ECONOMIC UTILITY
RESULTING FROM CERN CONTRACTS
(SECOND STUDY)

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ABSTRACT

The study attempts to quantify the economic benefit to high technology manufacturing industries involved in CERN contracts, in relation to their sales to CERN. It covers the period 1973-87 and complements an earlier study made in 1973-75 (see CERN Report 75-5). Interviews were carried out in 160 European firms, who supplied estimates of increased sales and cost savings due to CERN contracts. This "economic utility" totals 3107 million Swiss francs (up to the year 1987), compared to sales to CERN amounting to 748 million Swiss francs in 1982 prices. It is estimated that, by 1987, CERN's high technology purchases made in 1973-82 will have generated Economic Utility amounting to about 60% of the overall cost of the Organization during the same period. In 1982, about 75% of the increased turnover due to CERN resulted from sales to markets outside high energy particle physics, for example, railways, shipbuilding, refrigeration, power generation and distribution, and health care. The quantification model used is discussed in detail and some specific cases are presented as examples. The industrial managers interviewed during both studies have confirmed that the forecasts made ten years ago were, on average, accurate.
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SUMMARY

This report describes the methods and the main results of a study which aimed at the quantification of Secondary Economic Utility, defined as the sum of increased turnover and cost savings, generated in European high technology industry due to orders placed by CERN during the period 1973-82. The study was similar to one made ten years ago, covering the period 1955-78 (see Ref.[4]). However, based on the experience gained during the first study, a general quantification model and improved sampling and extrapolation methods were used this time.

Managers in 160 firms out of a total of 519 high technology suppliers to CERN were interviewed. They estimated their Economic Utility using the general quantification model presented to them during the interview. As in the first study they were asked to give, if possible, five-year utility forecasts; and it emerged during the study that when managers feel able to make forecasts, these are, on average, reasonably accurate.

If the utility obtained for the firms interviewed is extrapolated to the total of 519 high technology suppliers to CERN, the resulting total utility for the period 1973-87 expressed in 1982 prices amounts to 4800 million Swiss francs (where the values for 1983-87 are based on forecasts). The extrapolation error is about ±600 million Swiss francs. During the period 1973-82 CERN’s purchases from the 519 firms amounted to 1380 million Swiss francs.

It is estimated that about 15% of the Economic Utility generated since 1973 has come from purchases made prior to 1973. Correcting for this reduces the total Economic Utility to 4080 million Swiss francs for purchases made since 1973. The corrected utility/sales ratio is 3.0; which means that one Swiss franc spent by CERN in high technology generated three Swiss francs of Economic Utility. The overall cost of the Organization during 1973-82 was 6945 million Swiss francs, which gives a value of about 0.6 for the ratio of the corrected utility to total CERN cost. It may therefore be stated that, by 1987, CERN’s high technology purchases made in 1973-82 will have generated Economic Utility amounting to about 60% of the overall cost of CERN during the same period.

A comparison of results obtained in the first study with those of this study indicates that CERN’s “utility creating power” is essentially the same as ten years ago, and it also appears that the high technology branches supplying CERN are suffering less from the present economic difficulties than other sectors of industry.
CHAPTER I

BACKGROUND TO THE STUDY

About 30 years ago, a number of European countries collaborated to establish CERN in order that Europe could regain its place in the forefront of particle physics research. CERN has since built a range of sophisticated accelerators and research equipment to fulfil its mandate. Considerable resources have been necessary to accomplish this, and CERN has in consequence found itself assuming a technological and economic role in Europe in addition to the important scientific results it has achieved.

Economic and cultural effects of fundamental sciences, and the processes by which they create direct and indirect benefits to the society, have been reviewed from time to time, Refs.[1] and [2], for example. The primary function of CERN is to carry out "very basic research" in particle physics, and the direct product this research work is increased scientific knowledge or "culture", which may in the long term give rise to innovation. An additional direct effect concerns CERN's educational role in the training of physicists and engineers. The quantification of the economic value of these direct effects would be extremely difficult, if not impossible. However, CERN buys large quantities of high technology equipment and the firms fulfilling these orders often observe short-term (several years) economic advantages as a result of collaboration with CERN.

A first study, made in 1973-1975, attempted to quantify these secondary economic effects generated by CERN. In this study about 130 firms which had contracts with CERN were interviewed and asked to quantify such effects. The study verified that CERN, with its purchases of high technology equipment, often causes positive changes in the turnover and the production techniques of its suppliers, and that managers are prepared to elaborate and communicate quantitative information related to these effects. Details of this first study are published in Refs.[3] and [4]. Similar results were obtained during studies which quantified secondary economic effects created by the European Space Agency, Refs.[5] and [6].

Since the time when the first study on the quantification of secondary economic effects resulting from CERN contracts was made, the methodology of quantifying the economic effects has been refined, Europe's economic situation and its technology have undergone significant changes, and CERN itself and its relationships with industry have changed. CERN now spreads its orders over a greater number of firms than it did in the past, the number of other European and national organizations buying high technology equipment has increased; and European industry has been able to close some of the technological gaps which existed 15-20 years ago between Europe and the United States. A study of the resulting change in the nature of the economic effects is clearly of interest. In addition, the first study took place at a time when the effects being measured had arisen mainly during the construction period of the Intersecting Storage Rings (ISR). The effects arising during the construction period of the Super Proton-Synchrotron (SPS) were, however, only partly covered
by forecast values given by industrial managers. For all these reasons, it was decided to make a second study.

This paper reports results of the second study, carried out between 1982 and 1984. Improved methods for the quantification of secondary economic effects, as compared with those used in the first study, have been applied; in particular, a general quantification model has been developed to achieve the quantification of these effects in a more systematic and rigorous way. In addition, greater efforts have been made to define the total family of suppliers of high technology equipment to CERN, and to obtain a representative sample of these suppliers. This allowed the extrapolation of the results obtained for the sample to the complete set of firms from which the sample was taken.
CHAPTER II

ECONOMIC EFFECTS OF RESEARCH CENTRES

II.1 GENERAL DESCRIPTION OF THE EFFECTS

The principal aim of research centres is the generation of new knowledge, part of which, depending on its nature, will be used sooner or later as input in the innovation process at the end of which stand new or improved products or services. Beyond this, however, research centres may have important economic effects within the whole network of the economy. These effects may be essentially divided into three categories.

i) PRIMARY ECONOMIC EFFECTS: These result from the primary aim of the research centre when the centres produce innovations themselves, such as new energy sources, telecommunications satellites, etc.

