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Internal and external constrains on the orientation of science and technology to socio-economic development in a small country: the case of Finland

Strengthening the potentials of science and technology for socio-economic development is an explicit major concern of science policies everywhere. This is especially the case in countries on the so-called periphery, where the advancement of both science and technology and economic development are to a great extent dependent on one's position in the international science system on the one hand, and on the structure of world markets, on the other. The present paper focuses on the effects of structural constraints related to a peripheral position on the integration of science and technology into national development goals, and their consequences for indigenous scientific and economic development. Finland, because of its demographic, structural and historical characteristics serves as a good example of a small country on the European periphery.

It goes without saying that from a global socio-economic and scientific technological perspective Finland is a small peripheral country. Situated on the border of the Arctic tundra, it has a population of about 4.8 million inhabitants. As is typical of industrialized countries, more than half of the labor force is engaged in the service sector, about one-third in industry, and little over ten percent in agriculture. Finland's share of the world's industrial production is about 0.4 percent and of international trade about 0.8 percent. Economic development is greatly dependent on participation potentials in world markets.

The structural limitations imposed by size as well as language on the science system place the country also in this respect on the periphery. In 1987 R&D expenditures as a share of GDP was 1.7 percent and the estimated contribution to world science about 0.2 percent. As is typical of peripheral countries, scientific activities are pursued in the context of dual commitment to nationally and internationally oriented and informed R&D. There are 63 scientists engaged in R&D per 10,000 inhabitants and the research personnel represent 1.2 percent of the total work force. In absolute numbers, however, the scientific community in 1983 consisted of a little over thirty thousand persons (OECD, 1987).

It is an equally commonplace observation that Finland is also a capitalist country. As such, social and economic development is to a great extent determined by the constraints of the short-term economic rationality of capitalism. This implies that insofar as societal support and demands on science

and technology correspond to the functional needs of society, these functional needs are increasingly determined by the more or less invisible hand of the market.

Both of these self-evident characteristics impose certain internal and external constraints on the partnership between science and technology and social and economic development. On the one hand, the structural regulation of the scientific sector by the state, e.g. through science policy, imposes certain constraints on the scientific community. On the other hand, particular characteristics of the scientific community due to its small size, historical development, and cultural traditions produce internal constraints on the scientific sector itself, at time acting against at other time reinforcing the goals of the state structural regulation strategy. Both factors have had consequences on shaping the role played by science in contributing to the development goals of Finnish society. This is illustrated first by a historical review of the institutionalization of science and its role in societal development. This is followed by an analysis of the changing partnership between science and society following the radical transformations brought about by the post-war modernization of the country.

Historical perspectives on the evolution of the scientific community and the social role of science

The first step in the institutionalization of science came from the center during the Swedish colonial period, which lasted until 1809. It was initiated by the Swedish rulers' need to expand the higher educational system to meet the growing demands for more and better trained civil servants for the territorially expanding state. A new university was founded in 1640 in the politically safer, older province of Finland, in the former capital of Turku. Teaching was in Swedish, and for a long time the faculty was recruited from Sweden proper. From the point of view of indigenous social development, the early institutionalization of a university identified with a prestigious center facilitated the eventual emergence of a high social value placed on higher learning and scholarship in Finnish society. The university subsequently became the center of intellectual leadership in the country initiating a pattern of strong extra-academic and extrascientific ties of scientists.

The annexation of Finland to Russia as an autonomous Grand Duchy in 1809 signified the birth of a separate Finnish state and the beginning of intense national development. The transfer of political power over the university to Saint Petersburg was visibly sealed by moving it to the new capital of Helsinki, and renaming it the Imperial Alexander University of Finland (later to become the University of Helsinki). In 1852 the university underwent major structural reorganization toward scientification and disciplinary differentiation. It was divided into two faculties: the natural sciences and humanities. The reorganization was partly a reflection of the general modernization process of the universities of the time, but was also politically motivated to ensure Russia's political control over the university. The institutionalization of a strong, politically neutral natural sciences was expected to shift the balance of power from the potentially subversive nationalist ideological orientation of the humanities (Elovainio, 1972). This was only partly successfull, since a scientifically significant natural sciences did not emerge for a long time to come.

