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Veronica Stolte-Heiskanen
University of Tampere
Department of Sociology and
Social Psychology
P.O. Box 607
33101 Tampere, Finland





**Tarmo Lemola, Raimo Lovio**

# The relations between science and production in Finnish industry

## 1. Introduction

In its annual report for 1987, IBM reports that it used $ 5,434 million for research and development. This sum is tremendous, but so is also the quality: in both 1986 and 1987, the Nobel Prize in physics was awarded to researchers at IBM's research institutes in western Europe.

The example of IBM shows how essential R&D has become for enterprises operating in research-intensive fields. Part of the immense R&D input is used for basic-research type activity which may lead to Nobel Prizes and which, it is hoped, will later lead to significant innovations and commercial success. Emphasizing the interactions among science, technology and business activity is one of the crucial objectives of enterprises such as IBM.

This is how things stand in the world at large, but how are they in a small world — for example in Finland, where the total R&D expenditure in 1987 amounted to only one–fourth of the R&D expenditure of IBM? Is there an increased significance of R&D activities clearly visible also in the small enterprises of a small country such as Finland? What kinds of cooperation — possibly different from those in the large countries — have sprung up in between science and industry? What kind of problems in this cooperation are experienced as being especially timely at present?

In the following, we are making an endeavour to answer these questions by describing and explaining the qualitative change which has taken place in the relations between science and industry in the course of the past twenty years.

## 2. The late 1960's: industry almost without science

The first official statistics on research in Finland were published in 1971. The statistics covered 1969 and were prepared according to the reommendations issued by the OECD. They did not elicit a great surprise. They confirmed the general preconception that Finland's input into R&D was small. In 1969, a total of 6,409 individuals were employed in R&D tasks, and these individuals worked a total of 4,087 man-years. The share of R&D expenditure in the GNP was 0.7 %.

Being a small country it was understandable that the R&D input was small in absolute terms. What was more difficult to accept was that the relative input was so small. It was almost at the same level as the inputs of Norway and Denmark, but Sweden, which still at that time was overwhelmingly the most important standard of reference for Finland, was clearly ahead. In Sweden the GNP share of R&D expenditure was more than double that in Finland.

The backwardness was largely due to the small R&D input of the business enterprise sector. The share of industrial R&D expenditure of the value added of production was only 1.3 %, while in Sweden it was 2.6 % and even in Denmark 2.0 %.

In addition to the modesty of the enterprise-specific input, one special feature of Finnish industrial R&D activity has been the scantiness of collective research. There is only one significant research institute owned collectively by several companies, namely Oy Keskuslaboratorio Ab, founded as early as 1916, owned by the paper and wood processing industries. In the other Nordic countries the number of such private collective research institutes is clearly higher.

This gap left by enterprises has been largely filled by the state-owned Technical Research Centre of Finland (VTT). It was established in 1942, and its activities have covered a significant proportion of technical fields important for Finland. In 1969, VTT had a staff of somewhat more than 600, but considering the coverage of the activities, the volume of the activities of VTT in individual sectors of technology or industry was small. Furthermore, in a number of sectors its activity focussed on tasks having the character of testing and inspection.

The relations between enterprises and universities (there are universities of technology in Helsinki, Tampere and Lappeenranta and faculties of technology in Oulu and Turku) have always been close in Finland. At the end of the 1960's, many were of the opinion that these relations were even too close. However, even the higher education system was concentrating more on the training of high-level experts for the management and planning of production than on carrying out research directly serving companies.

In other words, at the beginning of the 1970's neither scientific research nor even R&D activity had yet become an essential part of production and its development. In some fields and in some companies there had, indeed, long been small-scale R&D units. Nevertheless, on the whole the research-intensiveness of industry was low in those days.

Why, then, was the situation in Finland such as it was? A key explanatory factor can be found in the structure of production. Finnish industry is dominated by non-research-intensive fields of process industry. Towards the end of the 1960's the contribution of forest industries to Finnish exports was still about 60 %. The metal industry was also quite capital-intensive, and a large proportion of the developed, more research-intensive industry still had the character of home-market industry. Another fact explaining the small size of the research input is the scantiness of military research.

However, the technological level of Finnish industry was clearly rising also in those days. This rise was largely based on the transfer of technology from abroad. The openness of international technology markets and possibility for the transfer to occur in a form which did not produce excessive dependence on the sources of that technology contributed to the success of this transfer. The basic factor was, however, the high level of knowledge of the recipients and appliers of the technology; the educational institution had played an important role in establishing this level of knowledge (cf. Lemola & Lovio 1986, Vartia & Vuori 1987, Ray 1988).