CERN’s primary aim is very basic research in particle physics and practical applications of its results can rarely be foreseen. Therefore, economic effects resulting directly from research done at CERN will hardly occur in the foreseeable future. However, the importance of long-term basic research for future technological progress is well known and has been discussed in some detail by Lederman, Refs.[1] and [2], and in the IIT report, Ref.[7].

ii) SECONDARY ECONOMIC EFFECTS: It is generally found that a major part of the scientific equipment necessary for carrying out the research is supplied by industry. Often the specifications and requirements are beyond the “know-how” currently available and thus represent a challenge to the manufacturer. Positive effects, such as new products, quality improvements, productivity increases, etc., arising from this challenge may be called the “Secondary Economic Effects” of research institutes, Ref.[8]. They are also sometimes called “spin-off” or “fall-out”.

The present CERN study is confined to these secondary economic effects. A quantification of all the secondary economic effects resulting from CERN is probably impossible. It was therefore necessary to select certain main effects which could be quantified, and for which industry was prepared to provide data. The description of these main effects, which we call “Economic Utility”, is given in the next section.

iii) MULTIPLIER EFFECT: This occurs with all public investments that create additional demand for goods.

It is because of the multiplier effect that the direct spending of CERN’s material budget in the member states, and the spending by CERN personnel in the region where they live, also stimulate the economy and create employment. These effects are not quantified in this study, but have been evaluated for DESY in Hamburg, Ref[9]. The Geneva Statistical Office, Ref[10], has studied the effects of the international organizations in Geneva.
II.2 ECONOMIC UTILITY

In order to fit the secondary economic effects into a larger framework we may use the "surplus" concept developed by Massé, Ref.[11], which is described in more detail in Appendix A. This concept considers all the economic agents (employees, shareholders, customers, suppliers and the state) in relation to the firm. It defines the gains, positive or negative, which these agents realize as a result of changes in industrial production. The sum of these gains, assuming it is positive, is called the "surplus" by Massé, who defines its value by comparing different years. But we can also define the surplus by comparing two different situations during the same time period. We can, for example, compare a firm which is in business contact with a research centre such as CERN, and the same firm without this contact. The comparison of these two situations may also show a gained surplus.

As shown in the Appendix A, the parts of the gained surplus, as reported by managers in firms which have been influenced by a research institute such as CERN, are increased turnover on the sales side and cost savings on the procedures and production side. We call the sum of these two effects "Economic Utility" so that

\[
\text{Economic Utility} = \text{Increased Turnover} + \text{Cost Savings}
\]

It is this part of the secondary economic effects due to CERN which is quantified in this study, and which was also quantified during the first study.
CHAPTER III

ECONOMIC UTILITY RESULTING FROM CERN

III.1 THE ECONOMIC UTILITY CREATION MECHANISM

Economic utility is stimulated by CERN through its purchases from industry. Indeed much of the equipment needed by CERN poses new problems, either by the technical specifications, or even by the sheer volume of complicated non-standard goods (e.g. hundreds of high-precision electromagnets or high-performance vacuum pumps) which are necessary for the building of an accelerator or related experimental equipment.

Firms which meet the challenge of such deliveries may afterwards be able to offer and sell new or improved goods to their other customers. Thus sales increases may be due to the following mechanisms:

i) NEW PRODUCTS: Firms may be led to market new or improved products as a consequence of the acquisition of new technology they have developed for, or together with, CERN. Also the volume of orders placed by the Organization, its non-competitive relation with industry, and the possibility of monitoring the performance of equipment delivered to CERN, may incite a firm to develop new products.

ii) MARKETING: The success of a product depends finally on its sales on the market. CERN's criteria for selecting products are known to be rigorous, and CERN is obliged to choose its suppliers on the basis of price for well-defined specifications. Considerable efforts are devoted to comparing products in order to choose the most suitable ones, and other customers may profit from this work by following CERN's choice. Further, material delivered to CERN is subject to strict performance control when in operation, sometimes for very long periods. Firms may refer to these facts in order to persuade other customers to buy their goods.

(It might be argued that a CERN supplier which increases its share of the market does so at the expense of its competitors; and that, from a European point of view, there might be no positive effect at all. This argument would be correct only in a market with conventional goods and a constant volume. We are dealing with markets which have high growth rates (electronics for example), and/or with products which change constantly due to rapid technological evolution. CERN buys products of the highest quality adapted to its purposes and at the lowest price. The resulting higher turnover forces the competitors of the CERN suppliers to improve their products, to the benefit of other customers. This is an efficient mechanism for keeping European industry abreast of overseas competition).

iii) QUALITY: Many firms producing in high technology fields sell their products primarily on the basis of quality. Contributions to quality represent, for these firms, an important element, since it permits them to maintain or improve their place in the market. CERN's quality requirements are often higher than that initially offered by the firms, but not so
high as to lead to products which are overpriced and hence find no other customers. CERN therefore has an appreciable effect, not only as a "quality standard", but also through its capacity to help overcome technical problems when they arise.

iv) MAINTENANCE OF PRODUCTION CAPACITY: Some areas of high technology are still awaiting a breakthrough in the marketplace. In the meantime, orders from research centres, such as CERN, may assure the survival of some production capacity related to such areas, thereby contributing to Europe's technological independence. CERN orders may generally help firms to survive difficult periods when other orders are low.

Cost savings may result directly from the CERN-industry connection if, for example, a firm learns something new as a result of an order from CERN. This may occur by fulfilling the Organization's requirements, or through contact with its engineers who showed how to improve a particular production process, or by using research and development results from CERN. Indirect cost savings may result from increased sales to - or stimulated by - CERN as described above.

