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H. Schmied

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A STUDY OF ECONOMIC UTILITY RESULTING FROM CERN CONTRACTS

H. Schmied

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ABSTRACT

The study attempts to quantify the technical and economic benefit to the manufacturing industries involved in CERN contracts, in relation to the expenditures on CERN by its Member States. Interviews were carried out in some 130 European firms, who supplied data on estimates of increased sales and decreased costs due to CERN contracts. This "economic utility" totals 1,665 million Swiss francs (up to the year 1978), compared with a sales value to CERN of 394 MSF. Utility/sales ratios range from 0.9 to 7.3 for application fields of cables, magnets, cooling systems, vacuum equipment, electronics, and steels; they are as high as 17.3 for computers and 31.6 for precision mechanics. Some 80% of the total reported utility results from sales to markets outside high-energy and nuclear physics, for example, railways, shipbuilding, refrigeration, power generation and power distribution. For the 877 MSF spent by CERN in European industry from its over-all budget of 3,500 MSF during 1955 to 1973, the total utility is estimated to be nearly 5,000 MSF. The method and procedure of analysis and quantification are discussed in detail and some specific cases are presented as examples.

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SUMMARY

The high-energy physics research programme of CERN makes unusual technical demands on the designers and constructors of equipment. Since a large part of this equipment is built by industry, it is clear that CERN receives a steady flow of technological information and help from this source. The present study has shown that these "pushed" technical demands have also had a surprisingly high beneficial impact on contracting firms, spreading out through many aspects of the firms' activities, and that these effects can be quantitatively assessed by the firms themselves in terms of increased sales and saved cost figures. In this study, the sum of increased sales and saved costs is defined as the *economic utility* due to a CERN contract.

Organizations such as NASA have already drawn attention to the existence of the "spin-off" or "fall-out" from space expenditure, but have tended more to follow the impact of specific technologies throughout society rather than studying the production figures of contracting firms.

The method of the utility study has been to interview the management of firms which have carried out CERN contracts, and to collect from them figures, firstly, *on increased sales* (increased volume due to improved quality or a CERN reference, new products developed within the firm or with other firms in a liaison initiated by CERN, or a market expansion stimulated by a CERN activity) and, secondly, *on cost savings* (production savings by adopting new techniques suggested by CERN, research and development savings because of development work done in CERN, cost savings on capital investment because of the new techniques, and marketing and promotion savings by using CERN as a reference).

One hundred and thirty-four firms have been investigated and 127 of them provided data useful in the context of this study. These 127 firms have yielded a total utility of 1,665 MSF estimated by the firms up to the year 1978 only, since in most cases industry does not forecast beyond that date yet.

The total utility reported by a firm is compared with its total sales to CERN and the resulting utility/sales ratio gives a measure of the degree to which CERN has been useful to the firm and of the firm's performance in exploiting the utility potential generated by CERN.

The firms are grouped in eight categories, taking as a criterion the kind of material delivered to CERN. These categories and their average utility/sales ratios are:

	Utility/sales
Cryogenics and supraconductivity	1.7
Electronics	4.8
Electric I (magnets, power supplies, cooling equipment)	2.2
Electric II (cables, RF equipment, condensers, etc.)	
Computers	17.3
Precision mechanics (electromechanical devices)	31.6
Steel (magnet-steel and welding materials)	7.3
Vacuum equipment	3.2

Within these categories two groups of firms emerged, which have achieved much higher utility/sales ratios than the average:

i) Firms situated in Great Britain, Sweden, Denmark, and Norway, which have made their first shipments in the Common Market Area to CERN and have subsequently, using as a reference their sales to CERN, penetrated into this market.

ii) Firms which have made significant technological progress working on a CERN contract and have been able to sell the resulting products outside CERN.

Some 80% of the total reported utility results from sales to markets outside high-energy and nuclear physics, as, for example, railways, shipbuilding, refrigeration, power generation and distribution, car-body design, material storage, and many others.

During the period 1955 to 1973, CERN spent a total of 877 MSF in the categories considered in European industry, of which 394 MSF went to the 127 firms in question. Applying the ratios appropriate to each category, the total utility generated by the expenditure of 877 MSF can be estimated to be 4,860 MSF. This total is of the same order as the CERN budget of the period 1953 to 1973 for the whole CERN programme, i.e. 3,500 MSF.

CONTENTS

1. AIM OF THE STUDY

One of the main purposes of CERN, in common with similar laboratories in the world, is to make available experimental equipment for basic research. In the case of CERN, the research subject is elementary particle physics, and its equipment is made available to physicists engaged in this research in all the universities of the Member States of CERN.

About 95% of CERN's research equipment, much of it involving comparatively advanced technology, is built by industry. It is therefore clear that CERN is to a large extent dependent on the technological standards of its suppliers. Whereas this is not contested, it has often been asked whether the increasing demands made by CERN on industry do not in turn influence their performance. In other words, it is asked whether the financial investments which the Member States make in CERN not only support European universities and produce new results in the field of nuclear particle physics, but also indirectly bring a technical or economic benefit to the manufacturing industries involved in the CERN contracts and hence to the Member States.

CERN is not, of course, the only organization in which this idea has been discussed in recent years. Many other organizations[1,2], often with the aim of helping to justify their budgets, have made similar claims and some have attempted to support their claims by quantified studies[3]. In America, in particular, organizations such as NASA[4,5] have undertaken quite elaborate studies, and words have been invented, such as "fall-out" or "spin-off" to describe the effects.

Economists have also been very active in this field, seeking to understand the mechanisms involved, and there is considerable literature on qualitative effects. Unfortunately, none of these studies has yet produced convincing results, and some have discredited the whole idea in the eyes of the public and governments.

In these circumstances it might seem rather rash of CERN to take up this problem, and had it not been that a more objective and quantitative method was suggested, which seemed to offer a way of throwing some light on the subject, CERN would certainly not have become involved.

The method which was suggested essentially placed the onus of proof and quantification on the industrial beneficiary rather than on the organization, thus avoiding the obvious criticism, of the studies previously carried out by other organizations, that the results were invalidated by self interest since the organizations themselves estimated the benefits. Clearly, such criticism could not be levelled at disinterested economists who have also studied the matter. However, so many of these studies lacked quantification that no clear relationships emerged.

2. METHOD OF ANALYSIS

The method used is in the general class of economic utility studies, where economic utility is defined as the added value resulting from a production process. Thus the analysis sought to clarify the creation of added value in the economic performance of individual firms as a result of manufacturing contracts awarded by CERN. The value of the contracts themselves is not taken into account in the analysis, but only the subsequent performance of the firms concerned and subsequent financial benefits which can be directly related to carrying out such a contract. The novel feature of this study is that the firms concerned identify the nature of the benefits and estimate their financial value. The role of the investigator in this case is consequently reduced to providing the firms with a list of the kind of benefits which might result, collecting in a discussion with the management of the different firms the figures which they have estimated, and collating the results.

Generally speaking, the economic utilities in question fall into two groups. On the one hand, there are increases in added value for the firms, due for example, to increased sales, and, on the other hand, cost savings, both related to a CERN contract.

Increases in added value may derive from the following:

- Sales of new products developed and put into production as a result of a CERN contract.
- Increased sales since the quality of the product was improved to meet CERN specifications.
- Increased sales of existing products due to their use by CERN.
- Sales of new products developed and produced jointly with other firms where the collaboration was due to a CERN contract.
- Market expansion due to a CERN activity subsequently exploited by the firm to increase sales.

In this study, increases in sales are used as an approximation to increase in added value. An explanation and justification of this assumption is given in Appendix A, where it is shown that the resulting error should not exceed 20% in most cases.

Cost savings due to a CERN contract will include:

- Cost savings in production, either due to the intervention of CERN staff or to expanded markets.
- Cost savings on Research and Development (R & D) for the firm, due to work done or paid for by CERN.
- Cost savings on capital investment for manufacturing plants, where these costs are partially covered by CERN contracts.
- Cost savings in marketing and promotion, due to using CERN as a reference.

