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A Technometric Model for the Assessment of Technological Standards and Their Application to Selected Technology-Intensive Products

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ABSTRACT

This article presents a quantitative model for the assessment of technological standards, which is applied to a sample of Japanese data compiled in 1982 that gives technical specifications of high-technology or high-commodity goods in Japan, the United States, and in some Western European countries. The metric model provides a systematic and checkable methodology by which to assess the achieved technological standards and disparities, allowing for cardinal measuring on different levels of aggregation. It does not consider the economic features of the products and processes analysed. The application of the model to a sample of 43 selected products (e.g., polyester filaments, color papers, coaxial cables, powder metallurgical products, machining centers, assembly robots, videotape recorders, semiconductor lasers, automobiles, nuclear reactors, to name only ten) of Japanese, U.S., and European origin (more than 5,500 data) indicates that despite the overall lead of Japan and the United States over European technological standards, the relative position of European—especially West German—technology is above average with respect to key technologies.

Through the analysis of all technical specifications available, we show that the Japanese position is strong in technologies related to resources and environment, whereas the United States is in the lead in computer-aided design technologies.

Introduction

Our institute's research project [9] was labelled "Technometrics" six months prior to the publication of the article "Foundation of Technometrics" [19] by D. Sahal in spring 1985. The independent use of the word *technometrics* may raise the question of whether or not the two concepts are more or less equivalent. At first glance they are not, because our research does not deal with the foundations of technology measurement but takes a somewhat more practical approach. The main object of the concept is to end up with comparative multivariate analyses of national technological standards at a fixed point in time or over a short period of time but not—as in [19]—to show the evolution of a

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specific technology over a period (100 years, for example). Nevertheless, some ideas are common to both approaches.

The competitiveness of national economies with a high level of human capital and correspondingly high wage levels depends on a steady development and a permanent introduction of new technologies. In the 1960s, the fear of a "gap" in research and technology between Europe and the United States was at least present in the Old World [24]. The fear of a gap disappeared during the 1970s, but since Japan has made its debut as "Number One" in high-commodity goods [28], the gap discussion has been revived, this time with reference to the industrialized countries of the three continents. In scientific response to "anti-gap" policy, deliberations concerning the question of quantitative measures, or at least impartial and objective approaches to assessing technological standards and deficits, are now ongoing in Japan [8, 27], North America [3, 5, 11, 14, 16, 26], Western Europe [7, 12, 13, 15, 18, 21, 22, 23], and in developing countries [25].

A promising approach to the analysis of these problems uses indicator measurements. On the one hand, a number of economic indicators has been well established to monitor the technological change in industry; on the other hand, valid indicators for measuring technological specifications directly are in the thinking stage. The technometric concept outlined in this article is an attempt to establish indicators, whose validity is restricted to the technical sphere. Such an attempt neglects economic concerns for the time being, but offers insights into the technological progress without too much interference by factors such as "market forces."

If one roughly follows Freeman [6], then the process of research, development, and innovation may be broken down for simplicity into the following stages:

1. Basic research aiming at hypotheses, theories, and formulas;
2. Applied research aiming at inventions and rough drawings;
3. Development aiming at technical specifications and blueprints; and
4. Construction and diffusion (through domestic branches and foreign markets) aiming at new products.

This structure shows that indicators based on technical specifications, which are output indicators for the process of research and innovation, should react considerably earlier than will the well-known economic indicators.

Two simple hypotheses may be formulated to explain possible discrepancies between inputs in research and development (R&D) and the corresponding outputs (in fact, the gross expenditures for research and development divided by the gross domestic product is roughly the same for most developed countries: 2.45% in the United States; 2.22% in Japan; 2.44% in West Germany; 2.38% in Great Britain in 1980 [17]). These two hypotheses are:

1. Deviations from the "expectation value" of the outputs (which should be identical in those countries with similar inputs) can be monitored by technical indicators measuring the output of R&D and will indicate failures in the national research and technology development systems;
2. Deviations from the "expectation value" are only detectable through economic output indicators, with technical outputs indicating the expected success. This will point out national failures in the fields of marketing, labor conflicts, international trade barriers, and the like.

Technometrics is based on the compilation of technological specifications of national products and their international comparison. Technological disparities within a national economy are excluded and domestic competition is not considered. Because competing domestic companies have access to the same national R&D know-how and human capital, domestic technological disparities are not a sign of a malfunctioning R&D system.

The highest standards among all domestic companies are taken as the national standards. Mean values and averages over samples of different domestic producers of the same technology are not required. The representativeness of such samples is not crucial to the results as long as both the enterprises with the most advanced standards and those with relatively simple standards are included in the survey. But in the case of effective competition among a large number of small or medium-sized companies, the inclusion of the most advanced companies in the sample would in fact require diligence and could otherwise cause severe problems of sample representativeness.