There are occasional losses resulting from the relation between CERN and industry, or as a side-effect of generating utility. These have to be taken into account when economic utility due to CERN is quantified. This fact is covered by the general quantification method which is described in the next section.

III.2 THE QUANTIFICATION METHOD

Economic utility caused by research establishments is actually produced in, and by, industry and this is where the data have to be collected for its quantification. They are in most cases, not readily available and are often confidential. Hence some conditions must be fulfilled in order to carry out a utility study successfully. First, the information must be collected by means of personal interviews. Many managers are prepared to provide information orally which they would not convey in writing. The mechanisms of utility creation are too complex to be covered entirely by a questionnaire, which could lead to misunderstandings. Second, quantification models have to be developed, which are sufficiently concise to be explained within the limited time available during the interview, and which are sufficiently powerful to cover the multitude of cases which occur.

Based on the experience gained in the first study, a general quantification formula for the quantification of economic utility due to CERN was developed for the new study. The basic ideas which underly the formula are given below.

For simplicity, the explanation of the basic ideas is limited to an example of the quantification of increased turnover utility. The general case including the quantification of cost savings utility is given in detail in Appendix B.

We assume that there are basic activities in a firm which essentially cause economic results such as turnover. Such activities, which are shown in Figure 1, are mainly related to the following: new products, marketing, research and development, production techniques, management procedures, quality standards, pricing. A firm may, for instance, say that 10% of its total turnover is due to its marketing efforts and 15% is due to activities which ensure good quality. Suppose now that the firm estimates that the influence of CERN has led to a 20% improvement in its marketing to other customers and helped to improve quality by 10%. We then conclude that 100 * 0.1 * 0.2 = 2% of the total turnover is due to CERN's influence on marketing, and in addition, 100 * 0.15 * 0.1 = 1.5% of the turnover is due to CERN's impact on quality. Generalizing this idea, managers can put percentage figures on the various activities of their firms and on CERN's influence on these activities.

purchases

It is, however, clear that often only some part of the total turnover of a firm is influenced by CERN (in Appendix B this is called "CERN Relevant Turnover"). From this relevant turnover,
the firm's direct sales to CERN must then be subtracted and the remainder multiplied by the above-mentioned percentages to give the increased turnover generated by CERN. Finally, any financial losses due to CERN, and any opportunity costs, or investment costs necessary to bring about the utility must be subtracted to obtain the increased turnover utility.

Possible cost savings are calculated in an analogous manner.

Since prices and influence factors are time-dependent, utilities are estimated by industrial managers in financial periods, each covering one year. As in previous studies, they relate not only to past events but also include, whenever possible, forecasts for the next five years.

III.3 THE SAMPLE OF FIRMS

CERN buys from approximately 6000 suppliers, about 10% of whom sell high technology goods. As it was considered necessary to make personal interviews in order to obtain accurate quantification data, and as the resources in time and money available for the present study were sufficient for about 170 firms to be interviewed, only a sample of the high technology suppliers of CERN could be considered in the present survey.

The first problem was to select the high technology firms from the total of 6000 CERN suppliers. Computer tapes giving details of CERN payments to firms for seven years during the period 1973 to 1981 (1974 and 1979 tapes were not available) were used for this purpose.

About 90% of the firms on the tapes are not high technology suppliers, and these were eliminated in two steps. Many were excluded by a decision to consider only those firms which had sales to CERN equal to or greater than 100000 Swiss francs in at least one of the seven years covered by the tapes. The resulting list contained more than 1200 firms, and checks revealed that only a small fraction of high technology suppliers was lost this way. By checking the firms remaining on the list individually, and eliminating those not supplying high technology equipment, a final number of 519
high technology firms remained. The results from the sample of firms interviewed have been extrapolated to obtain valid figures for the whole family of 519 high technology suppliers.

The family of high-technology firms was divided into two classes: firms which had participated in the first study (named "old" firms), and the rest (named "new" firms). It was decided to take about one quarter of the total sample from the "old" firms in order to be able to compare the results with those of the first study and to analyze the validity of the forecast utility values from the first study. This gives an over-representation of "old" firms; but, since a random sample was taken separately from both the "new" and the "old" firms, these two samples are representative each of its own group. In each group a stratified sample was taken, where the stratification (grouping) was made according to five industrial categories (see Table I) and two levels (less than, or greater than, one million Swiss francs) of the firms' total sales to CERN during the time-period being examined.

Apart from the grouping mentioned above, seven "old" firms were selected for the training of the interviewers. The selection of these seven firms was not done by random selection, and therefore the results for these firms were not used for the extrapolation to the whole group of "old" firms.

III.4 THE INTERVIEW PROCEDURE

The data were collected between May 1982 and June 1984. The group making the interviews consisted of the seven authors of this report coming from various disciplines. Each interviewer was provided with information concerning the firms, such as order volume and the nature of the material delivered to CERN. Before the interview, discussions were held with one or more CERN staff who had had technical contact with the firm. The most appropriate top-level manager in the firm was then contacted by telephone and asked if the firm would agree to participate in the study, and an appointment was fixed. In rare cases, where no appointment could be arranged, the interview was carried out by telephone.

To avoid misunderstandings, the interview was carried out, whenever possible, in the language spoken by the industrial manager. Interviews began with a short review of the first CERN Economic Study and stressing the confidentiality of any information provided by the manager, followed by a review of past and/or present contracts with CERN. Sales figures to CERN were checked, as well as the type of goods supplied, these figures being broken down, where necessary, by production branch of the firm. The type of utility created by the collaboration was determined using the quantification model. In some cases, where the utility was due to specific contracts obtained as a result of CERN influence, the manager provided absolute values of utility. Other information obtained, where possible, included distribution of surplus, origin of goods, comments on CERN's purchasing procedures, creation of employment, etc. Where a firm had participated in the first study, the previous forecasts for the first part of the period now being examined were compared with what really happened. It was helpful if the same manager could be seen on both occasions, as personal knowledge and memory play important roles in the estimation process, but, because of the effects of staff changes in ten years, it was in fact unusual to be able to do so.