## 3. From the 1960's to the 1980's: the development of technical research becomes a national project

### *First wave of development*

The above may give the impression that at the end of the 1960's Finland was in a state not only of backwardness but also of stagnation. The country may have been backward but it was far from being stagnant. On the contrary, the end of the 1960's constitutes a very expansive and important phase in the history of Finland's technology policy. At that time a significant proportion of those tools and other prerequisites was created on which later development was built.

At the turn of the 1970's, three important changes were effectuated in technology policy. Preparations for these changes began as early as the mid-1960's. First, the state began to give support, in the form of product-development loans and grants and tax reliefs, to the R&D activities of enterprises. Second, the operating conditions of universities and research institutes were considerably improved, and their activities were reoriented to better correspond to the increasing needs and demands of industry. Third, the state began to organize and finance technological goal-oriented research whereby nationally important research activity aiming at long-term development of industry would be increased and made more effective.

That the development of the technology policy became so timely at the end of the 1960's was due not only to the general irritation with the obvious backwardness but also to other factors. The fundamental reasons were the increasing internationalization and liberalization of trade. These imposed great new pressures on the one-sided structure of Finnish production, and on the low technological level compared with that in countries which were Finland's most important competitors.

A significant proportion of the state measures initiated at the turn of the 1970's centered on investments in the infrastructure. The main objective of the measures was to expand R&D activity and to improve the general prerequisites of this activity. Technology policy did not aim directly at influencing innovation by enterprises or at orienting research carried out by public research institutes. Although in the sense of guidance technology policy was neutral, it was nevertheless the *primus motor* for the process of change — indeed, representatives of enterprises participated closely in the formulation of the new policy.

Enterprises also amply increased their research inputs during the early 1970's (cf. Table 1). The principal direction in the organization of enterprise-specific R&D was from centralization to decentralization. From centralized research institutes and departments, R&D was shifted closer to production.

Enterprises also began increasingly to seek collaboration with research institutes — in particular with VTT. VTT was reorganized in 1972, and it began to grow vigorously.

Efforts were also made to increase cooperation between enterprises and universities, although in the first half of the 1970's — under the influence of the student movement — the government was slowing down the increase of research cooperation between enterprises and universities. In general, as late as the first half of the 1970's the science policy and university policy were relatively far from technology policy, which was in the process of evolution.

The vigorous development in the early 1970's was attenuated during the depression of the mid-1970's. Acute concerns of trade-cycle policy were given the main attention in the economic and industrial policy. Enterprises also slowed down their increase of the research input.

### *Second wave of development*

The years of depression underlined the traditional problem of the production structure in Finland, i.e. the difficulty of creating new, technologically high-standard production. Along with the depression, the problem of maturation of the old fields arose, too. Thus technology policy was faced with a multi-faceted problem at the end of the 1970's: how to secure the development of the old traditional sectors through their technological modernization, how to rapidly develop new, technologically high-standard production, and how to influence technological development in such a way that its effects on employment would be favourable?

An important instrument for the formulation of the new policy was the Technology Committee, appointed in 1979. The establishment of this committee was triggered by a need to formulate more systematically a goal-oriented technology policy, to assess the rate of technological development and analyze its societal impacts, and to channel public discussion regarding automation. Such a committee was especially demanded by the trade union movement; under the inspiration of foreign models, a discussion regarding the impacts of automation had been started within the movement.

The Committee was appointed in the spirit of a political consensus. In addition to representatives of various fields of technology and science, industry and public administration, also representatives of the most important trade union organizations were appointed to it. The importance of the work was emphasized by appointing for the Committee a political support group to which representatives of the parties in the Government and of the most important opposition party were appointed.

While the point of departure for the work of the Technology Committee was fear about the adverse impacts of automation, the final result was a strong and shared faith in the fruitfulness of technological change and that there must be also in Finland a vigorous orientation towards the exploitation of the new opportunities provided by information technology. The view was adopted that this required the strengthening of the previously adopted policy of expanding R&D and increasing goal-orientedness in technology policy. The latter meant an all-round promotion of national cooperation and the concentration of resources in nationally important new fields of technology.

Perhaps the greatest contribution of the Technology Committee was not so much its concrete proposals but that, as a cooperation mechanism, it effectively legitimized a technology policy oriented towards promoting the exploitation of automation and information technology. The core idea of this technology policy was to develop technology through corporate renewal and through raising the technological level of enterprises. In fact, the Technology Committee started up a great national project, the essential content of which has been a large-scale harnessing of national resources according to the needs of the high-tech export industry (cf. Lemola & Vuorinen 1988).