Assessing the state of the art of national technologies by technometric indicators does *not* provide a direct or immanent pathway to statements of competitiveness. Genuine economic analyses have to be added; that is, the technometric indicators may point out interesting issues, but they will not be self-explanatory. A proper interpretation is essential to fully understanding indicator measurements.

Conceptual Framework of Technometrics

Technometric indicators are aggregated figures composed of specifications in physical units. The composition procedure is defined below. Because the specifications indicate the state of the art of either a product or a process, forming distinct product and process characteristics is useful, but not essential [21]. If the product or process serves different purposes, different functional characteristics ("service characteristics" [21]) or weighted-priority characteristics have to be used. The characteristics should not be called vectors but *n*-tuples, mathematically speaking, because vector rules do not apply. In Table 1, the characteristics for the semiconductor laser (diode laser) are given as an example.

TABLE 1

Product and Process Engineering Characteristics for the Semiconductor Laser (Laser Diode, Wavelength 0.8 μm) as an Example for Technological Specifications. The Measuring Units are Given in the Table.

Semiconductor Laser (0.8 μm) Product Specification	Unit	Process Specification	Unit
Threshold Current	mA	Output Factor Wafer	%
Forward Current	mA	Output Factor Chip	%
Longest Wavelength	nm	Output Factor Component	%
Shortest Wavelength	nm	Size Wafer	⊖ mm
Spectral Width	nm	Precision Mounting	± μm
Beam Divergence Perpendicular	deg	Uniformity Coating	± %
Beam Divergence Parallel	deg	Striation	rel.
Signal-to-Noise Ratio	dB	Application Drive Process	%
Output Power	mW	Molecular-Beam Epitaxy	%
Transversal Modes	No.	Molecular Orbital Chemical	
Longitudinal Modes	No.	Vapor Deposition	%
Wavelength Instability	± nm		
Integrated Optical Fiber Connection	%		
Efficiency Fiber Output	%		
CAD Application	%		

Whereas process and product characteristics contain discrete physical entities, and may thus be regarded as somewhat impartial, the functional characteristics or priority lists contain deliberations on individual or collective purposes. These are therefore non-objective.

We call products and processes technical systems $T(i)$. For each system, some specifications $K(i,j)$ together with the elements of the functional matrix $F(i,j)$ are defined. If different countries and time series are considered, then the indices k and t are added. The maximum value of a specification—that is, the value of the company leading with regard to this specification—is denoted by $f = 1$, the minimum value by $f = 3$. For retrieval purposes, another index r is used to denote subclasses of all specifications K, such as product specifications, process specifications, key specifications for future importance, energy-related specifications, and the like. The K values may be ranked but cannot be cardinally aggregated as indicators. A metric system, therefore, has to be introduced.

The starting point for this metric system is the national maximum specification $K(i, j, k, f = 1, r, t)$ as outlined in the introduction: the technical standards of the leading enterprises within a national economy, which are regarded as essential for international comparisons. The fact that other companies offer technologically simpler and cheaper products at the same time is economically well justified but is of no interest for us in our use of the technometric model.

The metric is given by a transformation of $K(i, j, k, f = 1, r, t)$ into the dimensionless interval [0,1] by

$$K^*(i, j, k, r, t) = \frac{K(i, j, k, 1, r, t) - K(i, j, k\text{min}, 3, r, t)}{K(i, j, k\text{max}, 1, r, t) - K(i, j, k\text{min}, 3, r, t)},$$

with

K^* = the metric specification figure;

$k$max = the k for which $K(i, j, k, 1, r, t)$ is maximum for fixed i, j, and t;

and

$k$min = the k for which $K(i, j, k, 3, r, t)$ is minimum for fixed i, j, and t.

The maximum values of K^*, therefore, represent the highest technological standards. If the scale is inverse—that is, if the minimum value of K represents the highest technological level—then the formula

$$K^*(i, j, k, r, t) = \frac{K(i, j, k, 3, r, t) - K(i, j, k\text{max}, 1, r, t)}{K(i, j, k\text{min}, 3, t) - K(i, j, k\text{max}, 1, r, t)}$$

holds. The formulation of the functional characteristics determines whether or not the scale is inverse. But the final decision has to be made by technical experts. The specific fuel consumption of a car or the beam angle of a laser beam are examples for specifications with inverse scales.