Estimates of increased sales and cost savings are made by the firms themselves after discussions between the management and the investigator. The estimates must be made on a year by year basis, since utilities arise in sequence following the award of a contract. The sequence begins when the secondary effects of a CERN contract become evident in the opinion of the firm. It ends when the relationship of these effects can no longer be ascribed to the CERN contract, or when the effects of other contracts or events become predominant. If the end of the sequence is not yet in sight it is necessary to make an arbitrary time cut-off, which in this study was set at the end of 1978. This year was chosen simply because most of the firms involved plan for 4 to 5 years in advance, but no longer.

It should be clear from this brief description of the method that the analysis is attempting to compare the actual situation in which the firm has received CERN contracts with a hypothetical situation in which it did not, and had performed and planned accordingly.

Sales which are made as secondary effects of a firm's contract with CERN are in many cases made to industrial customers who use these products to rationalize their own production or to improve their products. This means that firms which have no contact with CERN at all may gain utility indirectly from CERN activities and these gains have appeared to be quite substantial in the few cases investigated. However, the aim of this study was to quantify utility at the first level, i.e. in those European firms which carried out manufacturing contracts or delivered goods to CERN, and to some degree in their suppliers. Negative effects on competitors of CERN contractors were not investigated.

3. PROCEDURE OF ANALYSIS

One of the foreseeable difficulties in a study of economic utility is to obtain quantitative information from industry. To solve this problem it was felt that, amongst others, two conditions had to be fulfilled: precise and relevant questions had to be put to industrial managers and the interviewed persons had to be sufficiently senior to be able to assess all the consequences of a CERN contract.

To obtain the necessary detailed knowledge about CERN contracts with industry and about the firms involved, as the first step of the study, 110 interviews with CERN staff from the technical divisions were carried out.

Three hundred and forty-five cases, involving 260 firms, where CERN might have created utility, were discussed in these interviews. Additional information, such as names of persons who could be contacted, was collected. Further knowledge about the firms was sought from their reports to shareholders and in the short write-ups contained in the Industry-Kompass[6]. All this information was filed and served to prepare the interviews in industry.

The interview in the firm usually followed a fixed pattern. The historical events in the firm's collaboration with CERN were reviewed. Next the person interviewed was asked to describe all subsequent effects CERN contracts had caused, following the list given in the previous section. Whenever a model was necessary to quantify the effects, several models were proposed by the investigator until agreement could be reached on the model applicable.

From all interviewed firms, except one, where the responsible manager could not find the necessary time to study his files to elaborate the figures, the required quantitative information could be obtained. Some firms have put several man-days of effort into the elaboration of the figures.

4. FOUR EXAMPLES OF CASES AND THE MODELS USED TO QUANTIFY THE UTILITY

Under this heading, four cases out of the 198 investigated in interviews with industry are described. The selection of these four typical cases was made to give some idea of the variety and complexity of the mechanisms leading to economic utility and of the models used for quantification. No case concerning cost savings was chosen because, where cost savings are concerned, quantification is much more straightforward than in cases where sales were influenced by CERN.

4.1 A new product is launched earlier with CERN's help

Historical events

During the construction of the Intersecting Storage Rings (ISR), it was decided that it would be preferable to make the final precision adjustment and checking of the hundreds of 60-ton magnets in the assembly hall, rather than in the accelerator ring tunnel. Then, of course, the problem of transporting them without altering their adjustment had to be solved. Prospection of the transporter market revealed the existence of a prototype of a hydraulically driven truck which was not yet operational. CERN took the risk of ordering an improved version which, after initial difficulties, carried all the magnets, without damage to their adjustment, to the ISR. The special features of this vehicle are that it starts and stops without jolting and jerking, it keeps its platform horizontal even when climbing hills with slope up to 8%, and it can go sideways.

The owner of the producing firm stated that the CERN contract had advanced the marketing of the truck by at least 3 years, during which time he had been able to sell a considerable number, due to the following events.

After World War II, the shipbuilding industry was changing its production process from welding a ship together piece by piece on the dock to prefabrication of sections. These sections were then assembled to make up the ship; the size of the sections increased with time (they might weigh over 1,000 tons by now) and the handling became increasingly difficult.

The "CERN transporter" helped the shipbuilding industry to solve one crucial problem, which is lifting up the ship sections and carrying them to storage areas and docks. The transporter works on the basis of a hydraulic drive and it can raise itself by 80 cm. It can be driven under a section which has been constructed on pillars, raise itself to pick up the section and drive it to any place. Thus, investments on overhead cranes or other lifting gear in the welding shops can be saved.

The quantification of secondary effects, in this case on shipbuilding, was outside the frame of this study, and only two shipyards were interviewed. They confirmed that it was extremely unlikely that either one of them would have taken the risk of buying an untried prototype. Once a reference could be given and a model seen at work, many yards ordered this new device.

Quantification

To quantify this case a rather simple model was used:

Utility is equal to the sales of ship section transporters the firm made between its first sale to CERN and the moment when it would have tried to market the transporter on its own, i.e. three years later. This model gives a conservative assessment of the utility, since for several subsequent years actual sales are likely to be higher than those the firm would have made, had they started marketing the transporter only then.

4.2 Work carried out for CERN influences a firm's decision to diversify

Historical events

Since its beginning, CERN has delivered approximately 90 million bubble chamber photographs to European high-energy physics research institutes and universities, where they are analysed with the help of scanning tables. In several cases laboratories wanted to use the same scanning devices as those of CERN. Industry was therefore invited to tender for production and delivery of scanning tables which have been developed at CERN. Firms awarded the contract received all the blueprints and the experience CERN's staff had acquired in making the first models: nevertheless, such a contract represents for a firm a stiff challenge to its skills and know-how in electronics and precision mechanics.

The tables could then be sold to high-energy physics laboratories all over Europe, and possibly to the United States and the Soviet Union as well. This gave the opportunity to some firms to export into what were, for them, new countries. Once they found out the way of doing so, they continued exporting other goods to these countries. In addition, the firms were able to investigate other applications for this newly acquired knowledge. Examples of applications marketed are scanning tables to scan the salt contents of human bones *in vivo* with X rays, and computer-controlled drafting tables. Such drafting tables are used for road building, car-body designing, shipbuilding, etc.

Quantification

Whenever a firm decides to exploit the know-how acquired during a contract with CERN, and to market a new product, the possession of this know-how represents an argument in its decision-making process. Other arguments may be free production capacity, a corporate strategy to diversify, specific needs of customers detected by Marketing, etc. To find the CERN-produced utility, the role that the successful scanning table contract played in the decision to diversify must be assessed. This can also be expressed as the part of the resistance against entering a new business which was removed by the argument that experience had been gained during the CERN work. After a listing of the arguments, percentage figures can be put to their respective weigths. The figure arrived at for the CERN experience multiplied by the sequence of the sales figures of the new product during its life gives the CERN-produced utilities. In all cases investigated the firms were able to supply the necessary percentage figures and sales sequences.

4.3 CERN influences a firm's potential to produce high-quality goods

Historical events

In many cases where CERN ordered complicated, non-standard material, such as magnets, vacuum chambers, power supplies, etc., CERN imposed a very strict control on the firm, either directly by prescribing the methods or indirectly by the tough specifications defined in the contract. Quite often this meant that the firm had to learn a new way of controlling quality: Management learned a new way of dealing with complex project work in order to satisfy CERN's requirements, quality control staff acquired know-how, and shop floor workers were trained in new methods and techniques. As a consequence, after such a CERN contract, a firm is in a position to offer its customers higher quality even on standard products.

Quantification

All people having worked on a CERN contract and afterwards being employed in another job, are considered to be an interface transferring the CERN knowledge into standard production. The contribution of this interface to the firm's quality, and the influence of the firm's quality on its sales, have to be assessed to quantify the effects.