The convergence between science policy and technology policy has been essential for the development in the 1980's. The beginning of the new, technology-intensive science policy has been dated as 1979: "In general, science policy has become more instrumentally oriented and subordinated to technology policy. ... In short, from a social science perspective, the 'soft and idealistic' science policy of the early 1970's has been replaced by the 'hard and realistic' policy of the 1980's" (Kaukonen 1987, 29 — 30). As if to confirm this, in 1987 the Science Policy Council became the Science and Technology Policy Council. An organizational consequence of the convergence between science and industry has thus been a convergence between science policy and technology policy.

At the most general level, the impacts of the national project are manifested in a rapid growth of the R&D expenditure. The share of the R&D expenditure in the GNP increased during 1981—1989 from 1.19 % to 1.86 %. The rate of growth in Finland has been one of the fastest in the OECD countries.

## 4. Increasing input by the business enterprise sector into technical research

In the 1980's, research input has increased at the fastest rate in the business enterprise sector. The annual increase of man-years of R&D work has risen clearly to above 10 percent (*Table 1*). In 1979 the number of man-years devoted to R&D work was 7,231, whereas in 1987 the figure was as high as 13,514.

The volume of R&D in the business enterprise sector has doubled in ten years. As a result of the rapidly accelerating growth of the research input by enterprises, the sector's share of the total R&D expenditure has increased at a steady rate in the 1980's. In 1979 the share was 54.8 % and in 1987 it was as high as 58.9 % (according to latest estimation: 60.9 % in 1989). In countries in which the total research input is higher than in Finland, the share of the business enterprise sector is usually also higher. For example, in Sweden and Norway the figure is higher than in Finland, but in Denmark it is lower.

Traditionally the number of enterprises engaged in R&D has been small in Finland. However, in the 1980's the number of enterprises which are, according to the statistics, engaged in R&D has increased at a rapid rate. In 1981 there were 549 such enterprises and in 1987 their number was 954.

R&D activity is, however, strongly concentrated in large enterprises. In 1988 there were fourteen enterprises whose R&D expenditures exceeded 100 million Finnmarks (FIM). These companies are listed in *Table 2*. According to reports by these enterprises, they used a total of 3,448 million FIM for R&D, which is approximately 75 % of the total research expenditure of the business enterprise sector. It is also more than the total research expenditure of the whole public sector, which was 3,122 million FIM in 1988!

As a rule, in Finland too, enterprises in the fields of electronics, mechanical engineering and chemistry make the largest input into R&D. With the exception of the field of electronics, state-owned enterprises have a rather strong position. State-owned enterprises, whose contribution to the gross value of industrial production is approximately 15 %, have traditionally been used for the development of basic industry. However, they no longer have the same role in reforming and strengthening of the industrial structure as they had in the 1950's and the 1960's.

The largest researcher and developer in the business enterprise sector is Nokia Oy. Its current principal field is electronics and it has 44,000 employees. After large corporate acquisitions abroad in 1987 and 1988, its research personnel at present numbers approximately 3,900, making it the largest research organization in the country (the personnel of VTT numbers 2,700). Its R&D expenditure exceeded in 1988 the limit of 1,000 million FIM. This is twice the sum of the total budget of the Technology Development Centre (TEKES), the principal state-owned funding agency for technological research.

What do the quantitative changes described above mean in terms of quality? Has quantity begun to turn into quality? What is the time span and depth of R&D in enterprises? What impacts will the activation of enterprises have on the other parts of the research system?

Answering these questions will require further investigation, but a number of general observations can already be made:

A significant proportion of the R&D activity of enterprises continues to be oriented towards the further development of existing products. Research, more specifically product development, is taking place both psychologically and physically close to the production, often as an integral part of it.

The larger enterprises have embarked upon measures to develop so-called strategic research. This research is often organized in the form of a separate research unit at the corporate level. The time span of strategic research is longer than that of R&D. However, it is not yet possible to speak of basic research in connection with strategic research. It is rather of the follow-up of basic research and of deepening of knowledge in narrow specialized areas of strategic importance for the enterprise.

Examples of scientification of innovation by enterprises have begun to be visible also in Finland. In a number of cases, however, the situation is that the basic ideas of an invention have largely been created in universities and research institutes, from which they have then been transferred to the enterprises. In the further development of the basic ideas the enterprises may have made sizeable inputs into work of a basic-research type.

In a study of the significant innovations of the Finnish electronics industry, we observed that in approximately every third case (8 out of 21 significant innovations), research having the character of basic research was carried out in connection with the development of the innovation. This research was carried out, in general on the initiative of the enterprise involved, either at a university or at VTT. However, the persons responsible within the company for the development of the innovation often also themselves held doctorates; they had prepared their doctoral dissertations or completed their dissertations in the course of the innovation process on the same topics (for greater detail, see Lovio 1987).

