1947-1953	6	+	+	I.	Reinnovation
1953-1964	11	-	+	II.	Maturation
1964-1974	10	-	+	II.	Saturation
1974-1979	5	+	-	IV.	Partial Decline

Table 14 shows clearly that highly innovative goods move mainly in and between the first, seconnd, and fourth quadrants. The yearly movements are not a good measure for the analysis when taken separately. No typical pattern arises because of random factors and abberations. It is again necessary to look at five-year periods in investigations of the kilo-price and the cumulative patent growth.

Table 14. Occupation of quadrants by product groups of FRG exports, 1969-1979 (11 years).

	Number of years in which the quadrant was occupied				Relation (I+II+IV)
	I	II	IV	III	:III
Electrotechnical goods	1	4	1	5	1.20
Automobiles	2	3	2	4	1.75
Yarn from chemical fibers	1	2	1	7	0.57
Precision and optical goods	0	7	2	2	4.50
Musical instruments	4	2	0	5	1.20
Office machines	3	3	1	4	1.75

Fig. 14 gives an overview of the movement of unit values in export and patent applications for three countries. From the view of unit values, the FRG is still in a favorable position when compared to Japan and the US.

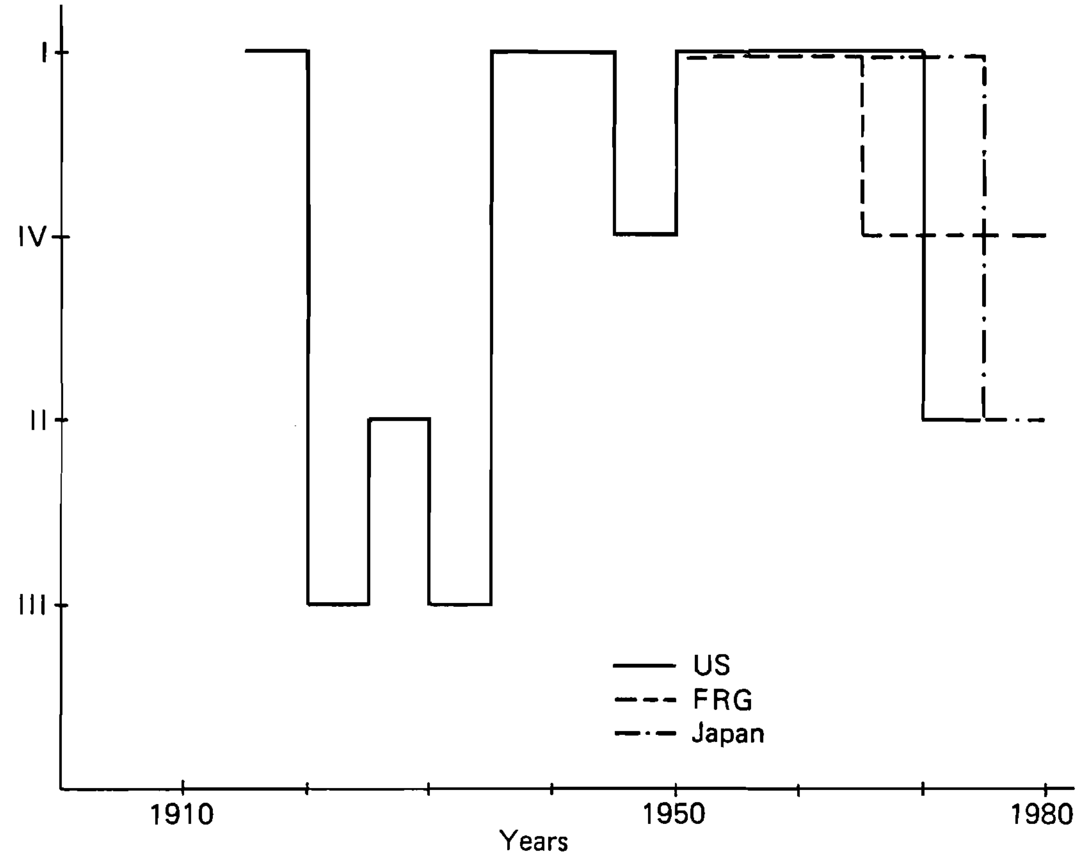


Figure 14. Changes between quadrants in the cases of the US, the FRG, and Japan.