During the interviews it was often possible to meet the director of the firm and/or the directors of various branches (technical and marketing directors), to visit the production lines, and to gain a better understanding of where problems had arisen, or could arise, when dealing with CERN. It proved necessary from time to time to explain the essentials of CERN's Financial Rules and related purchasing procedures, and to explain the way these rules have been laid down by the Council and subsequently checked for correct application.

A report, used exclusively by the members of the study group, was prepared after each visit made, and the information obtained was summarized in tables from which the data were entered into a computer for subsequent analysis.
CHAPTER IV
QUALITATIVE RESULTS

IV.1 GENERAL REMARKS

The industrial managers who were interviewed provided estimates of the increased turnover and cost savings due to the influence of CERN, but only occasionally gave information concerning the way in which these turnover increases have been achieved.

Increased turnover has in some cases led to the creation of employment, but many firms will probably have taken advantage of a certain amount of unused resources, and this has avoided the laying off of personnel.

The evaluation of the cost of increased turnover and the full quantification of the creation and maintenance of employment would require further investigations among the firms concerned.

Risk is a major obstacle to industrial innovation. When dealing with CERN the risk inherent in breaking new ground is likely to be less than when dealing with other customers. CERN can often help in solving technical problems, and failures are certainly not exploited by CERN to harm the industrial partner. After all, the only thing of interest to CERN is to obtain goods with the required quality within the time specified. All performance data on material delivered are available to the interested supplier, and this information is successfully used by some firms to save costs and/or to open new markets.

IV.2 IMPRESSIONS OF THE INTERVIEWS

Some interviews started cautiously, especially where CERN had not placed any orders for some years. On a number of occasions, although there appeared to be no probability of finding utility when the firm was first approached, positive results were nevertheless obtained during the interview.

In the branches where technological development was pushed by CERN, many firms appreciated the information and help given by CERN technical staff. This often helped them to overcome major problems which had not been foreseen in advance.

Marketing is an important factor, especially in the case of small firms which had not previously exported outside their own countries. CERN has succeeded in helping several such firms to initiate their export trade. The mere fact of having sold to CERN may be an important sales argument, although this was sometimes difficult to quantify.

CERN's quality requirements have helped some firms to penetrate overseas markets, or to be more competitive against overseas suppliers on European markets. In one or two cases, the quality requirements had a negative effect, because they were much above the level required by other customers. As expected, the CERN influence was acknowledged in connection with research and development and quality improvement. Quality problems were sometimes seen to have produced
changes in management procedures and/or structures, although quantification of the resulting utility was not always possible.

During the interviews with firms which had incurred losses on CERN contracts it became clear that this often resulted from an under-estimation of the production costs. Some interviews also showed that firms may offer special conditions to CERN in order to have, or maintain, CERN on their reference list. The cost of this can be absorbed if the technology learned from CERN contracts is used to satisfy other customers or to introduce new products in the market; but difficulties may arise when the expected openings in the market do not occur.

**IV.3 EXAMPLES OF CERN-GENERATED UTILITY**

CERN-generated economic utility seems to grow on soil of all kinds, provided that at least one of several conditions is fulfilled.\(^1\) Some of these were found to be:

- the firm is active in advanced technology;
- a good professional relationship exists between CERN staff and staff in the firm with sufficient executive power;
- the marketing manager is aware of the fact that, for some potential customers, CERN is a good reference;
- the staff responsible for the firm’s quality control have sufficient influence;
- the firm makes an effort to satisfy CERN’s requirements, without necessarily making a profit while doing so.

The following examples illustrate these points:

i) **TURNOVER INCREASE**: Several European firms are fighting for a share of the high- and ultra-high-vacuum market. Their major sales argument is based on improved performance of the equipment offered to their customers. However, the development of a new or improved product is expensive and therefore risky. Under these circumstances, the large CERN projects with their requirements for a comparatively large number of units have reduced the risks considerably; and CERN has played a significant role in the firms’ decisions to take the risk. CERN has significantly contributed to the breakthrough of several products on the market, and the firms in question were able to quantify CERN’s contribution to the corresponding sales. The net result of this is that the European vacuum industry is well placed compared to the overseas competition.

ii) **FIRM CREATED DUE TO CERN**: A small firm specializing in precision mechanical components was set up about 10 years ago with the idea that the firm would be able to sell a reasonable percentage of its production to CERN. The firm was successful, and has regularly sold to CERN, whose influence on the success of the firm has remained at the same level as at the time the firm was created. At the beginning of the collaboration the owner of the firm had to develop special metal alloys to satisfy the CERN specifications. This has enabled the firm to remain competitive both on the home and export market, so that, when economic difficulties resulted in a drop in the home market, the firm was able to increase considerably its exports to other European countries.

iii) **CERN AS A TESTBED**: CERN may serve as a long-term testbed, since all performance data on material delivered are available to the interested supplier: This has been particularly true for suppliers of photomultipliers, and other special kinds of tubes; and especially

\(^1\) Even if some or all of these conditions are satisfied, there is no guarantee that utility will be created, owing to the many existing obstacles to successful technology transfer or to unforeseen market developments.
in computing and related fields. Computer manufacturers test computers, computer systems such as networks, and software, extensively at CERN, where they benefit from the "know-how" and long-standing experience of CERN's experts. In particular, some firms test electronic equipment for reliability and performance at CERN before putting it on the market.

iv) MAINTENANCE OF PRODUCTION: Among the problems of managing a shipyard is that of irregular production levels. One shipyard has on two occasions successfully made bids for CERN contracts which enabled the yard to maintain its production level - and of course its work force - during slack times in its normal work of ship construction and repair.