As a result of the quantitative growth, the research units in enterprises are at present more self-sufficient and at the same time better equipped to exploit research carried out at universities and research institutes. At the same time the research units of enterprises have become worthy competitors for research units and research personnel in universities and research institutes. Enterprises pay higher salaries, they often have better equipment and a more flexible approach. Thus, also in Finland, the career of a enterprise researcher has emerged as an alternative to an academic career in the natural sciences and technology. This new alternative is attracting people away from universities and research institutes.

## 5. Increasing input by the state into technical research

The state has also increased its R&D input, although not at quite as rapid a rate as has the business enterprise sector. Nevertheless, the share of the state R&D input in the GNP has grown from 0.59 % in 1983 to 0.73 % in 1988 (figures excl. defence). This growth compares well internationally.

In the state input, the development of technical R&D which promotes industry has played a central role. In 1988, 29 % of the state R&D expenditure was allocated for the promotion of industry, whereas in 1981 this share had been 21 %. The most important R&D expenditure items of the state have been the national technology programmes and subsidizing R&D carried out by enterprises.

Overwhelmingly the most visible manifestation of the second wave of development of the technology policy of the early 1980's consisted of the national technology programmes. A new body for planning

*Table 1. Development of R&D in the business enterprise sector during 1969—1987.*

| Year | Man-years | Growth/year | Expenditure % of value added | Share of the BER&D, % |
|---|---|---|---|---|
| 1969 | 4087 | — | — | 48.6 |
| 1971 | 4942 | 10.4 | 1.6 | 54.5 |
| 1973 | 5712 | 7.8 | 1.5 | 53.2 |
| 1975 | 6254 | 4.7 | 1.5 | 52.1 |
| 1977 | 6526 | 2.2 | 1.6 | 51.9 |
| 1979 | 7231 | 5.4 | 1.7 | 54.8 |
| 1981 | 8367 | 7.8 | 2.0 | 54.7 |
| 1983 | 9660 | 7.7 | 2.4 | 56.8 |
| 1985 | 12051 | 12.3 | 3.0 | 59.1 |
| 1987 | 13514 | 6.0 | 3.7 | 58.9 |

*Source:* Science and Technology 1987, Central Statistical Office of Finland.

*Table 2. The enterprises which made the largest input into R&D in Finland in 1988, million FIM.*

| Company | R&D expenditure | Sector | Ownership |
|---|---|---|---|
| Nokia | 1,050 | electronics | private |
| Neste | 440 | chemistry | state |
| Valmet | 285 | mechanical | state |
| Kemira | 222 | mechanical | private |
| Wärtsilä | 220 | chemistry | state |
| Outokumpu | 200 | basic metal | state |
| Strömberg | 173 | electrical | ABB/Sweden |
| Orion | 160 | chemistry | private |
| Ahlström | 130 | diversified | private |
| Kone | 123 | mechanical | private |
| Partek | 120 | diversified | private |
| Rauma-Repola | 110 | diversified | private |
| Huhtamäki | 110 | diversified | private |
| IVO | 105 | electrical | state |
| Total | 3,448 | | |

*Source:* Talouselämä 1/1989, annual reports by the enterprises.

and financing technology policy, i.e. the Technology Development Centre (TEKES), was established in 1983 to lead these programmes. The Technology Development Centre plans and organizes national technology programmes, develops international technology cooperation, and finances, through loans and grants-in-aid, the R&D carried out by enterprises. It is indicative of the expansiveness of the technology policy of the state that the appropriations of the Technology Research Centre have nominally doubled in four years (504 million FIM in 1988 and 591 million FIM in 1989) (cf. Tekes 1989).

National technology programmes are means of concentrating resources in nationally important areas of technology development. A large number of similar examples can be found in most of the other industrialized countries. In Finland, similar to other countries, the increased complexity of technologies (a need to increase cooperation among different fields) and factors of enterprise and state finance have been regarded as the most important reasons for starting up the programmes.

In 1983 12 million FIM and in 1988 to 97 million FIM were used for technology programmes. At present there are about 15 programmes in progress, of which roughly two-thirds are oriented towards improving information technology. It is a crucial, and from the Finnish viewpoint somewhat new, feature that the programmes are implemented in close cooperation among enterprises, research institutes (VTT) and universities. The role of the VTT and the universities in carrying out the R&D work is central, but this work is largely carried out under management groups assembled from representatives of the enterprises.