In detail, the following figures must be found to calculate CERN's impact on a firm's sales through induced improvement of quality:

A) The sequence of that fraction of the firm's annual turnovers which may be influenced by work done for CERN.

B) A percentage figure expressing the management's opinion about the part of the sales which is made as a consequence of the high quality the firm offers its customers. A possible way to get such an assessment is to list the company's non-monetary assets; for example, agressive sales force, competitive prices, brand image, good relations with governments for obtaining public contracts, leadership in technology, flexibility of management, quality of products, etc. Once this list has been established, the management can put percentage figures on every item to indicate its importance.

C) The next step is to rate the contribution the interface made to the company's potential to produce high-quality goods. The staff employed by the firm to achieve the quality are listed (for example, quality control staff, foremen, engineering staff, etc.). The numbers of staff having worked on CERN contracts are counted and expressed as a percentage of the total force.

D) Thereafter the supervisors of the interface staff are asked to express their views on the part of the training that staff received on CERN contracts. The particular values are averaged again giving a percentage figure referring to the total interface.

E) The relative size of the interface may vary over the years. It is then necessary to elaborate all the above-mentioned figures for a given reference year and then apply correction factors for all other years. A rough way to estimate these factors is to find the ratios of CERN sales to that part of the firm's turnover which is influenced by work done for CERN (A) and to normalize these ratios with respect to the value of the reference year.

The sequence of turnover figures (A) is multiplied by the fraction (B), indicating the part of the turnover which is made due to the quality of products, and by the fraction (C), standing for the size of the interface, and by the figure (D) showing the CERN share in improving the interface capabilities. Multiplying the resulting sequence by the corresponding correction factors (E) gives the annual sequence of utilities attributable to CERN's influence.

4.4 CERN blocks a firm's Research and Development capacity for a period

Historical events

Consumers of electric energy who change their load very rapidly, such as steel mills, cement mills, and electric railways, pose a constant problem to the power-generating boards.

CERN may be counted amongst these customers, since most of the accelerators are pulsed and would considerably disturb the supply network if they were directly connected. In order to avoid such disturbances, CERN has devoted a continuing effort, wherever possible in collaboration with industry, to develop power supplies to smooth out load peaks. Its first "smooth" power supply was used for the PS accelerator, but with the installation of new accelerators at CERN the specifications for their power supplies became more difficult to fulfil. Development and production of one of these more recent installations took the producing firm two years.

During these two years, the power-generating authorities started to press all their customers to reduce their load peaks. As a consequence, the electric industry began to develop new power supplies to fulfil these requests.

The firm working on the CERN contract had no free development capacity to follow these trends, since the available capacity was employed for CERN. The know-how acquired on the CERN work was too sophisticated and the resulting power supplies too expensive to be competitive. Therefore, the firm was about one year behind its competitors when setting out to study simpler solutions. This delay caused smaller sales, for about three years, compared with those the firm could have made had the CERN work not hindered them in following the open market requirements.

During this three-year period electric energy became even scarcer and the electricity-generating authorities wanted even better smoothing of the peak power consumption from their customers. At that moment the firm with the CERN "know-how" was in a position to overtake its competitors and sales rose to higher levels than those which would have been possible otherwise.

Quantification

This case contains a sequence of negative and positive utility values. The negative utility of the first three years under consideration consists of the difference between the actual low and the hypothetical higher sales figures the firm could have achieved had they been able to follow the market's requirements. In the fourth year, the actual sales became higher than the hypothetical ones, since the firm could capitalize on the CERN knowledge. From this year onwards, the utility has a positive sign.

5. RESULTS

One hundred and forty-five interviews with senior managers representing 134 firms were made between mid-1973 and mid-1975. A hundred and ninety-eight cases were discussed during these interviews and quantitative information could be obtained to calculate their utility (some firms have spent several man-days of effort to work out the figures). Firms were willing to give the required information even when they had made losses on CERN contracts.

In parenthesis, it seems that the influence of such losses on goodwill has sometimes been overestimated by CERN staff, since some of the firms have tried very hard to get more money from CERN. Once this attempt (in most cases unsuccessful) has been given up, the loss was written off, as is a normal procedure in industry. The "get-more-money" attempt, however, seemed to have impressed CERN people more than the loss did industry.

Only 127 out of the 134 firms interviewed provided data which could be included in the analysis. From the remaining 7 firms, two are in industrial branches which are not considered, four are not CERN suppliers but benefited from secondary effects, and one could not provide quantitative information. Eight firms have not gained any utility so far. The reasons given are:

- lack of production capacity to exploit the acquired know-how;
- marketing unsuited to use the CERN reference successfully;
- the goods delivered to CERN did not live up to expectations;
- the material delivered to CERN is standard and the CERN reference has no influence on other customers.

The total utility in the remaining 119 firms amounts to 1,665 MSF. Only opinions expressed by firms' representatives are taken into account for the calculation of the figure. Losses which firms made on CERN contracts have already been deducted in this sum.

All utilities before and including 1974 are taken at the currency values of the year in which they occurred. From 1975 onwards the calculations were made using 1974 prices.

From 1953 to 1973, CERN spent 394 MSF on total purchases in the 119 firms which reported this utility and the 8 firms which have gained no utility so far. This means that 1 SF spent by CERN in the investigated industry had on the average created positive financial consequences of 4.2 SF.

Figure 1 shows a plot of the sequence of the total yearly utilities for the years 1955 to 1978. The graph presents the contribution of the PS, ISR, BEBC, and SPS projects to the utility. The remaining (white) part represents the utility created by the remaining CERN projects, for instance, MSC, smaller bubble chambers, high-energy physics experiments, and CERN's activities in general (for description of the projects see Appendix D).

In previous discussions about possible economic secondary effects springing from high-energy physics research, the argument was repeatedly advanced that these effects might consist of new technologies and products which could only be used again by high-energy physics or nuclear research. Since it was felt to be important to clarify this point, firms were also asked to break down by markets the sales of the products which were affected by CERN activities.

Using this information the utilities were divided, and grouped into two categories: utilities made through sales to high-energy physics and nuclear research clients; and utilities made through sales to customers who are not involved in this research. Within these two categories the utilities were further broken down into:

- utilities stemming from sales made with innovations stimulated by CERN;
- utilities achieved through increased sales of products, due to their use by CERN, due to new collaboration between firms, and due to market expansion caused by CERN;
- cost savings.

Table 1 shows this breakdown of the utilities. As can be seen from the figures, about 82% of the utility is related to customers who are not involved in high-energy physics and nuclear research. Indeed, CERN has created utilities which influenced areas as remote