At the time of annexation to Russia the overwhelming majority of Finland's 900,000 inhabitants were engaged in agriculture. In the relatively static agrarian society the immediate *aims of social development were the creation and consolidation of national culture* rather than the economic transformation of society. The sciences, as embodied in the university, were to play an important role in this process. The nation-building mission of the university as the intellectual and cultural center of society was reflected in the emphasis on *national* knowledge production: in the humanities on the history, language, folklore and traditions of the Finnish people, in the natural sciences on inventorying the natural resources of the country.

As part of this nationalization process there was also an increasing shift toward the creation of scientific and professional cadres among the Finnish speaking majority population. Up until 1880, when 14 % of the population was Swedish speaking, the majority of the university students were from the Swedish speaking minority.[1] However, the significant increase in the number of students by the end of the century was largely attributable to the rapid growth of enrollment from the Finnish speaking population (Löppönen & Tamas, 1985).

As it is well-known, Finland — along with the other Scandinavian countries — was a latecomer to industrialization. The process of industrialization was strongly dependent on exports, revolving around a single natural resource, the forests of Finland. As a result of the growing demands of foreign markets (especially England) the forest industry emerged as the main branch of industrial production. By the end

of the 19th century, the forest industry accounted for 30 % of the GDP. As is typical of peripheral countries, the initial impetus in the form of capital and technological know-how came from abroad — mostly from England, Germany, and the neighboring countries. (Jörnberg, 1979)

Due to the growing demands of foreign markets and the increased productivity of the forest industry, because of a combination of cheap domestic labor and imported technological know-how, the gross value of industrial production increased sixfold between 1885—1915. Despite the relatively rapid transfer of instrument and process technologies, because of the weak expectations of surplus value of innovations, problems in capital accumulation, and lack of qualified indigenous technical and commercial know-how, the diffusion of technology in the country remained slow. There was, however, a growing awareness of the need for the development of indigenous science and technology.

The attempts to integrate science and technology with national development goals were not without difficulties. While there was general agreement on the utility of science and technology for the advancement of societal goals, there was far less consensus on *what these goals should be.* The industrial revolution in Finland was at the same time a nationalist revolution with major cultural values at stake. The interests of the largely Swedish speaking economic elite centered on the promotion of industrial development, while the nationalist movement of the Finnish speaking majority placed high priority on agricultural development. These conflicting interests were also reflected in the diverse pressures on the institutional development of science and technology.

The growing needs of industry for engineers and scientists trained in the technical sciences led to increasing pressures to establish a technical university. This in turn met strong opposition from the Finnish speaking clergy and peasantry, whose ideological commitments and practical interests lay in the development of higher education in the agricultural sciences. On the other hand, attempts to establish a faculty of agricultural sciences at the University of Helsinki was successfully resisted by the university in its strong commitment to Humboldtian ideals in a struggle that lasted more than a decade (Elovainio, 1972). The conflict over technical versus agricultural sciences and over the legitimate home of the applied sciences — in which class, language and ideologies of national development intermingled — was eventually resolved by founding the first polytechnical university in 1908. In the same year a faculty of agriculture was finally established at the University of Helsinki (Stolte-Heiskanen & Alestalo, 1978).[2]

The legitimacy of the university as an institution primarily oriented toward the production of higher learning per se was deeply imbedded in the value system of Finnish society. The social function of the university was essentially one of enlightenment and education. Thus the growing demands of the productive sector for science oriented toward utilitarian ends had to be met by other institutional strategies. Beginning from the end of the 19th century this led to the creation of "mission-oriented" research institutes by the state, each specializing in fields related to the main sectors of economic exploitation of natural resources of the country (e.g. agriculture, geology, marine science, etc.).[3]

When Finland gained independence in 1917 industry still played a relatively minor role in production.[4] However, the intensified efforts of national development and demands for new infrastructures created by the newly independent state stimulated further institutional integration of science and technology into social and economic development. More sectorial state research institutes were established, and research also began to be more directly linked to the particularistic demands of the business enterprise sector, which began to create their own research centers — such as the research center for paper and chemical technology founded in 1917 by the strongly monopolized forest industry, or the research laboratory for biochemical research promoting the dairy economy founded around the same time by the major dairy firm, Valio.