v) INTER-COMPANY COLLABORATION: A small firm, which has supplied CERN with standard, but specialized, hydraulic equipment for about 15 years, entered into a commercial collaboration with several large firms because of contacts made at CERN. As a consequence of this collaboration the smaller firm's components are now standardized with the products of the larger firms, resulting in a large increase in turnover and exports to other countries.

vi) COMPLEX UTILITY WITH MANY INFLUENCE FACTORS: A firm was created more than ten years ago to produce precision mechanical products with a few employees. Three years after its creation it obtained its first CERN contract for mechanical components for electronic equipment which has since been widely used outside CERN. In order to keep abreast of competition and to be accepted as a CERN supplier over the years, the firm has constantly had to improve the precision and quality of its products. It did so by using the CERN specification as a sort of standard. It further successfully used the reference to CERN sales in order to acquire other customers, first in research, and later in other markets such as television, railways, subways, etc. A few years ago it undertook a major internal re-organization in order to increase productivity - a risk it was able to take because of the CERN orders and the resulting utility. Approximately half of this CERN-created surplus was re-invested, and the remainder used in equal parts to increase salaries, reduce prices and pay taxes. Furthermore, CERN has created or maintained, by its contracts or the related CERN-generated utility, a number of jobs within the total workforce.

vii) COST SAVINGS: A large electronics firm received an order from CERN for amplifiers which enabled the company to maintain its production levels when other orders were low. A certain amount of development work was required in order to satisfy the special needs of CERN, leading to cost savings which were used by the company to reduce sales prices.

viii) INNOVATION AND QUALITY: The innovations and/or quality improvements resulting from CERN contracts are often applied in fields which have no direct connection with high-energy physics. For example, the strict and complicated requirements of CERN concerning the optical and ageing qualities of light guides and scintillators has enabled one firm to develop products for solar energy applications. Since the technologies necessary to obtain the required optical properties of solar panels in production quantities are already known to the firm, it expects to be able to enter the market - which is only just beginning to expand - with a lead over its competitors. In this case it was still too early to estimate the full amount of CERN-generated utility.

ix) CERN AS REFERENCE: Being a CERN supplier can often be a useful reference for firms. In one case a firm making cooling equipment for CERN was able to gain admission to a trade association and, as a result, was able to obtain an increased number of contracts. In another case a firm building transformers used the fact that it was a CERN supplier to support its request for an international licence for certain products.

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x) NEGATIVE EFFECT: CERN’s quality requirements do not always have a positive effect on industry. In one case, the rigorous technical requirements of a CERN specification influenced a firm making electrical equipment in deciding to change its general assembly line procedures. The firm later discovered that these changes had resulted in a decrease in productivity.
CHAPTER V

QUANTITATIVE RESULTS

V.1 QUANTITATIVE RESULTS OF THE SAMPLE

It must be emphasised that (as was the case in the first study) the quantitative estimations of the CERN-generated utility were made by the industrial managers and not by the CERN interviewers. In case of doubt, the lowest figures were always taken.

Between May 1982 and June 1984, 166 European firms were interviewed, and 160 were able to provide useful information concerning utility. Of these 160 firms, 55 had no utility or could not quantify admitted utility, and 6 had made losses on CERN contracts which exceeded utility.

The period covered by the study runs from 1973 to 1982 for the firm’s sales to CERN, and from 1973 to 1987 for utility created by CERN. Previous studies on utility showed it was possible to obtain utility forecasts for about five years into the future. However, this time, because of the present economic uncertainties, managers were often very reluctant to give such forecasts, which were nevertheless obtained, for at least one year ahead, from 78 firms. The five-year forecast period until 1987 was therefore maintained in order to give results which are comparable with the previous study, but it is clear that the utilities reported for the later part of this period are under-estimated (see Figure 2).

Between 1973 and 1982, CERN spent 748 million Swiss francs*) with the 160 firms of the sample which provided information, and these firms reported a utility of 3107 million Swiss francs for the period 1973-1987. The utility arising from increased turnover amounts to 2983 million Swiss francs and utility from cost savings is 124 million Swiss francs.

It should be remembered that direct sales to CERN have been deducted from the increased turnover utility, and that values are net, i.e. opportunity and other costs, and any losses due to CERN, have also been deducted. These data represent a lower limit of the utility actually generated by CERN, for the following reasons. First, it is the impression of all the interviewers that there is no systematic bias which would lead firms to inflate utility figures to please CERN or the interviewer. Second, it is possible that the manager interviewed may not have been aware of certain utility situations, or he may not have been in his present position long enough to have experience of the whole period under review. Third, there remain some utilities which managers were sometimes unable to quantify, particularly the reference value of being a CERN supplier.

Figure 2 shows the histogram of the interviewed firms’ yearly sales to CERN and the resulting yearly created utility. The corresponding accumulated values are shown in Figure 3. The SPS project lasted from 1971 to 1978 with payment of invoices extending into 1979. SPS sales appear to have produced their utility with a delay of a few years. The values shown for the period

*) Financial data in Chapter 5 are expressed in constant 1982 prices (i.e. corrected for inflation).
Figure 2: Yearly sales and yearly utilities from 160 firms interviewed.

Figure 3: Accumulated sales and utilities from 160 firms interviewed.
1984-87 are comparatively low mainly because only about half of the firms interviewed made forecasts.

The utilities found for the various industrial categories are given in Table 1.