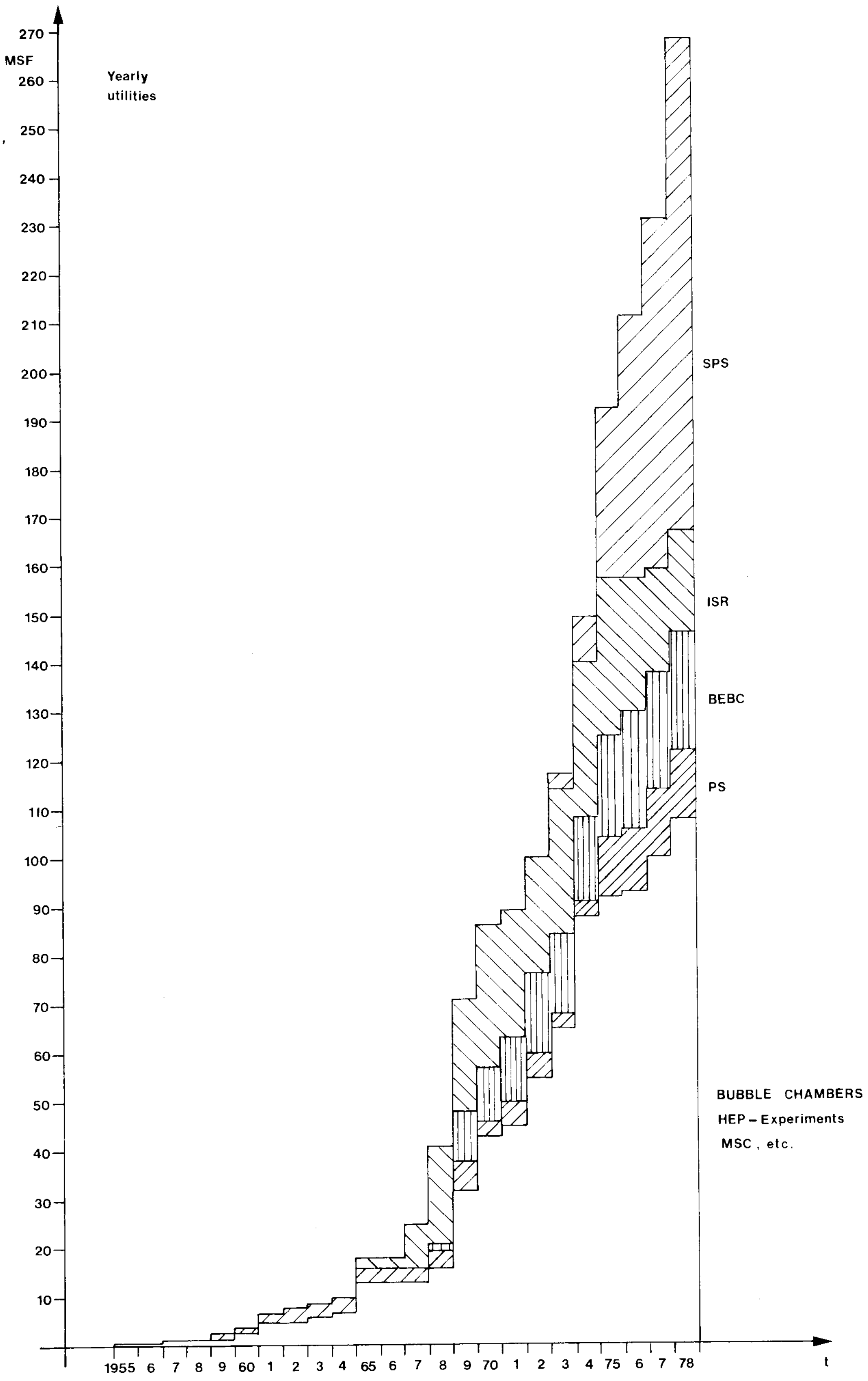


Fig. 1 The yearly utilities generated by CERN (investigated cases)

from its research as the technology of railways, refrigerators, shipbuilding, hydro-electric power generation, electric-power distribution, control of subways, material storage, car-body designing, oil prospection, television, and many others.

Table 1

Distribution of utilities by market

		MSF	%	%
Utilities related to high-energy and nuclear physics markets	Increased sales[a]	148.2	50.64	8.89
	Sales of innovations	143.3	48.95	8.59
	Savings	1.2	0.41	0.07
	Subtotal	292.7	100.00	17.55
Other markets	Increased sales[a]	614.4	44.78	36.89
	Sales of innovations	693.5	50.54	41.72
	Savings	64.3	4.68	3.85
	Subtotal	1 372.2	100.00	82.45
	Total	1 664.9		100.00

a) Due to use of CERN's name in the marketing effort, CERN initiating the collaboration of firms, and expanding markets.

The breakdown of the reported data by industrial category is as follows (see Table 2).

i) Computers: Whenever European companies can sell to CERN the impact on sales is considerable. CERN has further given technological help to European computer firms. Utility/Sales: 17.3.

ii) Cryogenics and Supraconductivity: The large-scale use of these technologies has not yet come. Utility/Sales: 1.7.

iii) Electronics: CERN has contributed to the advancement of European electronics technology and to the improvement of related components. Utility/Sales: 4.8.

iv) Electric I: Magnets, power supplies, cooling equipment: CERN relies in this field to a large extent on industry's know-how, in comparison with which improvements due to CERN contracts are lower than average. Utility/Sales: 2.2.

v) Electric II: RF equipment, cables, condensers: the remark made for Electric I is even more valid for this branch, where CERN purchases, for example cables, are mostly just standard products. Utility/Sales: 0.9.

vi) Precision mechanics: Scanning tables, particle separators, transport equipment and bubble-chamber components usually represent complex contracts creating considerable know-how and technological potential, which could be used in production of computer-controlled drafting tables, precision parts in nuclear reactors, high-power hydraulic equipment, etc. Utility/Sales: 31.6.

Table 2

Breakdown of data by industrial category (Figures in MSF)

	Computers	Cryogenics Supracond.	Electronics	Electric I	Electric II	Precision mechanic	Steel production	Vacuum	Totals
Net utility	302.8	69.0	343.0	275.3	61.6	277.0	231.1	105.2	1 665.0
Losses	0	1.7	0.3	8.0	6.4	5.0	0.2	0.2	21.8
Sales investigated	18.1	39.6	67.0	128.3	72.4	9.4	32.0	27.7	394.5
Utility/Sales	17.33	1.70	4.84	2.17	0.89	31.56	7.26	3.20	4.22
Total sales to CERN 1955-1973	65.8	71.4	272.2	192.1	128.9	36.1	63.0	47.7	877.2
Total T.O.	3 087	12 148	10 297	19 106	59 892	6 090	10 645	13 672	134 937
Utility/T.O.	0.0981	0.0057	0.0333	0.0144	0.0010	0.0454	0.0217	0.0077	0.0123
No. of firms interviewed	10	15	31	19	17	14	10	11	127
No. of firms without utility	0	1	2	3	1	1	0	0	8

EXPLANATION:

Net utility : Utility minus losses.
Losses : Losses the investigated firms made on CERN contracts.
Sales investigated: The totality of sales a firm made over the years to CERN.
Total sales : The sum of all purchases CERN made in a particular industrial branch.
Total T.O. : Sum of all total turnovers, all considered firms of a branch made during 1973.

vii) Steel production: Magnet steels and welding materials and techniques: low-carbon steels developed for magnets found a large-scale application in the production of small motors as used in washing machines and refrigerators. Utility/Sales: 7.3.

viii) Vacuum: Although CERN has undoubtedly pushed the ultra high vacuum technology and related components a good deal, the vacuum industry's customers are still reluctant to employ the resulting potential because sufficiently convincing arguments cannot be obtained from cost benefit considerations for replacing conventional vacuum by ultra high vacuum in production. Utility/sales: 3.2.

Within these eight categories two groups of firms are of particular interest:

i) The first group consists of those firms situated in Sweden, Norway, Denmark, and Great Britain, which have been helped by CERN to increase considerably their exports into non-traditional markets in other European countries. CERN tries to spread invitations for tenders as widely as possible: following such an invitation, these firms have made their first shipments into these areas, new for them. Having found out on this occasion that the difficulties of exporting into these regions were smaller than anticipated, and helped by the reference of their sales to CERN, they have subsequently established themselves in these markets. A few of them started by setting up a subsidiary or a sales outlet near CERN.

ii) The second group is made up of those firms which have made significant technological progress in order to fulfil CERN's requirements and have consequently been able to sell the resulting products to other customers.

Firms belonging to one or even both of these groups have achieved utility/sales ratios well above the average for their industrial category.

At the start of the survey CERN staff expressed the feeling that in general small and middle-sized firms showed more interest and worked more closely with CERN than their bigger competitors. Since, in most cases, a necessary condition for gaining high utility/sales ratios is a close collaboration with CERN, the dependence of those ratios on the firms' sizes would confirm this feeling. Indeed in the categories Cryogenics, Electronics, Electric I, Electric II, and Vacuum, utility/sales ratios do rise as the firms become smaller. For this fact, interviews in industry gave the following reasons: A significant proportion of the small firms were created by ex-CERN staff, or acquired, in their early stages, the technological basis necessary to stay successfully in business from a collaboration with CERN. In both cases, the close relationship between industry and CERN made it possible for the firm to benefit to a large extent from CERN's technological know-how and the help sales to CERN could provide in marketing.