Up until independence the University of Helsinki was the only institution of higher learning in the country. In 1917, a Swedish language university was established in Turku (Åbo Akademi), on the one hand, to ensure the continuity of the cultural reproduction of the Swedish speaking minority population, and on the other hand, to promote training in natural and technical sciences to meet the demands of industry to a great extent dominated by the Swedish linguistic minority.[5] Consequently, another, Finnish language university was created in Turku three years later (The University of Turku) by nationalist Finnish circles to educate nationally conscious civil servants and support research in the national sciences and humanities.[6]

The societal motives for supporting science are rarely based purely on the advancement of universal scientific knowledge production per se. The examples above illustrate how different and often conflicting social interests shaped the particular form of institutionalization of scientific activity of a small country. The initial functional needs giving

rise to the different institutional structures eventually changed or altogether disappeared in the course of societal development. However, the second order cultural interpretations of the social functions and role of science and technology that evolved in the process of institutionalization have had lasting effects on the later attempts at integration of science and technology with changing societal goals.

The process of institutionalization also gave rise to distinct patterns of internal constraints on the scientific community. Gieryn's concept of "boundary work" describes the ideological strategies employed by scientists in the construction of boundaries between science and non-science, and within science between different domains of expertise (Gieryn, 1983). The historical emergence of the Finnish scientific community suggests that such ideological boundary work is particularly actively pursued at the time when the "intellectual ecosystem" (Boulding, 1980) of scientific activities is being shaped.

In the demarcation of cultural versus utilitarian missions of knowledge production and in the competition over the relative status of pure science vs. useful science, humanities vs. natural sciences, of technical vs. agricultural sciences, different segments of the scientific community resorted to the prevailing competing ideologies of traditionalism and modernity, nationalism and progress, right wing politics, and internationally oriented national development. Under conditions of small size and the scientific community's peripheral position in the global scientific world, the boundary work inevitably led to the social and political identification and alliance of members of the scientific community with different societal groups whose interests the ideologies expressed. These "historical residues" (Yearly, 1987) of early politicization evolved into a pattern of internal constraints that continue to play a role in the self- regulatory policies of the scientific community in the face of structural strategies of societal direction of science and technology.

The reorientation of science in the post-war era of modernization

Following World War II Finnish society entered a period of massive structural changes associated with conscious attempts at modernization. In the process of national reconstruction *modernization associated with economic development became a major social goal* unanimously embraced by all sectors of society. An important part of the post-war efforts concerned the reorientation of science to meet the challenges of rapid social and economic change. Within academic science this meant the structural transformation of the university from the Germanic tradition to the modern Anglo-Saxon model. The old, chair-centered system of higher learning was reorganized into disciplinary departments facilitating the rise of a modern professional scientific community. Also the intellectual orientation of the scientific community shifted increasingly toward the Anglo-Saxon world of science.

As part of the universities' modernization process the natural sciences were upgraded and the modern social sciences came into their own.[7] The latter began to play an important role in the modernization processes by reinterpreting the social realities of Finnish society in terms of the concept of industrial society.

Although in the early post-war years science was still perceived as essentially a cultural good, there were growing debates over the position and function of science in a radically changing society. A conflict emerged within the scientific community between supporters of the traditional view of science as a purely intellectual pursuit of knowledge by a select group of savants and the proponents of modernization of science as a research activity carried out by trained professionals. This was articulated through heated political debates over the first post-war institution to be founded for the promotion of science.

Up until 1949 the only governmental body concerned with science administration was a scientific advisory board (Central Board of Science and Letters) appointed in 1918. The small amount of support to academic research was funded out of the state lottery profits, and to a limited extent by small private foundations. The support to academic science — such as it existed — was justified solely in terms of its contribution to the cultural development of the country.[8]

At the time when in the advanced industrialized countries the principle of science as a strategic national resources was already gaining grounds, in Finland the first post-war scientific institution, the former Academy of Finland was created to promote the "higher cultivation of the spirit". The founding of a prestigious assembly of 12 academicians was opposed by the modernizers in science, who called for the creation of a more comprehensive and universalistic research funding organization. They drew political support from the socialist party, who opposed the Academy on political grounds of perpetuating elitism and because of the known former right wing affiliations of many of the

academicians. In the established societal tradition of interest group politics a political compromise was reached by founding two research councils (humanities and natural sciences) alongside the 12 academicians. Since the resources of the research councils remained insignificant, even compared to e.g. private foundations, the issue hardly had any practical implications (Falk, et al., 1975).