Subsidizing of R&D carried out by enterprises through loans and grants-in-aid is another important expenditure item of the state. The most important public of funding agency is the Technology Development Centre, which in 1988 used 359 million FIM for subsidizing R&D carried out by enterprises. Although public appropriations have strongly increased in the 1980's, the proportion of financing by the state has remained almost unchanged. The proportionate share of public financing of the R&D expenditure of enterprises is relatively low, about 7 %.

The expansion in the 1980's is also reflected in the growth of VTT. In 1981, the staff of the VTT numbered over 2,000 and in 1988 about 2,700. A significant part of the growth of VTT has been based on commissions from enterprises and on the increase of financing by the Technology Development Centre in connection with national technology programmes.



Correspondingly, the expansion of research by the universities of technology has also been based on the increase of external funding. With the exception of the most recent years, the proportionate share of the universities in the state R&D expenditure has decreased.

Again there is reason to ask what kinds of qualitative changes have resulted from the increase in the public input into R&D. Has the growth meant an increased depth, diversification or expansion of the scope of R&D activity, or is the trend the opposite? Another question concerns the role of the state. Does it orient research or is the state input only passively following the short-term needs and wishes of enterprises?

It is clear that in the 1980's in the state R&D expenditure there has been an increase in the proportionate share of applied, technical research, that serves enterprise R&D. The focus of state-funded research has thus shifted somewhat from academic, basic research to applied, technical research. However, this increase of the proportionate share has taken place without an actual absolute reduction of appropriations for academic basic research in any field. In recent years, the appropriations for basic research have thus also increased, although at a clearly slower rate than those for applied, technical research. The rate of growth has been slowest in the infrastructure expenditure (posts and equipment) of the university system.

It seems that the role of the state not only as a source of funding for R&D but also as a planner and organizer has increased. This has, however, occurred in the spirit of a strategy of positive adjustment. The state has not striven to orient the development of technology and enterprises but has adapted its own measures in accordance with the needs and wishes of the enterprises.

The needs of the enterprises have been derived from those imposed upon them by the increasing internationalization and the related toughening of international competition. It is assumed that these pressures require a coordinated use of national resources, i.e. channelling them in parallel, especially in the field of information technology which is regarded as being important.

## 6. A new culture of collaboration between industry and universities

The development in the 1980's can also be described as a substantial lowering of the threshold between industry and universities. The high-tech



enthusiasm of the 1980's has spurred enterprises into collaboration with universities, and on the other hand the interest of university researchers and students in research-intensive entrepreneurial activity has clearly increased. Thus the cultural gap between enterprises and universities has narrowed.

The most concrete manifestation of the narrowing of this gap has been that enterprises have channelled a portion of their increased research input into commissioned research to be carried out at universities. Between 1983—86, the real growth of the research funds of the Finnish university system increased by 16 %. During the same period the external financing of research increased by 43 % and, of the external financing, the research expenditure financed by enterprises increased by 94 % (Mikkola 1988, 18). Within a few years, enterprises have thus almost doubled the research they commission the universities to carry out. As a result of this development, the universities of technology are currently receiving almost as much external financing from enterprises as they are receiving from the public sector (Academy of Finland, Technology Development Centre, Ministry of Trade and Industry, and others).

At the same time university researchers' and students' interest in establishing enterprises exploiting their own research results has increased. This is the case especially in the field of electronics, and even more generally in the field of information technology. Previously the number of enterprises created as a spin-off from research was small, but at present there are dozens of such enterprises operating in the field of electronics alone. In addition, there are enterprises which have been formed by an entire research team transferring from a university or a research institute to an enterprise established by themselves (Lemola & Lovio 1988).

Science parks have been established in Finland in recent years — following the example of other countries — to promote interaction between enterprises and universities. The first science park in the Nordic countries was established in northern Finland, in Oulu in 1982. After this, six new science parks have been established and some more are in the process of being established. Thus, from 1990 onwards there will be a science park in each university town in Finland. The proportionate number of science parks in Finland is clearly higher than in the other Nordic countries.

At present the seven science parks in operation include a total of 300 enterprises, and the staff of these enterprises totals 2,200. The plan is that in 1995 the number of such enterprises will be 900 and their staff will total 11,000. The enterprises operating in the science parks are in the main quite small, but some old large companies have also established new R&D units in them in order to recruit new researchers (Vuorinen, Tikka & Lovio 1989).

The science park model was introduced to Finland largely by professors of information technology on the basis of those they had seen in the U.S.A. and England. The enterprises, university laboratories and research institute laboratories which have been established in the parks, or which moved to them, are also mostly operating in the field of information technology. For example, about one-half of the 85 enterprises operating in the science park of Oulu are in the field of information technology. The Faculty of Technology of the University of Oulu and two electronics laboratories of VTT are operating in the park or in its immediate vicinity. There are electronics units of four large enterprises (Nokia, Norsk Data, Valmet and Rautaruukki) and 80 small enterprises in the park. Of the small enterprises, about a dozen are spin-offs from research projects implemented at a university or VTT. The science park characterizes itself as a meeting place for high-standard research and business activity (Tunkelo 1988).