In general, industry feels that small and middle-sized firms are under stronger competitive pressure than their bigger competitors, and may therefore have maintained more flexibility to exploit new technological potentials. Representatives of big firms think that they have larger R & D resources at their disposal and thus rely less on knowledge coming from outside the firm. To confirm this assumption, a further study and collection of data on each investigated firm's R & D strength would be necessary.

However, since 45% of the reported utility is made as a consequence of efficient marketing, it is doubtful whether the relatively greater R & D strength of bigger firms can totally explain their lower utility/sales ratios.

Exploitation of technological transfer is, amongst others, a problem of communication. The bigger the firm, the more difficult communication becomes and the more likely it is that knowledge gets lost before it can be employed for the profit of the company.

All these factors could explain the falling trend of utility/sales ratios with increasing size of the firm. However, in some fields considerable capital investments are necessary to exploit technological advances. This may explain the opposite trend among firms in the categories Steel, Computers and Precision mechanics, where the larger firms have gained comparatively more utility.

A statistical analysis of the data collected in industry and its results backing the above-mentioned relations may be found in Appendix B.

6. EXTRAPOLATION OF THE INTERVIEW FINDINGS TO THE TOTAL CERN CAPITAL EXPENDITURES IN THE INDUSTRIAL BRANCHES INVESTIGATED

In the years 1955 to 1973, CERN spent 877 MSF in purchases in the industrial categories investigated in the study, of which 394 MSF went to the 127 firms considered so far. Multiplying the total expenditures of all categories with the appropriate utility/sales ratios and adding them up, one arrives at the following estimate of the total CERN-generated utility: 4,860 MSF.

The analysis of Appendix B shows that there is a dependence of the utility/sales ratios on the firms' size. One underlying assumption when making the extrapolation is, therefore, that the firms not interviewed have the same size distribution as those covered by the study.

The total utilities divided by the amount of total sales (877 MSF) give a utility/sales ratio of 5.5, as opposed to the ratio 4.2 found from the corresponding values in the cases investigated (see Table 2). This apparent discrepancy stems from the fact that a relatively higher proportion of the sales was investigated in industrial categories with lower utility/sales ratios: 67% of the sales in the Electric I category with a utility/sales ratio of 2.2 as opposed to 26% in the Precision mechanics category (utility/sales 31.6).

The extrapolation has, however, to be analysed for possible subjective or objective biases before it can be trusted:

a) Biases introduced since only one person has carried out the interviews

Twenty-eight firms could not provide the figures during the interview. They elaborated them later and transmitted them in a letter or telex. In these cases a written document exists, prepared without the help of the investigator. Interviews were reported in a written form and discussed in detail with senior CERN staff. Further control was exercised by working groups from Danish and Austrian Universities (see Appendix C). They interviewed a few firms again and arrived at the same results.

b) Selection of firms

Since its creation all goods that CERN has bought in Europe in the domains investigated were supplied by approximately 340 industrial firms. To obtain preliminary information about these firms, 110 interviews with CERN staff members, chosen more or less uniformly from the technical divisions, were carried out; 260 firms were mentioned in the interviews and entered in a file. In the beginning of the study, during the first fifteen or so interviews in industry, the aim was to show whether or not CERN had actually created quantifiable utility. Therefore 15 firms were chosen using as a criterion the belief, at CERN, that these companies had gained utility. The interviews indeed showed that CERN had produced quantifiable secondary effects, but it also became clear that criteria concerning their volume as, for example, great effort invested by CERN into the advancement of a particular technology, were in themselves no measure for the actually generated utility.

On the contrary, a few cases where the firms were believed to have made nothing but large losses turned out to be very rich in utility. Indeed the mechanisms necessary for utility creation were mostly unknown at CERN. For this reason, it may be assumed that the 260 firms represent a fairly random sample of the total number of relevant CERN suppliers.

This sample was analysed to show what percentages of total annual purchases were covered by the companies contained in the file. The analysis revealed that the sample contains relatively more information about recent years than for the period from 1952 to 1966, with the exception of the PS construction period (1953/59). This seems to indicate a memory effect: information which is not directly linked with "big events", such as memorable projects, has a tendency to get lost, for two reasons: people involved in the work have left the organization and those who remained have forgotten the details of less remarkable events.

In the selection of firms to be interviewed, the following criteria were applied:
- at least two firms from each of the Member States (except Greece),
- a preference was given to those firms which have worked with CERN over at least the past three years.

It proved to be difficult for companies to make quantitative assessments about effects which have just started to show, or lie entirely in the future.

Outside these two criteria the selection of the 134 firms out of the 260 contained in the firms file was fairly random by country, sales to CERN, and category.

Obviously the combined effects of the "memory gap" (less information for the years 1952-1966) and the "older than three years" criterion have as a consequence that the sample of interviewed firms does not represent a constant percentage of CERN's yearly expenditures. A plot of annual CERN purchases made in the industrial branches investigated, the part of these purchases which was made with the investigated firms, and the percentages that these "investigated purchases" represent with respect to the total purchases are shown in Fig. 2. Utility/sales ratios for firms having worked with CERN twenty years ago are the same as those stemming from more recent collaborations. Thus, apparently, no bias was introduced with this way of selecting the firms.