The importance of the Academy debate lay in the unsuccessful testing of new principles concerning the future status and functions of science in society. Consequently, up until the end of the 1950's subsequent attempts by the scientific community to gain increased financial support for science in general remained relatively unsuccessful, partly because of internal conflicts between the traditionalists and modernizers over the relative status of the humanities and of "pure" vs. useful science. In the meantime, also the business enterprise sector began to express active interest in the potentials of science and especially technological research and development.[9]

After the war efforts to participate in international economic integration increased. In this industrial strategy the most important growth factors were good price competitiveness (low wage levels) and high rate of investments. The modernization of industry, however still relied on transfer of technology from abroad. The demands of high rates of investment placed the responsibility for the intensification of industrial production on the state. The state thus became the main provider of risk investments and promoter of the structural transformation of industry.[10] Despite the efforts of diversification of the industry and the consequent increasing demands for qualified manpower, the conditions for the development of science and technology to meet the newly emerging needs improved little in the immediate post-war period.

The "science as an investment" ideology already firmly institutionalized in the Western world, reached Finland only in the 1960's during a general period of change in Finnish society. The regulative functions of the state were enlarged and new administrative structures were created to accomodate the rapidly growing planning functions. In the general mood in favor of "rationalization" and planning in public decision-making, science and technology began to be systematically reassessed both by the state and the business enterprise sector as a means of promoting economic growth. This eventually led to the formulation of a science policy. The emergence of the active role of the state in the direction of science and technology toward national development, under modern capitalistic conditions of small countries inevitably led to the more or less explicit and permanent alliance of science and technology policy with industrial policy.

A state committee on the organization of scientific research was appointed in the beginning of the 1960's to survey the research system. The committee concluded that the ravages of the war, the narrow, particularistic focus in science around a few distinguished scientists, lack of support by the state, and weak research input from industry have led to a state of retardation of Finnish science when it is unable to fulfill its essential role in contemporary society.

The committee's report introduced for the first time the concept of *science policy*, designed to guide the direction of research and training and to channel funds for research. Also for the first time, the goals of scientific knowledge production became defined in terms of social utility: "The new goals of science are to contribute to the improvement of our material living conditions and appropriate utilization of research results" (Komiteamietintö, 1964). Subsequently the committee's proposals led to the evolution of a central science administration system by the end of the 1960's.[11]

A ministerial committee, The Science Policy Council, was established in 1963, whose most visible role has been to initiate science policy programs. In 1969 the old system of academicians' posts was abolished and the Academy of Finland was radically reorganized into a research funding agency composed of seven research councils. The Academy subsequently became the main state organ for science administration and science policy planning in the public sector.

The Ministry of Education was also reorganized to improve the central administration of the institutions of higher education, and the higher education system was rapidly expanded. The higher education reform was partly motivated by ideological demands for more egalitarian educational opportunities, partly by political pressures to diminish regional inequalities, and partly to redistribute student enrollments according to the changing needs for qualified scientific and technological manpower.

By the beginning of the 1970's a network of 17 higher educational institutions was created, the expansion taking place exclusively on a regional basis. The higher educational policy was relatively successful in the redistribution of the flow of students, especially in precipitating a substantial increase in enrollments in the technical sciences. The policy also promoted the goals of regional develpoment insofar as access to higher education considerably improved, and a stock of professional manpower

was created in the regions (Räty, et al., 1985). On the other hand, the integration of research with regional needs has met with relatively little success (OECD, 1987). In many disciplines it resulted in dispersion into dysfunctionally small units, and introduced a new element of internal constraints into the scientific community in the competition for centrally administered research funds. These problems are becoming increasingly evident with the growing emphasis on the research functions of the universities.

The industrial structure began to undergo major transformations during this period. On the one hand, the share of the labor force engaged in agriculture fell from 46 % in 1950 to 20 % in 1970, while that in industry increased from 27 % to 34 %. This trend intensified in the 1980's, with major expansions taking place in the service sector.[12]

The development of industry was particularly evident in the so-called research intensive branches of production. By the end of the 1970's more than half the productive enterprises were in the research intensive fields, and they employed about two-thirds of the industrial labor force. This process went hand in hand with the concentration of industry into larger business enterprises, where R&D activities can be most profitably exploited (Stolte-Heiskanen & Alestalo, 1978).