In other words, $K^* = 1$ in the above-defined metric (the technometric) shows the technological standard of the leading company in the leading country for each specification under consideration. The technical level achieved in comparison to other countries is determined by the width of the spread of the standards among the different countries. If the technological standards offered to and demanded by the international markets are widespread, then minor differences among the nationally leading companies cannot indicate a major technological gap. Accordingly, the technometric indicator values K^* will be close to 1 for all countries. Figure 1 shows some typical cases that have been chosen to illustrate the functioning of the metric system. Case A shows that the metric system gives equal values to all countries in all instances in which the most advanced levels in those countries are equal, despite the fact that the modal values of the national distribution are different and would result in a different K (mod) given in the center of the figure. Case B represents narrow-spread domestic distributions of technological standards with considerable differences between countries, and case C represents the situation in which the domestically available levels of technology in country $k = 3$ embrace the other countries. Case D shows an outdated technology in country $k = 3$, one which is not produced or offered to markets on this low level by any company of country $k = 1$.

The technometric fulfills the mathematical conditions of symmetry, of reflexive relations, and of the triangle inequality. If countries are compared by technological specifications one by one (no aggregation), then the technometric conserves the ordinal ranking of the original figures. In aggregated technometric indicators, those items with considerable international disparities dominate the distinctions and indicator values. The matrix of functional characteristics is not affected by the metricization. Restricting the elements of the functional matrix $F(i, j)$ also to the interval [0,1] is useful, however.

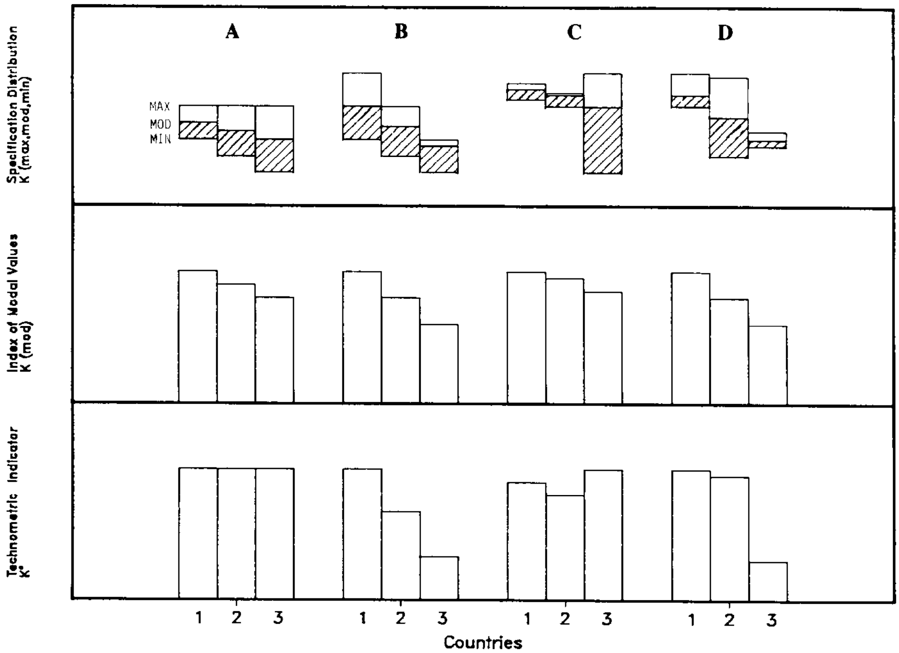

Fig. 1. Illustration of the technometric. Random types of situations are outlined (see text). The first row represents the distribution of the original specifications in physical units with maximum, modal, and minimum values. The center row gives the randomly indexed modal values *not* used by our method. The bottom row represents the technometric values. Cases A to D all exhibit declining modal values from countries $k = 1$ to $k = 3$. Technometric evaluation gives different pictures for cases A to D.

An aggregated technometric indicator is then of the form

$$I = \frac{\Sigma K^*(i\ ,j\ ,k\ ,r\ ,t) \cdot F(i\ ,j)}{\Sigma\ F(i\ ,j)}.$$

The summation may be performed over all t values (time average), some r (specific technological criteria), all i, j of a fixed k (country performance), all j with fixed i (technological systems or products), and some combinations. Some examples are given in the following sections.

In the literature, a number of similar approaches can be found. To our knowledge, none of the proposed concepts aims at a quantitative comparison of solely technological specifications on the level of national economies. To point out some differences between the approaches taken so far (not complete) we may classify most of the recent papers according to three categories are not complete:

1. *Category 1:* The models are based on the study of long-term developments (dozens of years);
2. *Category 2:* The models are not exclusively restricted to technology but are based implicitly or explicitly on economic factors (for instance, on price ratios); and
3. *Category 3:* The models cannot be differentiated with respect to national standards. They can be differentiated either between individual enterpreneurs or on the most advanced technology on a world-wide basis.