**Table 1:** Breakdown of Sample Data (160 firms) by Industrial Category

<table>
<thead>
<tr>
<th></th>
<th>Electronics, Optics, Computers</th>
<th>Electrical equipment</th>
<th>Vacuum, Cryogenics, Superconductivity</th>
<th>Steel and Welding</th>
<th>Precision mechanics</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net utility (MSF)</td>
<td>1576</td>
<td>877</td>
<td>355</td>
<td>225</td>
<td>74</td>
<td>3107</td>
</tr>
<tr>
<td>Corrected utility* (MSF)</td>
<td>1340</td>
<td>745</td>
<td>300</td>
<td>190</td>
<td>65</td>
<td>2640</td>
</tr>
<tr>
<td>Losses (MSF)</td>
<td>3.7</td>
<td>5.4</td>
<td>5.3</td>
<td>0.4</td>
<td>0.2</td>
<td>15.0</td>
</tr>
<tr>
<td>Sales investigated (MSF)</td>
<td>220.1</td>
<td>359.2</td>
<td>101.3</td>
<td>35.8</td>
<td>31.2</td>
<td>747.6</td>
</tr>
<tr>
<td>Corrected utility/sales ratio</td>
<td>6.1</td>
<td>2.1</td>
<td>3.0</td>
<td>5.3</td>
<td>2.1</td>
<td>3.5</td>
</tr>
<tr>
<td>Number of firms interviewed</td>
<td>57</td>
<td>46</td>
<td>22</td>
<td>16</td>
<td>19</td>
<td>160</td>
</tr>
<tr>
<td>Number of firms without utility</td>
<td>12</td>
<td>19</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>55</td>
</tr>
</tbody>
</table>

* Corrected utility equals 85% of net utility, for explanation see Section V.2.

Because of the complexity of modern European industry, it is very difficult, if not impossible, to determine exactly which country benefits from the utility generated. This is particularly true for multinational suppliers. Therefore it has not been possible to make any breakdown of the information by country.

A part of the increased turnover making up the utility consists of sales to the high energy and nuclear physics market. Although it was difficult to obtain reliable information on this for the full period of the study, reasonably accurate values obtained for 1982 showed that only 24% of CERN-generated increased turnover consisted of sales to the high energy and nuclear physics market. Indeed, CERN's purchases have stimulated technological improvements in fields which are not related to high energy and nuclear physics such as, solar energy, electrical industry, railways, computers and telecommunications.
V.2 EXTRAPOLATION OF THE SAMPLED DATA

The extrapolation of the utility obtained for the random sample to the total family of firms from which the sample was taken was made using the group averages. A few of the firms interviewed reported utilities which were noticeably higher than the utilities of other firms in their group, and although these cases (outliers) could be explained, they were not considered to be representative. They were therefore excluded from the computation of group averages, and hence not used for the extrapolation.

Between 1973 and 1982, CERN spent 1379 million Swiss francs with the 519 high technology firms, and the total utility for the period 1973-1987 obtained by extrapolation amounts to 4796 million Swiss francs. Errors can occur in the extrapolation process from two sources: errors in estimating the group averages, and errors due to the difficulty of assigning multi-branch firms to the correct group. This extrapolation error (99% confidence interval) has been calculated to be ±623 million Swiss francs.

When comparing the 3107 million Swiss francs of utility for the 160 firms to the 1689 million Swiss francs of extrapolated utility for the remaining 359 firms, two points have to be taken into account. First, the sales to CERN by the firms interviewed already represents 57% of the total high technology sales to CERN. Second, the outliers contributed strongly to the utility of the interviewed firms but did not contribute to the extrapolated values.

Assuming that the utilities of the years 1973-75 are essentially the result of CERN orders prior to 1973, the utility corrected for this effect is about 85% of the net utility. The corrected utility/sales ratio then gives a measure of the utility created by CERN's high technology purchases made during the period 1973-82. For the sample this ratio is 3.5, which compares well with the ratio of 3.7 found last time.\(^\ast\) The overall (after extrapolation) corrected utility/sales ratio becomes 3.0.

\[\text{Table 2: Breakdown of Total Data (519 firms) by Industrial Category}\]

<table>
<thead>
<tr>
<th>Net utility (MSF)</th>
<th>Corrected utility* (MSF)</th>
<th>Sales (MSF)</th>
<th>Corrected utility/sales ratio</th>
<th>Number of firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics, Optics, Computers</td>
<td>2638</td>
<td>2245</td>
<td>537.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Electrical equipment</td>
<td>1205</td>
<td>1025</td>
<td>472.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Vacuum, Cryogenics, Superconductivity</td>
<td>471</td>
<td>400</td>
<td>152.9</td>
<td>2.6</td>
</tr>
<tr>
<td>Steel and Welding</td>
<td>300</td>
<td>255</td>
<td>104.6</td>
<td>2.4</td>
</tr>
<tr>
<td>Precision mechanics</td>
<td>182</td>
<td>155</td>
<td>111.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Totals</td>
<td>4796</td>
<td>4080</td>
<td>1378.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>

* Corrected utility equals 85% of net utility, for explanation see Section V.2.

* This ratio is based on data expressed in constant 1977 prices, which explains the difference to the ratio published in Refs.\(3\) and \(4\), which was based on data expressed in current prices.
Table II gives a breakdown, by category of firm, of the extrapolated utility generated by CERN in the total family of 519 high technology suppliers. Figures 4 and 5 show these data in graphical form.

**Utility by Industrial Category**
(Millions of Swiss Francs)

![Bar chart](chart.png)

- **Figure 4**: Total sales and total utilities from 519 high technology suppliers, broken down by industrial category.

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**How the Utility is Shared**

![Pie chart](chart2.png)

- **Figure 5**: Total utility from 519 high technology suppliers, showing the contribution by industrial category.
The total cost of CERN in 1973-82 was 6945 million Swiss francs. The corrected utility/total cost ratio is therefore $0.85 \times \frac{4796}{6945} = 0.59$. Remembering that the firms interviewed have tended to provide low estimates of the probable actual utility, it may be stated that, by 1987, CERN purchases (high technology goods only) made in 1973-82 will have generated utility amounting to at least 59% of the total cost of CERN during the years 1973-82.

V.3 FORECAST VALUES AND ACTUAL EVOLUTION

During the first study most of the firms interviewed provided forecasts for the period 1974-78. About forty of these firms were selected by the random sampling process to be interviewed again this time, and they were questioned on the actual evolution of the utility during the forecast period. Out of these firms thirty-six provided data which could be compared to their previous forecasts.

This comparison showed that many firms actually realized utilities which were close to their forecasts, although in several cases the forecasts proved to have been too high or too low. This can be explained by:

- turnover of the firm different to the forecast,
- CERN effects coming earlier or later than expected, or not at all,
- losses due to CERN which could not have been foreseen,
- CERN influence on the firm different to the forecast,
- person interviewed unable to remember everything that happened ten years ago.