The 1960's was the golden age of science in Finland. Economic *growth optimism* coupled with *planning optimism* also put faith in the *endless frontiers* of science and technology to promote social and economic development. Science policy efforts concentrated on the creation of appropriate infrastructures and on the *quantitative* increase of human and material resources without any structural regulation. R&D investments rose from a negligible 0.35 % of the GDP in 1956 to 0.80 % by 1969, and to 1.7 % by 1987. From the mid-sixties there has also been a steady increase in the share of the business enterprise sector in the total R&D investments from 48 % in 1964 to 56 % in 1983 (OECD, 1987).

However, as in all advanced Western societies, the optimism of the economic growth era began to wane in the 1970's. On the one hand, the assumed relationship between quantitative expansion of the scientific effort and economic growth proved to be less direct than expected. On the other hand, there was a growing awareness that without social direction technological and economic progress based on scientific and technological research does not unconditionally increase the the general welfare of society. Consequently, in the early 1970's there was a shift from what has been called policy *for* science to a policy *through* science (Salomon, 1977). This introduced conscious attempts at structural regulation of scientific-technological activities toward social goals defined by the political and socio-economic sectors of society.

For the first time, the different interest groups of society began to actively participate in the formulation of science policy. The business enterprise sector was the first to draft its own research policy program in 1970, wherein the need for formulate research policy according to the dictates of industrial policy were explicitly stated (Suomen Teollisuusliitto, 1970).[13] Also all major political parties prepared their own science policy programs by the mid-1970's. Each pressure group drew upon the expertise of allied factions of the scientific community. Subsequently, the cleavages that emerged in the scientific community as a result of the political alliances created during the rise of the radical student movement at the end of the 1960's were further reinforced by the split over science policy.

Eventually the first comprehensive science policy program, drawn up in the spirit of OECD recommendations by the Science Policy Council and the Academy of Finland, came into effect in 1973 (Central Board of Research Councils, 1973; Science Policy Council, 1975). Science policy was conceived as an integral part of the government's overall societal policy, and aimed at linking science more closely to the improvement of the quality of life. Accordingly, societal policy goals were to serve as the main guidelines in allocating resources to various sectors of science. Five priority areas were defined that were optimistically expected to contribute to "an increase in employment and economic welfare, reduction of inequalities and improved balance of payments" (Central Board of Research Councils, 1973).

By the end of the decade, however, it was evident that for a variety of reasons the science policy program failed to achieve its goals. On the one hand, the definition of priority areas represented the outcome of a process of political compromise, without consideration of the possibilities of transformation of societal goals into research objectives. Moreover, the program was based on a naive assumption about the role of science-based intelligence in the "rationality" of the political decision-making process. On the other hand, in the face of the traditional resistance of the academic scientific community to encroachments on their autonomy by science policy directives led to their circumvention. Through a self-regulatory sharing strategy the resources allocated through the priority areas were

in fact used in the traditional way for basic research goals defined by the scientists themselves. Empirical studies have shown that science policy guidelines concerning research goals have had at best a negligible influence on the selection of research themes of projects supported under the priority programs (Stolte-Heiskanen & Alestalo, 1983).[14]

Another important reason for the failure of the socially relevant science policy program, however, is found in the structural constraints embedded in the state administration, wherein the planning process is subordinate to the budgetary process. As such, the long- term expectations expressed in politically formulated planning objectives are regularly confronted by the economically determined short-term budgetary constraints. (Seppälä, et al., 1985) Of course, this concerns not only science policy, but also planning in any other sector, such as e.g. social or regional policies. Thus the science policy program, based on ambitious plans for increasing the financing of research was rapidly challenged by the effects of the world-wide depression in the mid-1970's, which necessitated a tightened fiscal policy.

Because of the economic recession, the planned growth in research investments remained way below the mark, and the reduction was affected especially in the not economically oriented, so-called socially relevant research areas (Räty & Csöndes, 1985).

Recent developments and emergent constraints on science and society

Recovery from economic stagnation required a change in the competitive situation of the Finnish industry. In the quest for increasing penetration of the Western markets *innovative capacity* became of equal if no greater importance than *quality*. Consequently, the stimulation of industrial innovation came to be considered as the crucial means for promoting economic growth in the 1980's. Thus, after the mid-1970's the country embarked on the adoption of an innovation policy based on offensive measures to stimulate innovation through industrial diversification and restructuration of exports. Since technological innovation has become the primary means of competition, the last decade has witnessed a further intensification of the integration of technology policy with industrial policy, and an increasingly one-sided priority given in research efforts to industry-related objectives.