Thus, Sahal's work [e.g., 19, 20] falls into Categories 1 and 3, the papers from Manchester [7, 22] and the work of the Rand Corporation [e.g., 3] belong to Category 2. Some of the research of both groups also fits into Category 1. Recent theoretical work by a West German university group [23] is said to be applicable and valid for country-to-country comparisons, but empirical evidence has only been provided so far within Category 3.

Our technometric model attempts to fill an analytical gap: it does not fall into any of the three categories.

Application of the Technometric Model to a Sample of Japanese Data

The Agency of Industrial Science and Technology (AIST) of the Japanese Ministry of International Trade and Industry (MITI) published in 1982 a survey on the technological specifications of a large number of advanced technologies. The survey was performed by the private Japan Techno-Economics Society (JATES) [1] (we shall refer to this study as JATES/AIST). According to the Japanese industrial classification, 43 product groups had been selected. A great variety of technical data had been compiled [10] with the help of a Delphi inquiry (two successive questionnaires), industrial experts, and expert panels. Because the data include maximum and minimum values, modal figures, and priorities representing the required functional values F, the data can be used in our technometric model. We modified the sample data because the JATES/AIST report included a few economic figures, such as sales and prices, that had to be excluded from our technically based calculations. The modified data set contains more than 80% of the original data.

Some features of the sample are given in Table 2. It gives a good representation and covers most of the Japanese industrial system. Table 2 also shows the Standard International Trade Classification (SITC-Rev. II) corresponding to the products. By comparing Table 2 with the high-technology product list of the OECD from 1985, one can see that most of the products in the sample are indeed high-tech products.

We presented selected data to industrial and technological experts in the Federal Republic of Germany so that they could check the translation of the technical specifications from the Japanese and the validity of the translations. These checks produced rather satisfactory results. A full-scale check of all the data given was not possible, however, because this would have meant repeating the entire survey.

The data-evaluation procedure of JATES/AIST is an ordinal ranking method for selecting a single item (the most important figure) from each technological system [10] for the purpose of classifying the achieved technical standard. This method neglects a great deal of the available information. We therefore did not regard this approach as adequate, we did not use it for the purpose of this paper, nor did we evaluate it in detail. Instead, we used for our technometric model the modified Japanese *data* concerning technical specifications for carrying out the analysis that will be explicated in the following sections.

Technological Standards for Selected Technology-Intensive Products

Figure 2, Figure 3, Figure 4, and Figure 5 show the indicator values of the 43 products in the JATES/AIST data as they have been calculated with the technometric model. If the rule for significant figures [4] is strictly applied to the original data, then the margin of error of the indicator values in Figures 2, 3, 4, and 5 lies between 6% and 13%. Other sources of error cannot be treated numerically, but do certainly exist. Thus, the given margins of error here and below are lower limits.

Figures 2 and 3 summarize the results for those product groups being compared to West German technology. The products are arranged in such a manner that the series decline from left (in Figure 2) to right (in Figure 3) for the German indicator values. Thus, Figure 2 shows all products with relatively good West German performance and Figure 3 shows those with relatively moderate standards in West Germany. Figure 4 shows the technometric indicators for the product groups compared among Japan, the United States, and European countries other than the Federal Republic of Germany. Assigning some products to a single European country (e.g., airplanes, communication satellites, and videotape recorders) is not possible. Those "European" products, labelled EUR in Table 2, are also included in Figure 4, although they could just as well be positioned in Figures 2 or 3. Figure 5 exhibits the technometric results for the product groups, for which no European data were available.

In this article we do not want to interpret the results for each of the 43 products we reevaluated, but wish to emphasize certain points to prevent misinterpretations. The product groups under consideration are still quite heterogeneous. As an example, the technical specifications of nuclear reactors (see Figure 2) are composed of data for boiling-water reactors (BWR) and pressurized water reactors (PWR). The good technometric indicator value for the Japanese "reactor" is fully explained by the fact that the specifications of Japanese BWR are much better than are those of the corresponding West German ones. The German export of nuclear power plants, however, is based only on the PWR type.

Furthermore, the reader should not forget that the indicators do not represent time averages but reflect a momentary picture of technological standards in 1982. This also influences the interpretation of technological performance, as is best shown in the case of polyester filaments (see Figure 3). According to the economic crisis legislation in

TABLE 2

Synopsis of Important Parameters of the Data Sample Taken from JATES/AIST. The products under Investigation, Their Classification (Japanese Industrial System and SITC), the Compared Countries, Types of Available Characteristics, Numbers of Items, and Numbers of Data are Compiled. (ROK, Republic of Korea; ITA, Italy; FRG, Federal Republic of Germany; GBR, Great Britain; FRA, France; SWZ, Switzerland; NET, the Netherlands; EUR, Europe).