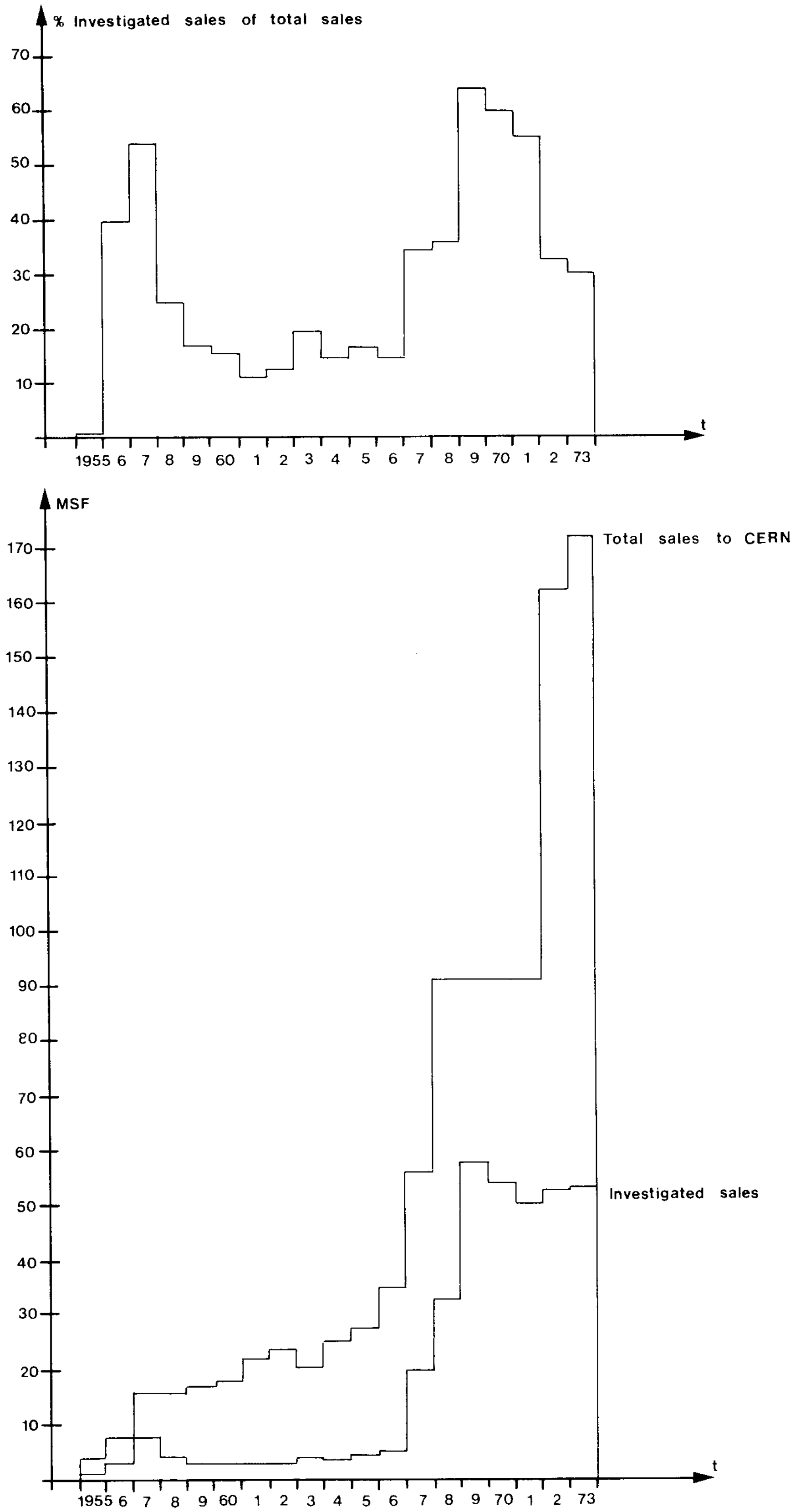


Fig. 2 Investigated and total sales to CERN in the categories investigated

To summarize the question of selection bias, the lack of relevant information at CERN made it impossible to enter into the file and later to interview only those firms which gained greater than average utility. The two selection criteria applied and the "memory gap" also do not seem to have introduced a bias. Tests applied on the firms not investigated, like sales to CERN, case distribution by category and country distribution show that the selected firms are a random sample.

c) The possibility that industry exaggerates the utility

The results obtained from the interviews with managers in industry seem to represent a lower estimate for the utility, for the following reasons:

- All firms know CERN's strict financial and purchasing rules, which prescribe competitive tendering, with the tender lowest in price and offering the required quality being accepted. Therefore it is well understood that mere friendliness, i.e. giving exaggerated utility figures, will not help to get more contracts in the future. Owing to problems which can occur between the parties to a business contract, a few firms were in conflict with CERN at the time of the interview but were still prepared to admit utilities they had gained.
- Several firms agreed, in principle, that additional utilities were created, but no way could yet be found to quantify them.
- Some industrial managers had difficulties in admitting that their firm could have learned something from somebody else.
- In a few cases the figures provided were obviously too low compared with information given to other CERN staff, or evidence from publications, etc., since the firm feared that admitted utilities would be used by CERN to negotiate lower prices on the occasion of the next contract.

7. REASONS FOR CERN'S PERFORMANCE IN CREATING UTILITIES IN INDUSTRY

7.1 CERN's role in the innovation process

To classify the ways CERN interacts with industry, it is useful to recall the meaning of the term "innovation". The definition suggested by the British Central Advisory Council on Science and Technology[7], suits this purpose: "The *technical*, *industrial* and *commercial* steps which lead to the marketing of new manufactured products and commercial use of new technical processes and equipment."

Further criteria applicable to the analysis of CERN's influence on innovation are presented in the "Report on Project Sappho on Success and Failure in Industrial Innovation" [8]. This report summarizes, in five statements, the research findings as to the conditions for success in the innovation process:

"1) successful innovators were seen to have a much better understanding of user needs;
2) successful innovators pay much more attention to marketing;
3) successful innovators perform their development work more efficiently than failures but not necessarily more quickly;

4) successful innovators make more efficient use of outside technology and scientific advice;
5) the responsible individuals in the successful attempts are usually more senior and have greater authority than their counterparts who fail."

The last of these statements is not relevant, since CERN can hardly influence the degree of seniority of managers employed by industry for given purposes. The results of the interviews show that CERN has certainly helped innovative firms in all the other four ways.

Since CERN's mission consists of high-energy physics research, there is a constant demand for new, complex, and sophisticated, research equipment to carry this research forward. CERN has built up a pool of staff to satisfy this steady demand, which makes it necessary to exploit and, whenever feasible, push forward the frontier of present technology. These staff try to accomplish the physicists' wishes, whenever possible in collaboration with other laboratories and industry. The result is a high rate of innovation. The resulting know-how is in principle available to industry, at least for the part which was elaborated by CERN. Hence new technologies are freely available to industry and industrial effort can be saved.

In order to collaborate successfully with industry, CERN learned long ago that precise definition of the requirements is indispensable. Specifications written by CERN are usually very detailed and appreciated by contractors. CERN in this way helps industry to fulfil criterion 1 (better understanding of user needs) in the Sappho report. Some firms have actually adopted CERN's way of writing specifications when subcontracting or ordering.

Besides the above-mentioned attempts to meet high-energy physicists' wishes concerning experimental equipment, CERN staff have been building complicated particle accelerators which have to run with high utilization for several decades. Industrial suppliers have found, as a consequence, that CERN is an excellent test field for products, which are either tested before being installed, or for which the working duty over many years in the machines corresponds to an extensive test period. Results of tests and working performance even over a long time are communicated to the supplier interested. Often CERN participates in improving components which have failed. In this way it helps industry to perform its development work more efficiently (criterion 3) with respect to the technical problems involved.

When CERN orders considerable quantities of products containing a fair amount of innovation (magnets, power supplies, vacuum pumps, etc.) it is not only paying for delivery of goods and the contained technological know-how, but also financing large-scale production facilities, thus laying the basis for further exploitation of the innovation involved. When problems occur during production, which the firm is unable to solve, CERN gives technological help, advising or even delegating specialized manpower. So the fulfilment of the 4th criterion (efficient use of outside technology) is sometimes even imposed on a firm.

The second criterion of the Sappho report states that "successful innovators pay much more attention to marketing". Under most circumstances supplying CERN gives the firm an excellent reference, in particular where overseas competition is concerned. In agreement with the findings of the Sappho report, companies having a weak marketing department, and not fully exploiting the potential provided by the CERN reference, were found to gain smaller utilities than other firms in comparable situations.

One of the troubling aspects of innovation for firms is the possibility of failure. Not being forced to show commercial results, CERN is prepared to take higher risks when trying out new ideas than other customers. Therefore CERN may take a substantial share of the technological risks of an innovation, having considerable "trouble shooting" reserves when problems occur. As a consequence, industry's risks are lowered. Another facet of this risk aspect is that CERN certainly takes no competitive advantages from difficulties a supplier may encounter. CERN merely wants high-quality products in time, for the previously fixed price and, rather than making trouble if problems arise, there are usually CERN staff members giving help at all levels to obtain these results.

Table 3 summarizes this analysis in a matrix showing CERN's contribution to the three steps of innovation and the criteria taken from the Sappho report.

Table 3

Ways in which CERN helps industry

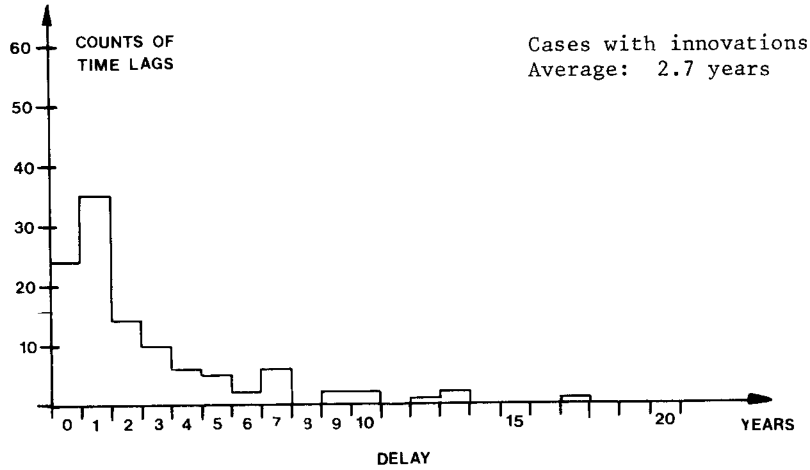
CERN's contribution / Steps in innovation	Cost-free available know-how	Lower risk	CERN financing large-scale production	Marketing reference	CERN as test field for products	Improved planning and control	Help with manpower to solve problems	Good definition of needs
Technical	X	X			X	X		X
Industrial	X	X	X		X	X	X	
Commercial				X				
Criteria from Sappho report				2	3	3	4	1

Another indication of CERN's positive role in the industrial innovation process is the relatively short time period, on the average, between a firm's work for CERN and the start of the secondary effects. Figure 3 shows a plot of the frequency of these time lags. The average time lag is 2.2 years and the delay reported with the highest frequency is one year!