At the same time there has been an increasing emphasis on the promotion of international scientific cooperation. The means for participation in the international scientific community have been substantially improved. Basic research is especially strongly encouraged to be oriented toward the centers and the goals of basic research are increasingly stipulated by criteria of international excellence. Internationally oriented scientific activities have thus become a significant means of competition within the scientific community for accumulating nationally socially convertible cultural capital.

In 1981 a more pragmatic science policy program came into effect (Science Policy Council, 1981). It was less guided by the imperative of improving the quality of life than by more limited *goals of advancement of industry and concomittant advancement of technology.* According to this new science policy program, since in the past science paid insufficient attention to the impact of the international economic situation and to the development of new type of production based on the available natural resources, now there is a need for research oriented toward the solution of techno-economic and structural problems of society. Consequently, in addition to basic research, particular emphasis is to be put on research on energy resources, research promoting the innovative capacity of industry, and research related to societal policy and public services. (Science Policy Council, 1981, Report of the Finnish Technology Committee, 1982). Developments in the structure of R&D funding, however, show that of the four policy priorities only those related to industrial policy have been vigourosly supported.

Although since 1977 there has been a steady increase in the total resources devoted to science and technology, the share of basic research in the total public R&D investments has declined from 54 % in 1970 to 39 % in 1984, while there was a 169 % growth in the funding of technological research.[15] In 1986 the share of research in social development and services constituted 14 per cent of government R&D funds. In the same year the share of the Ministry of Trade and Industry of R&D funds allocated to ministries was greater than that of the Ministry of Education, responsible for supporting the universities (39 %, and 37 %, respectively). In general the main home of basic research, the universities, have become more dependent on various external sources of funding, their share now being over 40 per cent of the universities' research expenditures. The increase in extramural funding has come mainly from governmental administrative units and the business enterprise sector. (Kunttu, 1986; OECD, 1987). Thus the share of contractual research has steadily increased in both absolute

and relative terms.

One can say that on the surface the strategy of integration of science and technology into economic development has been successful. As the recent OECD review of Finnish science and technology policy concludes, "the performance of the Finnish economy has been better than the average of the OECD countries in the 1980's". Around the turn of the decade (1977—1982) the GDP increased at an annual average rate of 3.7 %. The structure of industry has changed, and metal and engineering products superceded forest products as the largest sector of industrial production. The formerly dominant position of the forest industry in exports has decreased to 38 % and the share of the metal industry grew to 35 % and of the chemical industry to 13 %.

Although forest products remain important to the Finnish economy, industrial modernization and restructuring have led to the development of material and energy saving new high-technology sectors, especially in industries associated with chemicals (plastics, pharmaceutics), electronics, information and telecommunications, as well as more broadly metal and engineering industries at large. While the share of high-technology products in exports is still a relatively low 5.2 %, its importance is rapidly growing. Recently, the annual growth in the relative share of high-tech export products has increased at an annual rate of 21 % (OECD, 1987; Åkerblom & Virtaharju, 1987). According to OECD statistics Finnish international publication output has increased from 260 in biotechnology, 82 in new materials and 30 in microelectronics in 1975 to 356, 111 and 52, respectively, in 1985 (OECD, 1988).[16]

It is another question, what are the long range consequences of this success story for sustained economic development and for social development, as such. Obviously the socio-economic development of Finnish society is increasingly influenced by the external constraints of the international market. Consequently, in the course of its evolution into the present-day advanced industrial society, national development goals have been progressively narrowed down first from nation-building to modernization and then to international economic competitiveness. In this process diffuse expectations concerning the social role of science and technology changed to specific demands. Concomittantly there has been a steady increase in the structural regulation of science by a socio-politico-economic system that is inevitably increasingly guided by *economic and technocratic frames of reference.*

Industry, whether private or publicly owned, operates according to criteria of capital accumulation and optimal returns. Characteristically, in advanced capitalist societies, such as Finland, the state assumes the responsibility for securing the conditions of capital accumulation and realization of profits. One part of this regulative function of the state is to allow for the realization of centrally administered capital intensive technologies, another is to support an elaborate R&D system, which provides the necessary know-how for increasingly science based innovations. Thus, a substantial part of the science and technology system becomes structurally and socio-politically integrated into administrative and economic strategies.