Standard Industrial Classification for Japan	Industrial Branch	Sample Sequence No.	Products Included in the Sample	Countries Compared Other than Japan & United States	Types of Available Characteristics (PC = Process, PD = Product)	No. of Specification Items (Modified)	No. of Data	SITC Classification
200–219	Textiles Man.	1	Apparel	ROK	PC	20	120	842.4,844.1
261–269	Chemical	2	Urea Fertilizers	ITA	PC	28	168	562.16
	Products	3	Syndyes for fibers	FRG	PD	4	24	531.21
	Manufacturing	4	Polyvinylchloride	FRG	PD, PC	32	192	583.4
		5	Polyester Filaments	FRG	PC	20	120	266.5
		6	Surface-Active Agents	FRG	PD	15	90	554.2
		7	Antibiotics	FRG	PD	9	54	541.3
		8	Color papers	FRG	PD, PC	21	126	882.23
301–309	Ceramics	9	Cement	FRG	PC	27	162	661.2
		10	Ceramics for Electronics	FRG	PD, PC	28	168	764.99,663.92
311–319	Iron and Steel	11	Common Steels	FRG	PC	28	168	671.2
	Manufacturing	12	Special Steels	FRG	PC	16	96	672.4
321–329	Non-Ferrous	13	Common Aluminum	FRA	PC	21	126	684.1
	Metals and	14	Coaxial Cables	FRG	PD, PC	15	90	773.1
	Products	15	Optical Fibers	GBR	PD, PC	22	132	664.94
	Manufacturing	16	Powder Met. Products	FRG	PD, PC	30	180	695.43
341–389	General	17	Gas Turbines	FRG	PD, PC	21	126	714.88
	Machines	18	Construction Machines	FRG	PD	20	120	723.4

	Manufacturing	19	Machining Centers	FRG	PD	23	138	736.7
		20	Spinners	FRG	PD	19	114	724.41
		21	Air Jet Looms	SWZ	PD	19	76	724.51
		22	Injection-Molding Mach.	FRG	PD	24	144	728.42
		23	Exhaust Gas Desulfurizers	FRG	PD	15	90	711.2
		24	Copying Machines	FRA	PD	24	144	751.82
		25	Ind. Assembly Robots	FRG	PD	8	48	744.28
351–359	Electrical Machinery Manufacturing	26	Ultra-High-Tension Transformers	FRG	PD	15	90	771.11
		27	Refrigerator/Freezers	ITA	PD	18	108	775.21
		28	Videotape Recorders	EUR	PD	19	76	763.81
		29	Large Computers	—	PD	16	64	752.3
		30	Digital Radiography	NET	PD	20	120	774.2
		31	Spectrum Analyzers	—	PD	23	92	874.83
		32	LSI Memories	—	PD, PC	44	176	776.4
		33	Full Cells	—	PD	18	72	716.21
		34	Semiconductor Lasers	GBR	PD, PC	46	276	776.3
361–369	Transportation Equipment Manufacturing	35	Passenger Cars	FRG	PD, PC	35	210	781.0
		36	General Ships	GBR	PD, PC	23	138	793.2
		37	Civil Aircrafts	EUR	PD	36	216	792.4
371–377	Precision Instruments Manufacturing	38	LSI Probers	—	PD	21	84	874.83
		39	Theodolites	SWZ	PD	21	126	874.12
		40	Liquid Chromatography	FRG	PD	29	174	874.4
—	Others Outside Japanese Classification	41	Nuclear Reactors	FRG	PD	23	138	781.7
		42	Communications Satellites	EUR	PD	59	354	714.4,764.3
		43	Package Software	FRG	PC	9	54	759.9
—	Sum	43	All Sample Products	—	—	984	5584	—