However, average time lags of utilities resulting from big CERN projects have become shorter during CERN's existence: whereas utilities related to the PS project (1953-1959) occurred with a delay of 5.0 years after the CERN work, utilities springing from the BEBC and ISR programmes (1965-1971) took only 2.5 years to come to life.

7.2 CERN helps to close the "technological gap"

The technological gap between Europe and the US contains, amongst others, two things: an imaginary part made up of a belief in European technological inferiority, and the current standard of European management, which has not yet reached the best US level in many firms. In both cases CERN has, within the limited possibilities of its budget, contributed to improving the situation.



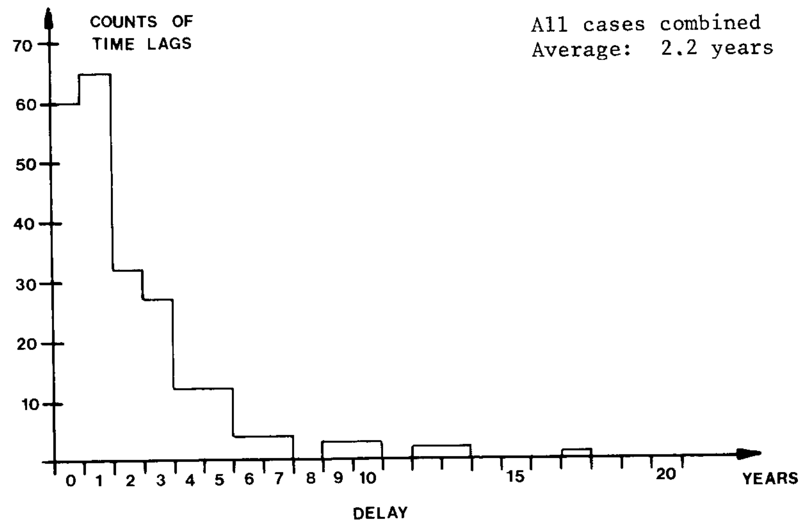


Fig. 3 Frequency of time lags between CERN action and beginning of secondary effects

CERN's freedom to give contracts to the Member and non-Member States without being compelled to observe a quota system, means that CERN purchases are based on an objective comparison of price/quality ratios of European and overseas products. If a European producer comes out first in such a comparison he has an excellent tool to remove the market's prejudice about European products. Quite a few firms have used this opportunity successfully and they have stated that CERN would lose much of its attractiveness if it changed its present purchasing policy to an observation of contract quota with the Member States.

In some cases CERN has gone further and contributed to the launching of products which need not fear US competition. An example of this is the CAMAC electronics standard, initiated by European nuclear research and high-energy physics laboratories and now sold by European firms in overseas markets.

As to the improvement of management in Europe, CERN has contributed by stimulating improvements of some of its suppliers in:

- cost calculation;
- cost and project control;
- quality standards and quality control.

At the time CERN was created, some firms had very rudimentary methods of calculating the costs of technological products: the costs of the raw materials used were multiplied with experience factors (representing necessary manpower and overheads) giving the total price.

Having lost money on a fixed-price contract with CERN, more than one firm has very rapidly changed its cost calculation and cost control procedures. CERN has forced firms to improve their project control in order to deliver on time. Some companies have introduced PERT on CERN's request.

As to the improvement of quality control, companies were either obliged indirectly by the requirements of a contract to improve their methods, or they took over devices, prescriptions, or procedures, developed by CERN.

8. CONCLUSIONS

Since its creation in 1952 and to the end of 1973, CERN received 3,500 MSF from its Member Countries. Out of this, 877 MSF were spent by CERN in those European firms which are considered in this study. These expenditures created an estimated total utility of 4,860 MSF which will be accumulated by the end of 1978.

It is tempting to compare the "input" 3,500 MSF with the "output" 4,860 MSF and to consider the utility as a return on the 3,500 MSF invested into CERN. This is not permissible since the following condition is not fulfilled:

For a return on investment calculation, the total return must be known. This unfortunately, is not the case, since the result presented quantifies only utilities created in firms which have been in contact with CERN, and in some of their suppliers. Other customers of these CERN contractors have also gained utilities which are not included in the figures when, for instance, they could use the marketed innovations to increase their production efficiency or to improve their products. Customers who buy goods which the selling firm claims are accepted by CERN also save money: they benefit because CERN has found out by sometimes costly tests, and by comparing more suppliers' goods than most other customers can, that a particular product's price/quality ratio is superior to that of its competitors.

Finally, there may be negative effects, which would also have to be considered if the total return was to be calculated: competitors of CERN contractors may have suffered losses in the short run.

However, it may be safely assumed, as a few investigated cases suggest, that the quantitative balance of the effects mentioned above shows a positive sum, but without studying all the effects in some detail, no estimate of its size can be made.

The estimated utility resulting from this study represents, therefore, sales which some European firms would not have made and cost savings they would not have achieved, had they not dealt with CERN.

The study would have to be extended if it were desired to estimate the positive and negative secondary effects mentioned above, and also, by comparing CERN with other types of investment in science, to see whether similar results could be obtained in other ways.

Acknowledgements

This study would not have been possible without the enthusiastic collaboration of industry, and I must therefore gratefully acknowledge the invaluable help I received from all those members of the 134 firms whom I consulted.

I wish to express my gratitude to Professor W. Jentschke, Director-General of Laboratory I, who gave the authorization and the necessary encouragement for the study to be carried out. My thanks are also due to Dr. J.B. Adams, Director-General of Laboratory II, for his invaluable help and encouragement.

In the course of the work, I had many constructive discussions with Dr. M.G.N. Hine and Mr. C.S. Taylor, who gave me considerable help with many aspects of the Report.

Dr. Tumlir, Director of the Trade Intelligence Division of GATT, took great interest and provided me with much useful advice and material.

This kind of work would become very difficult without the help of a computer, and I am most grateful to Miss S. Kurjo, who was responsible for the computer file program.

I would also like to thank all those CERN staff members who gave me the necessary technological information and contributed so many suggestions.

Last but not least, my grateful thanks go to Dr. C.J. Zilverschoon for his directives, his advice, and his help, at all stages of this study.

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APPENDIX A

JUSTIFICATION FOR SUBSTITUTING SALES FOR ADDED VALUE IN THIS STUDY AND AN ESTIMATE OF THE RESULTING POSSIBLE ERROR

The value of sales of a particular firm consists by definition of the sum of the value added by the firm and the cost of purchased raw materials, semi-finished products and services. The value added by the firms operating in the industrial branches investigated in this study amounts on an average to 57.5% of sales. [This figure was compiled using the relevant British[9] and German[10] statistics]. This does not, however, mean that the quoted sales figures exaggerate the total utility due to CERN contracts by approximately a factor of two, because the remaining 42.5%, covering purchased raw materials, semi-finished products and services, contains in its turn the values added by the suppliers to their purchases of raw materials.

Ninety-six percent of the reported total utility consists of sales industry could make as a secondary effect of contracts carried out for CERN. To the extent that suppliers of these industries increased their sales of semi-finished products, raw materials and services, and hence also their added value, the substitution of sales for added value does not introduce an error into the calculations of total utility. This is, however, an assumption, and the utility data represented by sales have to be analysed in more detail to estimate an upper limit to the resulting error.