An increasingly expensive science and technology system in a small capitalist country can be effectively sustained only by the combined efforts of the state and the business enterprise sector. The external constraints imposed by limited resources and limited sources of financing necessitate the adoption of self-regulatory strategies by the scientific community, based on compromises and contractual sharing of resources among socially determined domains of interest. Thus there are both internal and external constraints on the scientific community against its operation under *alternative criteria* of scientific relevance and technical feasibility. In other words, in small peripheral countries there are strong forces acting upon the scientific community, which prevent the possibilities for autonomous conceptions of scientific and social progress. This is probably one reason why the ideology of science and technology in the exclusive service of economic growth has so far not been seriously challenged either by society at large or by the scientific community. Unlike in many advanced, industrialized center countries, with a few individual exceptions there are no organized dissent groups in science rallying around an "ideology of limits", or focusing on the social costs and long range consequences of scientific and social development guided by the technological imperative. One can only guess what the ultimate consequences of these constraints for indigenous science and society will be.

FOOTNOTES:

1. At present 6 % of the population belongs to the Swedish speaking minority.
2. In 1924 the Faculty of Agriculture was expanded to include also forestry.
3. Today there are 25 such mission-oriented state research institutes.
4. In 1917, 70 % of the country's 3.3 million inhabitants were engaged in agriculture, 20 % in industry and 10 % in services (Löppönen & Tamas, 1985).

5. Because of the high priority given to training in technical and natural sciences, this university maintained a leading role in the production of the country's engineers up until the end of the 1950's (Lång & Rosenberg, 1975).
6. The University of Helsinki became formally Fennocized only in 1937.
7. From 1945 to 1969 there was more than a 300 % increase in professorial chairs in the social sciences. For detailed discussion of the post-war development of the social sciences, see, Stolte-Heiskanen, 1987.
8. As late as 1935 the scientific advisory board rejected all applications for research grants for projects with practical implications of results (Falk, et al., 1975).
9. For detailed discussion of the development of the relationship between science and technology and the business enterprise sector, see T. Lemola & R. Lovio's article in this issue.
10. The focus of the state's industrial policy, as it emerged in the 1950's and 1960's is reflected in the Cabinet programs of the two decades, which centered on the support of export industries, diminishing the discrepancies between production costs and prices of the export industry, effective tax reductions to industry, promotion of the utilization of raw materials, support of small and medium-sized enterprises and promotion of industrialization in the underdeveloped regions (Alestalo, 1985).
11. The high priority given to science and technology by society is reflected on the political level by the fact that the proportion of legislation concerning the promotion of science and technology of all laws passed during this century reached an all time high of 3.3 % during the 1960 decade (Alestalo, 1985).
12. In 1980 the share of agricultural sector decreased to a little over 10 %, while more than half of the labor force was engaged in the service sector (Alestalo, 1985).
13. The business enterprise sector's research program eventually became incorporated into the program of the Academy's Research Council for Technology, and found further public support through the increased share of research funds allocated to the Ministry of Industry and Trade, mainly responsible for supporting technological research and industrial R&D.
14. Even in the theoretically strongly mission-oriented state research institutes as recently as in 1982 only 1 % of their research personnel was of the opinion that science policy factors have an influence on the choice of their research problems, as opposed to the 16 % who considered the state buraucracy and industry to have such an influence (Alestalo, 1987).
15. The stock of research personnel has been also rapidly changing in all sectors since the 1970's, the fastest growth occuring in the business enterprise sector. The proportion of all R&D personnel in the enterprise sector has been around 40 % over the last 10—15 years, and during this period its research intensity (measured in man years/all persons performing R&D) has increased from 69 % to 77 % (OECD, 1987).
16. Biotechnology relevant subfields include biochemistry, microbiology, immunology, genetics & heredity, pharmacology, cell biology, virology and chemical engineering; subfields relevant to new materials are polymers, chemical physics, solid state physics, metals & metallurgy, material science; micro-electronics relevant subfields include computers, electrical engineering and electronics, solid state physics and biomedical engineering. Publication counts are based on Computer Horizons Research Inc. data. (OECD, 1988)

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