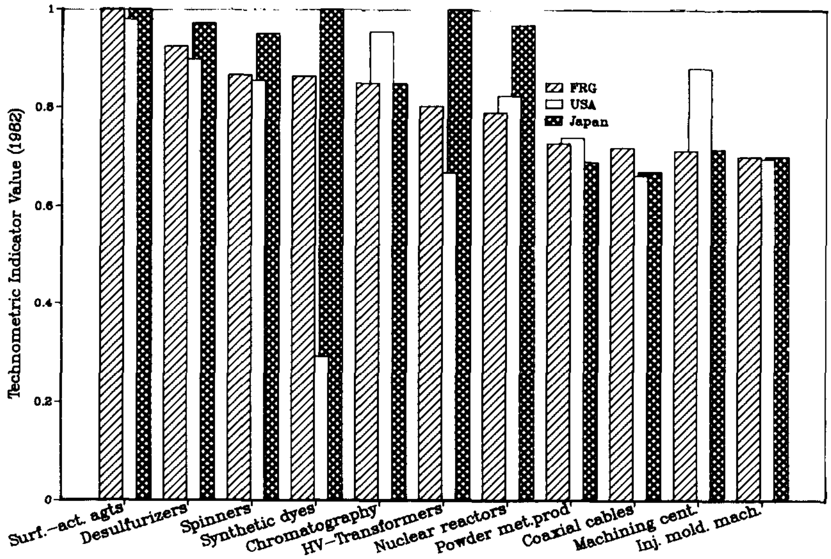

Fig. 2. Technometric indicator values of 11 technology-intensive products with relatively good West German performance. Original data have been extracted from a sample of data compiled by JATES/AIST [1] in 1982. Each value has a minimum margin of error of 6% to 13%. The products are arranged in such a manner that the series declines from left to right for the FRG products.

Japan, a selection process was begun in 1978 for eliminating several plants in the synthetic fibers industries based on the plant performance. As a result, the technological progress may have been accelerated from 1978 to 1982, the period during which the data were compiled in the JATES/AIST sample. So the excellent indicator value for Japanese polyester filaments (Figure 3) may not reflect a typical situation.

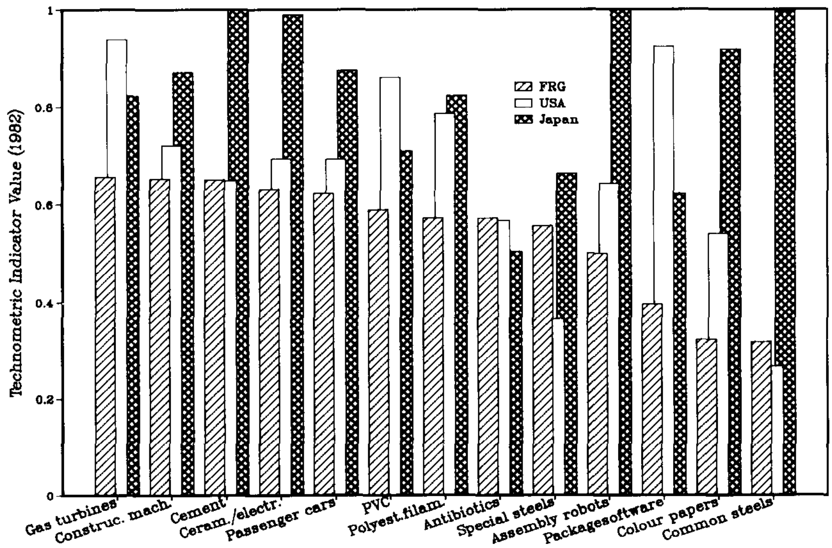

Fig. 3. Technometric indicator values of 13 technology-intensive product groups with relatively moderate West German performance. Data source and margins of error as for Fig. 2.

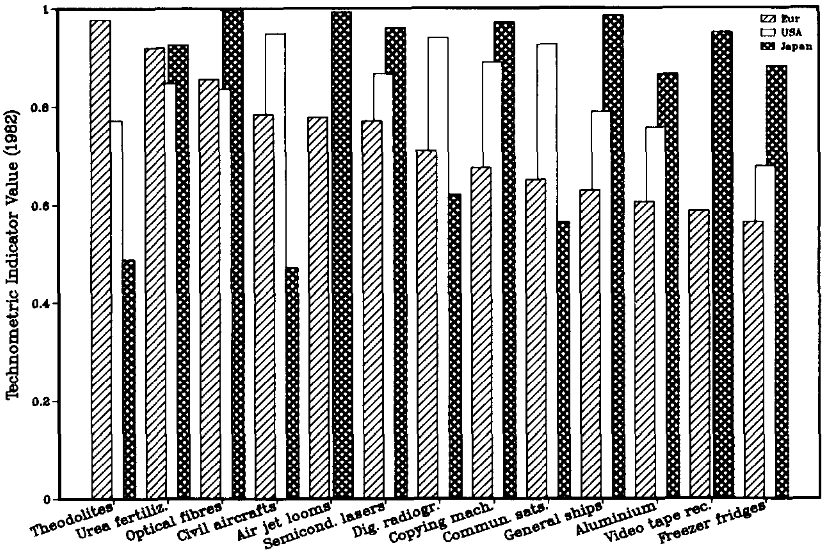

Fig. 4. Technometric indicator values of 13 technology-intensive product groups compared among Japan, the United States, and diverse European countries. The countries are identified in Table 2. Data source and margins of error as for Fig. 2. The products are arranged in such a manner that the series declines from left to right for the European countries.