Out of the 36 firms, 21 had forecast utilities which turned out to be too high, and 15 forecasts which were too low. In spite of these variations, the total utility actually realized was within a few percent of the total utility forecast. In order to find out whether, on average, this difference between the forecast and the realized utilities was statistically significant, tests (t-test and signed rank test) for both the differences of the utilities and the differences of the utility/sales ratios were applied. None of these tests revealed a significant difference between the forecast and the actually realized utility values. We have therefore no reason to reject the hypothesis that managers can, on average, give correct utility forecasts.

Acknowledgements

We acknowledge the kind collaboration of the persons interviewed in the participating companies, without which this study could not have been achieved.

We wish to thank Professor H. Schopper, Director-General of CERN, Dr. R.F. Hen, Director of Administration, and Dr. M. Lazanski, Leader of Finance Department, for their approval and financing of the project, and our respective Division/Department Leaders for agreeing to our participation and granting us the time necessary to carry out the study.

Even though we made use of computerized purchasing records, much other vital information was supplied by members of the Finance Department, and for this we are most grateful.

Our thanks go to the CERN scientific and technical staff who provided us with details of the orders placed with, and goods delivered by, the suppliers interviewed.

Finally, we have much appreciated and benefited from the help, comments, and suggestions of many of our colleagues throughout this study.
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APPENDIX A: THE THEORETICAL CONCEPT

The theoretical concept of the study described here has to fulfil three requirements:

- it has to be adapted to the level of information which industrial managers are willing to provide,
- managers must understand what information is required, and
- the concept must be such that the required information can be provided at all.

The "surplus" concept, as developed by Massé, Ref.[11], turns out to be an appropriate basis for this. The basic ideas of Massé's surplus concept are given below.

Consider an industrial firm which, for convenience, produces only one article. Let \( V \) be the number of units of the article it produces in year \( n \). Let \( F_j \) be the number of units of the \( j \)-th production factor (manpower, machinery, materials, capital, cash resources, etc.) which the firm makes available to produce the \( V \) units of the article in year \( n \). Suppose that all produced units are sold. If \( P \) is the unit price of the article and \( P_j \) is the unit price of factor \( F_j \), the equilibrium equation (output = input) for year \( n \) is given by

\[
PV = \sum_j P_j F_j. \tag{1}
\]

Now, consider year \( n + 1 \). Denote by \( F_j + \Delta F_j \) the number of units of the production factors made available in year \( n + 1 \) and use corresponding notations for the other quantities. For year \( n + 1 \) the equilibrium equation must then be written as

\[
(P + \Delta P)(V + \Delta V) = \sum_j (P_j + \Delta P_j)(F_j + \Delta F_j). \tag{2}
\]

We rewrite the equation (2) in the following way:

\[
PV + P\Delta V + \Delta P(V + \Delta V) = \sum_j P_j F_j + \sum_j (P_j \Delta F_j + \Delta P_j (F_j + \Delta F_j)). \tag{3}
\]

Comparison of equation (1) with equation (3) shows that the first term on the left-hand side and the first term of the right-hand side of equation (3) cancel. Remembering that equation (1) describes the situation of the firm in year \( n \) and equation (3) in year \( n + 1 \), we see that the terms left over in equation (3) describe the change in the factors, the prices and the produced units from one year to the next.

For proper economic interpretation, Massé rewrites equation (3) to obtain

\[
\Delta V = \sum_j P_j \Delta F_j = -\Delta P(V + \Delta V) + \sum_j \Delta P_j (F_j + \Delta F_j). \tag{4}
\]

The terms on the right-hand side of equation (4) represent a distribution of resources. The first, \(-\Delta P(V + \Delta V)\), goes to the customers as the result of a price change (to their advantage if \( \Delta P \) is negative), the second, \( \sum \Delta P_j (F_j + \Delta F_j) \), is the allocation to the different production factors. The left-hand side must give, therefore, the gained resources to be distributed. Massé calls the left-hand side the firm's "gained surplus" and the right-hand side the "distributed surplus".

It is clear that a gained surplus can occur only if something in the firm changes. For instance, the firm may sell more due to better marketing, to better quality, to the introduction of a completely new product, etc. It may also have been able to increase productivity, to obtain better interest conditions on loans, or to improve its situation in other ways. On the other hand, if all the
increased turnover is accounted for by increased production costs, both sides of equation (4) will become zero and there will be no gained surplus.

There must be driving forces which cause these effects to be positive. One of these driving forces might be a contact with a challenging customer such as CERN who asks a firm for new products, requires higher quality, provides a good marketing forum, and so on.

In a given year we may therefore consider a firm in two different situations.

a) The firm has no contact with CERN.
b) The firm has contact with CERN.

Using Massé's concept we can then define a surplus gained by the firm and a corresponding distributed surplus by comparing situation (a) with situation (b) in the same way as we did in equation (4) for the situation of the firm in two different years. If we observe a gained surplus we can say that this surplus was caused by CERN.

It may be very difficult, if not impossible, during the limited time of an interview for an industrial manager to provide information on CERN's influence on each different production factor and its unit price. He may, for example, be able to estimate the hypothetical development of only a few of the production factors. (Of course not all production factors are influenced by CERN. For instance, CERN has practically no influence on the capital cost (interest) of a firm). It was therefore decided to ask industrial managers to quantify only two elements contributing to the gained surplus, namely the sales increase and the cost savings due to CERN. In any case, these are the dominant elements and seem to be the ones which industrial managers can quantify with a reasonable effort. It is therefore necessary to replace the second term of the left-hand side of equation (4) by two terms, so that this becomes

\[
PΔV - \sum_{p} P_p ΔF_p - \sum_{c} P_c ΔF_c = -ΔP(V + ΔV) + \sum_{j} ΔP_j(F_j + ΔF_j) .
\]

where, on the left-hand side, the second term represents the change in production costs necessary to achieve the increased turnover, and the third term represents the cost savings due to CERN.