The relationship between patent applications and kilo-prices was analyzed by G. Goebel, a summer-student at IIASA in 1981. He found that the Japanese apply for patents in special product fields in a country one or two years before they launch a marketing campaign. In Summer 1981 he predicted a marketing coup by the Japanese in the field of cosmetics in the West European countries. At the end of the year West German economic journals reported this Japanese offensive (Wirtschaftswoche 38/81, 49/81). (Walter Goldberg was so kind to inform me about this fact.)

6. SOME REMARKS ON THE KILO-PRICE OF EXPORT COMMODITIES IN A STRATEGIC CONTEXT

Japan is at present the most successful country in terms of kilo-prices and market penetration. Table 15 shows the general situation between 1975 and 1980. The high kilo-price of Japanese exports is a structural effect. It does not mean that Japanese export strategies are based exclusively on goods with high and fast-growing kilo-prices. Such commodities are not typical for expanding market fields. When looking at the 99 commodity classes of NIMEXE for 11 countries we found the pattern registered in Table 16. The Japanese market expansion of 1975 occurred in three areas of high, but relatively slowly growing kilo-prices.

Table 15. Kilo-prices and market shares of 11 countries' exports to the EC.

Country	Average Kilo Price 1980		Growth Index of the Kilo-Price from 1975-1980	Share in World Exports to the EC Countries		
	Euro-dollar per Kg.	Percent		1975	1980	Difference
FRG	0.55	21	1.73	12.87	12.16	-0.71
Japan	2.57	100	2.64	1.98	2.37	0.39
US	0.48	19	1.47	8.55	8.38	-0.17
Austria	0.67	26	1.73	1.10	1.33	0.22
SU	0.20	8	2.25	1.56	2.09	0.53
CSSR	0.20	8	1.14	0.34	0.28	-0.06
Hungary	0.59	23	1.40	0.29	0.26	-0.03
GDR*	0.32	12	.10	1.19	0.16	-0.03
Brasil	0.11	4	1.51	01	0.80	-0.09
Mexico	0.30	12	0.83	0.13	0.20	0.07
Mozambique	0.25	10	1.08	0.05	0.01	-0.04

*Not including exports of the GDR to the FRG

Table 16. Expansion of 11 countries 1975-1980 on the EC market.

Country	Product Group (NIMEXE)	Kilo-Price relative to Japan's average (2.57 Eurodollar/kg)		Growth of Kilo-Prices relative to each country's average	
		higher	lower	higher	lower
FRG	Cars	x		x	
Japan	Films	x			x
	Cars	x			x
	Musical Instruments	x			x
US	Precious stones	x		x	
	Coins	x			x
Austria	Wood		x	x	
	Fuel		x	x	
	Plastic materials		x		x
	Steel		x	x	
	Elec-trotech nical goods	x			x
	Cars	x			x
USSR	Fuel		x	x	
	Basic chem. goods		x		x
	Prec-ious stones	x		x	
Hungary	Fuel		x	x	
	Kohlen wasswer stoff		x		x
	Plastic materials		x		x
	Steel products		x	x	
	Machin-ery		x	x	
CSSR	Meat		x	x	
	Fuel		x	x	
	Plastic materials		x		x
	Wood		x	x	
GDR	Furni-ture		x	x	
	Fuel		x	x	
	Plastic materials		x	x	

	Steel products		x	x	
Mosambique	Fish	x		x	
	Fruits		x	x	
	Coffee		x	x	
	Oil seeds		x	x	
	Nat. Harze		x	x	
	Sugar		x	x	
	Ore		x	x	
	Fuel		x	x	
Mexico	Fuel		x	x	
Brasil	Dehydrated meat		x	x	
	Steel		x		x
	Machinery	x			x
	Cars	x			x

Japan's penetration strategy combines various measures:

1. Preparation of the attack by intensified patent applications in the foreign country.
2. Careful selection of small market segments with the aim of gradually moving across the entire market.
3. Using the cost saving benefits of a large home businesses.
4. Trying to combine product innovation and process rationalization.
5. High attention to quality and special brands.
6. Selection of a concentrated geographic area and a segment that is small and perhaps unimportant to domestic companies.

I have come to the conclusion that upgrading through innovations is a challenge to the economy because it involves more than advanced products alone. It requires a strategy that aims at relatively high kilo-prices and a maximum of benefits from sales on foreign markets. While it is impossible to upgrade exports without innovations, highly innovative products alone (those with high and fast growing kilo-prices) cannot ensure the necessary progress in a given period. The other leg of the strategy should be the maturing areas and decreasing costs.

On the other hand, without highly innovative products in the background, we will be lacking the maturing areas of the future.

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