None of the indicator values given were normalized to account for the size and for the differences in the research and development system of the countries compared. Science indicators are usually normalized with the help of the gross domestic product (GDP), the gross expenditures on research and development (GERD), or the number of researchers, scientists, and engineers (RSE). As for the technometric indicators given here, we do not know of the appropriate means for applying a normalization procedure.

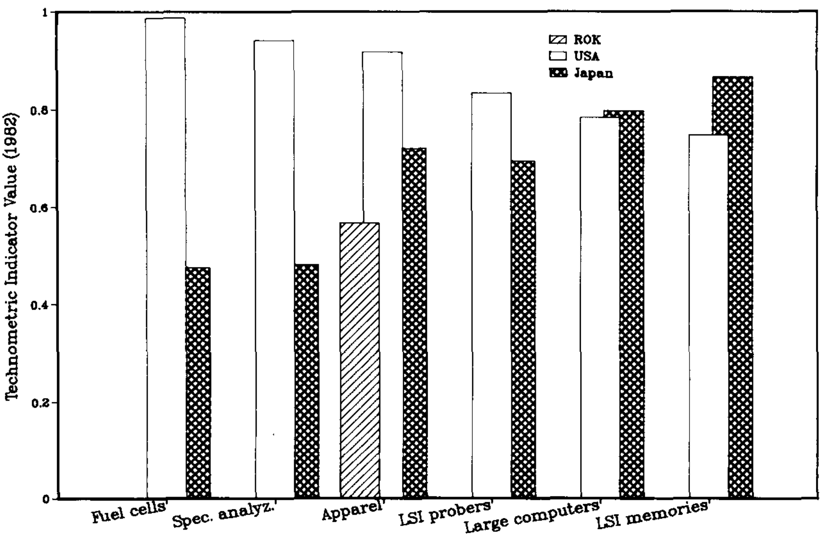

Fig. 5. Technometric indicator values of six technology-intensive product groups compared between Japan and the United States; no data gathered for European countries (ROK, Republic of Korea). Data source and margins of error as for Fig. 2.

Considering the technological standards of European countries, which are on average somewhat lower than those for the United States and Japan (see also "National Technological Standards" below), the reader should remember that these were achieved with smaller scientific and economic resources. For 1982 [17], West Germany, Japan, and the United States had GDP ratios of 1:1.8:4.6, GERD ratios of 1:1.7:4,8, and RSE ratios of 1:3.1:5.4. Because the technology specifications in the JATES/AIST data were given for single European countries for nearly all products except the EUR products (see Table 2)—West German cars but not French cars and Swiss theodolites but not British theodolites are under investigation—we see no point in regarding Europe as a uniform country with larger scientific and economic resources than the United States or Japan.

National Technological Standards

If one further aggregates these product indicators to form an overall national standard in industrial technology (or at least for the technologies included in the sample), the results are 0.81 in Japan; 0.77 in the United States; and 0.69 in Western Europe.

The minimum margin of error (see above) for the figures given is about 2%, or in absolute values ± 0.02. Therefore, the standards in the United States and Japan must be regarded as not significantly different. Within the minimum-error limits the indicator values are equal. But the result implies that an overall European technological gap may exist. Nevertheless, the leading nations are far from being in the lead in every field, because this would be indicated by a value of 1.00. Even the European countries end up with a value that lies clearly in the upper half of the interval [0,1]. This interval is defined by the national technological standards of all countries under investigation.

The technometric indicator value for Europe is derived from technological data of different countries. We see little point in comparing the European contributions according to countries, because the selection process in the JATES/AIST survey preferred West German products. For those product groups, however, in which the top European products are a priori assumed not to be of German origin (Swiss theodolites, British ships, Italian freezers, and so forth), a different European country was chosen [10]. The sample is therefore representative for West German technology (good and bad examples), but not for the other European countries (only their assumed top products have been selected).

Technological Disparities

Due to existing substantial disparities in many technological and economic fields, the European countries should not be treated a priori as a uniform technology community in such analyses. We therefore restrict ourselves in the following analyses to the subset of the JATES/AIST data being compared to West German technology.

The concept of our technometric model permits the aggregation of the given data according to the objectives, depending on the analyses required. Disaggregating the product data into groups of specifications is possible. For grouping criteria for the data, technical features, such as rational use of resources including energy, minimization of environmental impacts, application of computer-aided design technologies, automation, and labor productivity were chosen.

The grouping of the single technical specifications according to the above features is determined by the technologies and is therefore unambiguous. The result of this analysis is given in Table 3. Because the number of items included is limited, the precision is poor. Based on these figures, we can make the following recommendations:

TABLE 3
Technological Disparities for Special Technical Features in 1982. The Underlying Sample is the Same as for Figs. 2 and 3.