Training programmes implemented jointly by enterprises and universities have in recent years become also a new form of collaboration between enterprises and universities. For example, Nokia Oy has started a rather extensive training programme for its staff. The express objective of the programme is to raise the academic degree of every second staff member in the enterprise by one notch within ten years. For example, the aim is to produce in the near future 200 licentiates in technology. The theses and dissertations will be written mainly during the regular work on topics determined by the company.

Interaction between enterprises and universities has thus become clearly closer. It is evident that the enterprises are benefitting from this increased collaboration. They are receiving research services which they themselves are either unable or unwilling to perform. On the other hand, good contacts with universities ensure that active enterprises will be able to recruit the best part of the new graduates for R&D tasks.

As regards the universities, the situation is more conflicting. On the positive side the universities thus obtain new resources and in part also challenging research projects of interesting content. Thus the risk of research becoming too confined is not great.

On the other hand, commissioned research and the general orientation towards entrepreneurial activity may weaken basic research. According to a recent study, the increasing number of doctoral dissertations in the field of technology, which had been continuing for a long period, changed to a decline in 1985 (Räty 1988, 13—14). The study anticipates the future as follows: "It is probable that the number of inspected dissertations in technology will rise, because the research institutes and even industrial enterprises will themselves train some (perhaps even most) of the doctorates they will need. But indeed the number of doctoral dissertations should in some twenty years almost double from what it is at present in order that the ratio between the demand for professorial posts and the number of doctorate holders should remain at the present level." (Räty 1988, 33).

## 7. Rapid internationalization of R&D activity

Up to the 1980's the R&D of Finnish enterprises was highly national. In this respect the change has been especially drastic in the most recent years.

The original intention was to exclude Finland entirely, — for foreign-policy reasons — from the Eureka programme, which began on the initiative of the French government. However, Finland actively sought participation. At present there are about 230 Eureka projects in progress, and Finnish enterprises or research institutes are participating in 24 of them.

In 1986 a special treaty on R&D cooperation was signed between Finland and the Comission of the European Communities. The treaty has opened the doors to Finnish companies and research institutes to participate in the big research programmes of the Comission (e.g. ESPRIT, RACE, BRITE). For the time being the Finnish research organisations and enterprises are involved in more than 30 research projects.

Finland joined the European Space Agency (ESA) as an associate member in 1987. The conversion of the separate agreement between Finland and CERN into membership is at present under discussion. Finland has already joined the European Molecular Biology Laboratory (EMBL).

Almost 200 million FIM is being used by the state annually in Finland for international scientific-technical research projects. This sum is not large in an international comparison, but on the Finnish scale it begins to be considerable. Therefore both enterprises and politicians who are involved in science and technology policies have initiated a discussion on how rapidly international collaboration should be expanded after the explosive start of recent years. For example, the full membership in CERN would cost annually FIM 50 million, which Finland has not been willing to pay, at least for the time being.

Participation in international research will thus consume a great deal of resources. There may also be the risk that international collaboration directs research away from nationally important topics of research in which there is no interest in other countries (for greater detail on these problems, see Stolte-Heiskanen 1987).

## 8. Special Finnish development features and problems

Now it may be asked whether the development features of the relations between science and production described above include certain features typical of Finland.

If we examine the matter qualitatively, our answer is briefly: No! It could rather be said that Finnish enterprises and politicians involved in technology policies have been relatively fast in adopting the models developed in the larger OECD countries. For example, the coordination of science and technology policy, the initiation of national technology programmes, and the founding of science parks occurred in Finland at least as briskly if not even faster than in the other Nordic countries. It is thus no wonder that the group of OECD experts who evaluated Finland's technology policy in 1986 ended up with a very positive statement (OECD 1986). The "model" of Finland complies very precisely with the line of development recommended by OECD. Original innovations concerning the orientation or organization of the technology policy have not been developed in Finland.

Finland's special feature is, after all, primarily quantitative: the quantity of R&D activity has been lower than average, in both absolute and relative terms compared to the other OECD countries, but the rate of growth has been faster than the average. In a wider international comparison the special features of Finland may — mainly in the quantitative sense — resemble the development features of certain newly industrialized countries (South Korea, Taiwan).