	Utility from sales by CERN contractors				
	With innovations due to CERN 46%		Due to use of CERN in marketing 44%		Market expansion caused by CERN 10%
	Replacing existing products		Bought otherwise in		
	yes 30%	no 70%	Europe 25%	Overseas 75%	
% of total sales	6 A	13.5 B	5 C	14 D	4 E

Whenever the utility created by CERN contributed to the growth of an industry without affecting sales of existing products and/or to stimulating purchases in Europe which otherwise would have been made elsewhere, it can be assumed that the suppliers of these industries also increased their added values. This assumption is valid for the following classes of purchases in the above table:

B) innovations which do not replace existing products,

D) products purchased overseas had not CERN helped European firms to market their material,

E) sales made in markets expanded as a result of CERN's activities.

Assuming that in the remaining two cases:

A) innovations which substitute for existing products, and

C) the use of CERN in the marketing which incited customers to buy from one European supplier rather than from another,

the suppliers to the CERN contractors were merely changing the address of their deliveries, the error introduced when substituting sales for added values is 11.0% (A + C).

To this figure the part of raw materials and semi-finished products imported into Europe from overseas has to be added. A detailed investigation carried out by the Viennese study group (see Appendix C) suggests that this part is on an average less than 10% of total sales made as utility. Hence the total error, when taking sales instead of added values has an upper limit of 21%. This error is well within the error margin contained in the information from industry and in particular it is felt that this error is, at least to some extent, offset by utilities which were not reported by industry because the relevant information has in the meantime been lost, and by utilities which were in principle admitted but for which no way could be found to quantify them.

APPENDIX B

STATISTICAL ANALYSIS OF THE REPORTED DATA

In order to gain more insight into the mechanisms of utility generation and to back qualitative impressions gained from interviews, the data received from industry were analysed in a multiregression computer program.

It was aimed to establish the possible dependence of the utility on the firm's:

- total sales to CERN;
- total turnover in 1973 as a measure of its size;
- industrial category;
- export policy; and on
- the significance of the technological advance which led to the utility.

The following formula represents an optimum solution to this problem, and it is possible to explain with it 95.2% on the variations of the data:

$$Ut = \text{sales}\left[a \times MKT + b \times TECH + f(TO_{73})_i\right] ,$$

where

Ut = total utility of a firm;

Sales = total sales the firm has made to CERN;

MKT = 1, if the firm is situated in Great Britain, Norway, Sweden or Denmark and has established itself in new European markets due to its contacts with CERN, otherwise = 0;

TECH = 1, if the firm could sell the significant technological progress made during CERN work to other customers, otherwise = 0;

TO_{73} = total turnover made by the firm in 1973, as measure for its size (i designates the industrial category).

Results produced by the multiregression programme: a and b are two constants independent of the industrial category. Their values are:

$$a = 15.19 \pm 1.07$$
$$b = 15.85 \pm 0.69 .$$

Table B1 reproduces the values (and their errors) for the category factor $f(TO_{73})_i$ for all categories and for a range of turnovers. The lower half of this table represents the category factors $f(TO_{73})_i$ calculated for the average firm size within a particular category.

Two examples may help to show how the utility of an average firm can be estimated:

i) An electronics firm with a 1973 turnover of 10 MSF, which has sold material for 2 MSF to CERN, may have gained approximately 3.5 times this value in utilities.

ii) For a northern electronics firm, with a 1973 turnover of 1,000 MSF, which has entered the Common Market Area with a significant technological progress due to CERN, the firm's sales to CERN have to be multiplied by the sum of three factors: 3.3 (Electronics category) + 15.2 (Marketing) + 15.9 (Technology) = 34.4 to obtain its utility.

Table B1

Category factors calculated by the multiregression program

T.O. 1973 MFS \ Category		Cryogenics Supracond.	Electronics	Electric I	Electric II	Computers	Precision mechanics	Steel welding	Vacuum
	1	1.72 ± 0.19	3.56 ± 0.16	2.99 ± 0.16	2.11 ± 0.19	3.76 ± 0.41	6.21 ± 0.49	2.39 ± 0.27	3.47 ± 0.41
	10	1.56 ± 0.20	3.46 ± 0.19	2.62 ± 0.18	1.65 ± 0.17	4.86 ± 0.89	9.18 ± 0.89	2.54 ± 0.35	3.35 ± 0.48
	100	1.42 ± 0.20	3.27 ± 0.22	2.30 ± 0.19	1.29 ± 0.15	6.29 ± 1.02	13.56 ± 1.56	2.71 ± 0.44	3.23 ± 0.54
	1 000	1.29 ± 0.21	3.28 ± 0.25	2.01 ± 0.19	1.01 ± 0.13	8.13 ± 1.53	20.04 ± 2.67	2.87 ± 0.53	3.13 ± 0.60
	10 000	1.17 ± 0.21	3.19 ± 0.28	1.76 ± 0.19	0.79 ± 0.11	10.50 ± 2.26	29.62 ± 4.48	3.06 ± 0.64	3.03 ± 0.65
Average T.O. for each category	800	1.30 ± 0.21							
	350		3.32 ± 0.24						
	1 000			2.01 ± 0.19					
	3 500				0.88 ± 0.12				
	300					7.13 ± 1.25			
	450						17.40 ± 2.21		
	1 050							2.88 ± 0.54	
	1 250								3.12 ± 0.60

Figures significantly higher than this utility/sales ratio of 34.4 have in fact been reported by firms during the study.

Assuming that the investigated firms represent an unbiased sample of the total family of CERN's suppliers in the industrial categories considered, the factors mentioned above can also be used to make an estimate of the total utility generated by CERN (a discussion of biases possibly introduced may be found in Section 6 of this report):

$$\text{Total utility} = 1665 + \sum_{i=1}^{8} (\bar{c}_i \times R_i) + (a \times S_a + b \times S_b) \times 1.23 \ ,$$

$$= 4270 \pm 760 \text{ MSF} \ ,$$

where

$\bar{c}_i$ = category factor normalized for average firm size;

R_i = uninvestigated CERN expenditures in each industrial category (total 483 MSF);

a = factor marketing = 15.19;

b = factor technology = 15.85;

S_a = sum of investigated sales made by all the firms in the group MKT;

S_b = sum of investigated sales made by all the firms in the group TECH;

1.23 = (877/394 - 1)

877 MSF = total CERN expenditure in investigated categories;

394 MSF = total of investigated sales.

The term $(a \times S_a + b \times S_b) \times 1.23$ expresses the assumption that firms not investigated have made technological progress or established themselves in new markets with CERN's help in the same proportion as those covered by the study.

This estimate of the total industrial utility generated by CERN is consistent with that reported in Section 7 of this report.

APPENDIX C

NAMES AND ADDRESSES OF NATIONAL UNIVERSITY INSTITUTES WHICH HAVE JOINED THE STUDY TO INVESTIGATE NATIONAL ASPECTS IN MORE DETAIL

Institute of Management, University of Aarhus,
Universitetsparken,
8000 Aarhus,
Denmark

Professor Madsen
Dr. Bruun

Institut für Betriebswirtschaftslehre
Hochschule für Welthandel,
Franz-Klein-Gasse 7,
1190 Vienna,
Austria

Dr. Kemmetmüller

APPENDIX D

BIG CERN PROJECTS MENTIONED IN THE REPORT

PS	Proton Synchrotron Proton Accelerator for energies up to 28 GeV Construction period: 1953-1959 Cost: 120 MSF (current prices of that period)
MSC	Synchro-cyclotron Proton Accelerator for energies up to 600 MeV Construction period: 1955-1957 Cost: 24 MSF (current prices of that period)
BEBC	Big European Bubble Chamber Construction period: 1966-1971 Cost: 96 MSF (current prices of that period)
ISR	Intersection Storage Rings For observation of proton-proton collisions between two proton beams accelerated up to 30 GeV. Construction period: 1965-1971 Cost: 327 MSF (1965 prices)
SPS	Super Proton Synchrotron Proton Accelerator for energies up to 400 GeV Construction period: 1971-1979 Cost estimate: 1,150 MSF (1970 prices)