Technical feature (Retrieval Criterion)	Technometric Indicator Value USA	JAP	FRG	Lowest Margin of Error	No. of Product Groups	No. of Specification Items	No. of Data
Rational Use of Resources	0.65	0.83	0.71	7%	16	34	204
Energy Resources Therein	0.61	0.77	0.69	10%	11	15	90
Non-Energy Raw Materials Therein	0.68	0.89	0.73	10%	14	19	114
Minimization of environmental Impacts	0.68	0.89	0.62	8%	10	28	168
Noise Pollution Therein	0.54	1.00	0.42	15%	5	7	42
Effluents Therein	0.72	0.86	0.73	9%	9	21	126
Liquid Effluents Therein	0.78	1.00	0.90	15%	5	8	48
Gaseous Effluents Therein	0.69	0.77	0.55	11%	7	13	78
Design Technology	1.00	0.87	0.83	8%	12	28	168
Numerically Controlled Technologies Therein	1.00	0.91	0.82	11%	12	14	84
Computer-Aided Technologies Therein	1.00	0.82	0.83	11%	12	14	84
Precision Machinery Technology	0.72	0.87	0.70	12%	5	11	66
Computer-Aided Manufacturing Technologies	0.90	0.71	0.78	11%	5	13	78
Labor Productivity	0.53	0.89	0.26	13%	8	9	54

Japanese industry should improve the CAD and CAM technologies;

U.S. industry should consider environmental impacts of their production plants and resource intensities more carefully;

West German industry should likewise enforce the rational use of resources in industrial production and should not fall behind in reducing industrial environmental impacts.

Because the labor productivity is substantially influenced by sociocultural circumstances, purely technological deliberations are inadequate; therefore, no further comment is made here as to these figures.

Technometric Guess at the Future: Dynamic Positions

We attempted to demonstrate the applicability of our concept to forecasting purposes in the following example. In a publication [2] subsequent to the JATES/AIST survey, the products included in [1] are classified as being in the technological development stages of *growing* and *mature*. Some examples—e.g., communication satellites, assembly robots, and liquid chromatographs—are regarded as growing market products; coaxial cables, polyester filaments, special steels, and others are classified as mature products. If we now group all technical specifications belonging to the category of growing products as *newer* technologies and all the others as *older* ones and relate the overall indicator of the newer to the older technologies, then the resulting ratios (new/old) are (with a minimum margin of error of 3%) 0.76:0.87 = 0.87 for Japan; 0.90:0.69 = 1.29 for the United States; and 0.67:0.67 = 1.00 for West Germany.

This reveals a better "dynamic" position for the United States, which may be correlated with the fact that Japan still adopts foreign technologies to some extent. Therefore, Japan is in a relatively stronger position in the field of mature technologies as it is in the field of growing technologies. For West Germany, the technological gap between it and Japan is smaller for the new products than for the mature ones.

The findings above can be supported by a still further disaggregated analysis based on a categorization of the "key" and "standard" technologies. For this purpose, the single specifications have each been assigned to one of the above categories. The authors of the JATES/AIST survey asked their Delphi participants to indicate *key* items [10]. According to their definition, key technologies are those which play an "important role in the future development of technology and thus represent base technologies" [1]. So the technometric indicator for key technologies should point out future technological strengths.

The ratios of key technologies to standard technologies are 0.81:0.83 = 0.97 for Japan; 0.84:0.68 = 1.23 for the United States; and 0.71:0.58 = 1.22 for West Germany. These indicate strong technological potentials in the United States and in West Germany (the minimum margin of error is 3%). Because the key technologies are expected to dominate the technological strength of the countries in the future, the existing gaps based on standard technologies may be closed to a certain extent.

Conclusions and Outlook

Taking the Japanese data as basis for some model calculations, we have attempted to show that the technometric concept is quite useful for creating a variety of indicators. If one uses only one type of indicator, however, then this may greatly restrict the reliability of the analysis. Therefore, future work should focus on comparative studies on whether different types of indicators lead to similar or contradictory results. Such analyses should include econometric, bibliometric, and patent indicators.

For this purpose, a much narrower scope of technologies could be advantageous. The Japanese data used here covered the whole industrial production range according to a standard classification of branches, which may be too extensive to enable one to draw specific conclusions. Instead of picking out the semiconductor laser as an example of lasers, as was done by JATES/AIST, one could generate technometric indicators for different types of lasers; for example, ion lasers, helium-neon-lasers, carbon-dioxide lasers, metal vapor lasers, eximer lasers, dye lasers, laser diodes, and other solid-state lasers. Although this would prove to be a most time-consuming task, it could nevertheless open up important new perspectives, thanks to the detailed coverage of a sharply defined technological field.

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