The shortage of researchers, which came about as a consequence of the rapid development in the 1980's, has become the biggest practical problem in the R&D activity of enterprises in the rapidly developing fields of information technology and biotechnology. In the development programme prepared by the Academy of Finland for the fields of biotechnology and molecular biology for 1988—1992, it is stated that "the small number of competent researchers constitutes a substantial obstacle to extensive exploitation of biotechnology in our country." Our survey on innovation in the electronics industry arrived at the same result (Lovio 1988, 34—36). "In Finland money is now comfortably available; there is rather a shortage of experienced people at the project leader level. It is true that there seems to be a similar shortage everywhere," states a leading researcher in neural network computers (*Uusi elektroniikka* October 17, 1988).

The pull into applied R&D has thus been so strong that the training of researchers, traditionally taking place in the universities, has not been able to keep up with the demand. Basic research, and training occurring in conjunction with it, would thus clearly need an additional injection, at least in rapidly growing fields, so that the R&D by enterprises would not in the near future drain this source. At the same time, better conditions for research should be secured for researchers in universities, and the gap between their salaries and those paid by the industries should be narrowed.

There is a risk that the shortage of researchers and, more widely, the increased need for supplementary training for individuals already working in enterprises, will be reacted to by increasing the quantity while compromising with the quality.

The qualitative change which has taken place within the past twenty years in the relations between science and production, i.e. the rapid growth of R&D in enterprises and its increasing interaction with scientific basic research, may lead to exhaustion of the sources if the basis of the scientific infrastructure is not secured.

At the same time, the increasing interaction between science and production even at its most effective cannot and will not lead to a situation in which scientific research is subordinated to technological research: the technological push of science will cease if its relative independence and its development according to its own laws are entirely eliminated.

Furthermore, a technology-intensive science policy also requires other than applied technical research. As the Chairman of the Central Board of Research Councils of the Academy of Finland, reminds us:

> "As we know, technological development is accompanied by certain threats and risk factors. On the theoretical level there has often been discussion about a so-called technosystem which, as an autonomous system complying with its own laws, will rise above the traditional culture and political activity and reduce choice in people's lives and in the functioning of the national culture. At a more concrete level we see how technological development, if poorly managed, may bring about ecological catastrophes, produce pollution, increase unemployment, and cause deterioration of work. These consequences are not caused by researchers of technology, but they may appear if technology is allowed to develop into an autonomous system and if the effects of technological development on nature, man and society are not monitored sufficiently. For this very reason inputs into technological research require more support and activity also in other fields. In fact, the greater the input into technology and scientific-technical research, the greater the input must be also into, for example, environmental research, social sciences, and humanistic cultural research." (Allardt 1987, 8—9).

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recent study, the increasing number of doctoral dissertations in the field of technology, which had been continuing for a long period, changed to a decline in 1985 (Räty 1988, 13—14). The study anticipates the future as follows: "It is probable that the number of inspected dissertations in technology will rise, because the research institutes and even industrial enterprises will themselves train some (perhaps even most) of the doctorates they will need. But indeed the number of doctoral dissertations should in some twenty years almost double from what it is at present in order that the ratio between the demand for professorial posts and the number of doctorate holders should remain at the present level." (Räty 1988, 33).

## 7. Rapid internationalization of R&D activity

Up to the 1980's the R&D of Finnish enterprises was highly national. In this respect the change has been especially drastic in the most recent years.

The original intention was to exclude Finland entirely, — for foreign-policy reasons — from the Eureka programme, which began on the initiative of the French government. However, Finland actively sought participation. At present there are about 230 Eureka projects in progress, and Finnish enterprises or research institutes are participating in 24 of them.

In 1986 a special treaty on R&D cooperation was signed between Finland and the Comission of the European Communities. The treaty has opened the doors to Finnish companies and research institutes to participate in the big research programmes of the Comission (e.g. ESPRIT, RACE, BRITE). For the time being the Finnish research organisations and enterprises are involved in more than 30 research projects.

Finland joined the European Space Agency (ESA) as an associate member in 1987. The conversion of the separate agreement between Finland and CERN into membership is at present under discussion. Finland has already joined the European Molecular Biology Laboratory (EMBL).

Almost 200 million FIM is being used by the state annually in Finland for international scientific-technical research projects. This sum is not large in an international comparison, but on the Finnish scale it begins to be considerable. Therefore both enterprises and politicians who are involved in science and technology policies have initiated a discussion on how rapidly international collaboration should be expanded after the explosive start of recent years. For example, the full membership in CERN would cost annually FIM 50 million, which Finland has not been willing to pay, at least for the time being.

Participation in international research will thus consume a great deal of resources. There may also be the risk that international collaboration directs research away from nationally important topics of research in which there is no interest in other countries (for greater detail on these problems, see Stolte-Heiskanen 1987).