Managers were asked to estimate the first and third terms, but were only occasionally able to provide information concerning the second. In order to express the fact that in this case we are not quantifying all parts of the gained surplus due to CERN, we call the sum of sales increases and cost savings due to CERN the utility \( U \) defined by

\[
U = PΔV - \sum_{c} P_c ΔF_c .
\]

In order to quantify the utility caused by CERN, a mathematical model was developed. This is described in Appendix B.
APPENDIX B: THE QUANTIFICATION FORMULA.

In order to provide a general formula which allows the quantification of the utility due to CERN, we denote the utility arising from increased turnover as \( U_s \) and the utility from cost savings as \( U_c \). We then rewrite equation (6) as

\[
U = P \Delta V - \sum_c p C F_c = U_s + U_c .
\]

In order to arrive at a simple quantification formula for \( U_s \) and \( U_c \), we need a simple model of the mechanism of utility creation.

Taking a simplified view of the mechanisms which determine the success or failure of a firm, we assume that there are certain basic activities, such as launching new products, marketing, research and development, management procedures, manufacturing techniques, quality control, pricing, etc. The efforts devoted to these different activities, which we shall call "Economic Success Activities", bring about the economic results of the firm. Managers usually know the relative effect (not necessarily in money terms) which each activity has on turnover, production costs, etc.

He may say, for instance, that 15% of the firm’s turnover \( M_t \) is due to their marketing activities. We then call the value 0.15 the marketing success factor for turnover. Such factors, by which we multiply the total turnover to obtain that part of the turnover caused by the corresponding success activities, we call "Economic Success Factors for Turnover". It is clear that the sum of all possible economic success factors for turnover must be 1, since all the success activities together cause the total turnover \( M_t \).

In the same way, we define "Economic Success Factors for Cost Savings", which give the relative effects on cost savings \( M_c \). Once again the sum of these factors must equal 1.

We denote the economic success factors by \( E_{as} \) and \( E_{ac} \). The first index \( a \) indicates the success activity, while the second indicates sales \( s \) or cost savings \( c \).

Using the economic success factors, we can quantify the parts of the total turnover \( M_t \) and the cost savings \( M_c \) which are due to the corresponding economic success activities. In order to quantify the utilities \( U_s \) and \( U_c \) due to CERN, managers have to quantify the influence that CERN has had on the different success activities of the firm. Here a manager has to compare the two different situations mentioned in Appendix A: (a) the firm in contact with CERN (real situation), and (b) the firm not in contact with CERN (hypothetical situation). If, for instance, a manager finds that CERN’s contribution to launching new products was 30%, and if \( E_{ns} \) is the new product success factor for turnover, then the product \( 0.3*E_{ns} * M_t \) gives the firm’s turnover caused by CERN resulting from new products, and represents a sales utility due to CERN. We call the factor 0.3 the CERN influence factor on the new product success activity for turnover.

Such factors, by which we multiply the corresponding economic success factor to obtain CERN’s contribution to the corresponding success activity, will be called the "CERN Influence Factors on a Success Activity". Unlike the Economic Success Factors, the sum of which must equal 1, the CERN Influence Factors can take any value between 0 and 1. If all CERN influence factors are zero, CERN has no positive effect on the firm and there is no positive utility. We denote the CERN influence factors by \( C_{as} \) and \( C_{ac} \), where the indices are the same as those used for the success factors.

The quantification equations for \( U_s \) and \( U_c \) therefore become:

\[
U_s = (CE)_s * M_t ,
\]

(8)
\[ U_c = (CE)_c \cdot M_c , \] (9)

with

\[ (CE)_s = \sum_a C_{as} \cdot E_{as} , \] (10)

\[ (CE)_c = \sum_a C_{ac} \cdot E_{ac} , \] (11)

where the index \( a \) on the right-hand side of equations (10) and (11) covers all economic success activities.

Some corrections have still to be made to equations (8) and (9) so that they apply to all cases. In equation (8) we have to take into account the fact that CERN usually influences only part of a firm. To illustrate this, consider a firm making transformers, electric motors and household appliances. Suppose that this firm has made electromagnets for CERN, and that this has subsequently led to improvements in the manufacture of their transformers and motors, but that there was no CERN influence on the household appliance business. The total turnover \( M_t \) of the firm in equation (8) must therefore be multiplied by a factor \( C_t < 1 \), which gives the fraction of total turnover in transformers and motors, influenced by CERN. We call \( C_t \cdot M_t \) the “CERN Relevant Turnover” and \( C_t \) the “CERN Relevant Factor” of the total turnover. Since the CERN relevant turnover still includes sales to CERN \( M_s \), we have to subtract \( M_s \) from the CERN relevant turnover, since direct sales to CERN are not sales increases due to CERN’s influence on the firm’s economic success activities.

In addition, the resources used to produce the items sold to CERN could have been employed for other customers. We call these sales which would have been made elsewhere “Opportunity Cost” \( M_o \), and this must also be subtracted from the sales utility given by equation (8).

Taking these points into consideration, the sales utility is given by

\[ U_s = (CE)_s (C_t \cdot M_t - M_s) - M_o . \] (12)

Equation (9) must be expanded to take account of any investment costs \( M_i \) which were necessary in order to produce the cost savings, and we obtain

\[ U_c = (CE)_c \cdot M_c - M_i . \] (13)

Combining equations (12) and (13) and taking into account any losses \( M_l \) which may have occurred due to CERN gives the final quantification equation

\[ U = (CE)_s (C_t \cdot M_t - M_s) - M_o + (CE)_c \cdot M_c - M_i - M_l , \] (14)

which, together with equations (10) and (11), is the basis for the quantification of the utility due to CERN. When applying equation (14), we have to take into account the fact that, in principle, all quantities are time-dependent. Therefore, the utility is calculated on a year-by-year basis, and is later expressed in fixed prices referring to a reference year, so that the utilities of different years can be added to give the total utility of a firm.