## 8. Special Finnish development features and problems

Now it may be asked whether the development features of the relations between science and production described above include certain features typical of Finland.

If we examine the matter qualitatively, our answer is briefly: No! It could rather be said that Finnish enterprises and politicians involved in technology policies have been relatively fast in adopting the models developed in the larger OECD countries. For example, the coordination of science and technology policy, the initiation of national technology programmes, and the founding of science parks occurred in Finland at least as briskly if not even faster than in the other Nordic countries. It is thus no wonder that the group of OECD experts who evaluated Finland's technology policy in 1986 ended up with a very positive statement (OECD 1986). The "model" of Finland complies very precisely with the line of development recommended by OECD. Original innovations concerning the orientation or organization of the technology policy have not been developed in Finland.

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Tarmo Lemola
Technical Research Centre of Finland (VTT)
Vuorimiehentie 5
02150 Espoo
Finland

Raimo Lovio
The Finnish National Fund for Research and Development (SITRA)
Uudenmaankatu 16—20 B
00120 Helsinki
Finland





# REVIEWS

Paul Feyerabend (1984): *Wissenschaft als Kunst.* Frankfurt am Main: Suhrkamp, 169p.
Paul Feyerabend (1987): *Farewell to Reason.* London: Verso, 327p.

With these two collections of articles, most of them easily accessible to the non-specialist, Feyerabend transgresses the limits of the philosophy of science somewhat more radically than in his earlier work. Even though various facets and mechanisms of "Western rationalism" have been criticized by Feyerabend all along, in the books reviewed here one can detect a shift of emphasis (away from primarily science-internal questions like methodological anarchism) and a widening of perspective (recurrent discussion of global problems).

Of the twelve articles in *Farewell to Reason (FR)* two papers (on creativity and on progress in philosophy, arts and the sciences) also appear in *Wissenschaft als Kunst (WK),* and of the six articles of *WK,* one (on Aristotle's theory of the continuum) is but a shorter version of a study contained in *FR.* Of the remaining three articles of *WK* two deal with familiar Feyerabendian topics (the sciences as political institutions) and the title essay deals with the relation between science and art. *FR* also includes critical papers on Popper and Putnam, studies on Mach's and Einstein's theories of research, on Galilei, the emergence of scientific rationality among the Greeks, notes on relativism, and two programmatic papers, one of which gave the book its title.

Since this wealth of material cannot be adequately dealt with within the limits of a brief review, I shall confine myself to a brief summary of, and some critical comments on, the following themes: (1) the relations between science and art, (2) relativism and (3) Feyerabend's employment of historical examples.

(1) *Science and art.* The parallel between science and art — an interesting topic that has been discussed previously e.g. by Kuhn (1977) — is used by Feyerabend for two main purposes: to elaborate upon his conception of progress and to attack what he regards as mystifying conceptions of creativity. In "Wissenschaft als Kunst" *(WK* 17—84), Feyerabend outlines the art theory of Alois Riegl (developed in the latter's *Spätrömische Kunstindustrie* (1901)), and then applies the Rieglian model of stylistic periods to the history of science. Just as the history of art consists of stylistic periods each of which contains its own inherent goals, ideals, means, methods and criteria of success, so also the history of science does not display any universal and context-independent axiologies and methodologies. In other words, ways of ordering experience are relative to specific historical styles, i.e. — in Riegl's *fin de siècle* vocabulary — relative to a specific *Kunstwollen.* As Feyerabend puts it in another essay, "Progress in Philosophy, the Sciences and the Arts" *(FR* 143—161, *WK* 85—106), the judgment that "qualitative progress" has taken place can only come from *within* a given framework.

In examining the ideas of Riegl, who was first and foremost a historian, Feyerabend could well have stated some of his own historiographical principles (as he did, although very vaguely, in Feyerabend (1975) and (1978)), but he does not take this opportunity. We also learn very little about art or the artlike aspects of science despite some interesting historical examples. Art is used, much like voodoo or gangster mobs in Feyerabend's earlier analogies, in a predominantly negative way. It is a weapon for attacking some of the presuppositions (the notion of unrelative progress in this case) underlying the belief in the inherent superiority of science as compared to other human enterprises.

In his treatment of creativity, Feyerabend somewhat surprisingly rejects the whole notion as mystifying and useless. He exemplifies this mysticism by quoting Einstein, who saw theory construction as "free mental creation" *(FR* 132), and he uses Mach to point out the weaknesses of Einstein's conception. Mach is able to overcome the mystifying account because he moves away from the "separatist view on human being" underlying it, "the view, that is, that there exists an 'objective' world and a 'subjective' realm, and that it is imperative