# The Role of R&D in Industrial Policy: Rise and fall of a research driven strategy for industrialisation

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## Abstract

R&D has played a central role in Norwegian public industrial policy for only a relatively short period. Before 1963, there was little interest in linking technological research policy to a wider national industrial strategy. During the mid 1960s, attempts were made to link public research more closely to industrial development, and the state became more engaged in funding industrial R&D. During the 1980s, governments increased public industrial R&D funding substantially, and for a short period of time research became a core element in national industrial policy. However, from the early 1990s the situation again changed. Public research policy lost its significance in wider national industrial strategies.

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## *Introduction*

R&D has played a central role in Norwegian public industrial policy for only a relatively short period. Before 1963, there was little interest in linking technological research policy to a wider national industrial strategy. During the mid 1960s, attempts were made to link public research more closely to industrial development, and the state became more engaged in funding industrial R&D. During the 1980s, governments increased public industrial R&D funding substantially, and for a short period of time research became a core element in national industrial policy. However, from the early 1990s the situation again changed. Public research policy lost its significance in wider national industrial strategies.

What happened between mid 1960s and 1990 to create a wider interest in research as part of industrial policy making? This paper argues that the rise of support for publicly funded R&D as part of industrial policy was closely linked to the emergence of new technologies, and to an ideology that linked future industrialisation (and welfare) to the emerging technologies. From the 1960s electronics, computers, telecommunication, control technologies, etc. were seen as important knowledge bases both for modernisation of older sectors of society and for development of new industrial sectors. As much of the technological development in the new industries was based on R&D, the industries were defined as “research-based” or “research-driven” industries. By the 1980s, there were many examples of rapidly growing companies of this type, and there was a wide acceptance that *research-driven industrialisation* was crucial for future industrialisation and welfare.

The ideology of research driven industrialisation was promoted from the 1960s by a small group of people closely linked to the Labour party, technological research, and the defense sector. This small group of people – the modernisers - succeeded in becoming influential in political decision-making in a number of areas, and supported the creation of public institutions for research-driven industrial expansion during the 1960s. (Wicken 1994) The support systems were strengthened during the 1980s as the ideology got a hegemonic position in the discourse on industrial policy. At this time, there was a broad political consensus on the importance of this type of industrial strategy, which had publicly funded R&D as a core element.

This development may be seen as a specific strategy for creation of a *R&D-intensive network-based* type of industrialisation. (see Wicken 2007) The long term intention of the group of modernisers was to create a new type of industrial development that was independent of natural resources. They represented a political attempt to make Norway's industry more modern and strengthen what believed to be future growth sectors, and public R&D policy became a central part of this strategy. A number of public institutions that supported this type of industry were established during 1965-1990 and the outcome was a public R&D policy system with specific characteristics.

## *R&D enters industrial policy*

The new interest in R&D for industrial development that emerged during the 1960s was linked to the wider politics of technology during the Cold War. The Sputnik shock from October 1957 may be seen as a turning point . The Soviet Union was able to put a

satellite into orbit and was believed to have inter-continental ballistic missiles that could reach America. Sputnik was interpreted as a challenge to the military superiority of the West. The reaction from the American government and later by Western European governments was a large scale investment in public research and education, and the elevation of issues related to science, technology and knowledge to central positions in political debate. The US rapidly increased defence R&D and soon entered into a race with the Soviet Union that focused on space technologies.

A rethinking of national science and technology priorities took place in Norway's close ally, Great Britain, during the early 1960s. In 1963, British Prime Minister Harold Wilson gave the famous speech on the 'White Heat',[1] and this was linked to a wider discussion in British media on "Linking science with industrial growth".[2] The discussion in Britain was closely linked to developments in the OECD where the Science and Technology Department introduced a prescription for how OECD countries should achieve the overall objective of the 1960s: increase GNP by 50 per cent. The OECD suggested that all countries should introduce a science policy directed towards industrial development.[3] The OECD became a driving force for the establishment of industrial science policies, both through national reports and also by a series of reports on the 'technology gap' between America and Europe throughout the 1960s. Maybe most important was the construction of the concept 'Research and Development' – R&D - by an OECD committee in 1963, a concept introduced as an instrument to promote 'R&D policies' in Western economies. (OECD 1963)

These developments within the USA, UK and the OECD strongly influenced the emergence of a strategy that incorporated R&D into industrial policy. The discussion in Britain during 1963 sparked an internal debate within the Norwegian Ministry of Industry on how to organise and regulate public R&D for industry.[4] The OECD's 1963 assessment of the situation in Norway also influenced the policy development.[5]

Research had, of course, been a part of Norwegian industrial activities and also part of Norwegian industrial policy before the 1960s. Research had for a long time been incorporated in *small-scale decentralised* resource-based production in Norway (see Wicken 2007 for more discussion). The state established a public research infrastructure for both fishing and agriculture in the 19th century, and this infrastructure has since increased in size. The establishment of collective industrial research institutes during the 20th century also contributed to the establishment of a public knowledge infrastructure for this type of industrialisation. Some publicly funded R&D also supported innovation in the *large- scale centralised* form of industrialisation. Both the Technical University (NTH) and research institutes like SI, IFA, CMI and Sintef collaborated with laboratories and management in many of the large scale process industry companies. However, research did not play a strategic part in policymaking for these industries during the 1950s. Research was seen a 'servant', subordinated to those in control of the production, and not a strategic factor that influenced future investments and policy decisions. This was particularly the case in politically important process industries during the 1950s, when research was linked to incremental improvement in efficiency in existing processes,

rather than being viewed as a form of investment that might transform the industrial and economic structure of Norway.

In the 1960s there was a renewed interest in establishing improved R&D support systems for both the small-scale and large-scale Norwegian industrial sectors. To support the small-scale decentralised form of industry, a new financial fund for collective industrial research (Bransjeforskningsfondet) was established in 1967, and during the 1980s a number of institutions for promoting diffusion of new technologies among small companies were introduced. The support system for the large-scale centralised form of industry became more complex, and involved changes in education and university research that were linked to demands from the emerging oil sector during the 1970s.

The ideology linked to how R&D could contribute to the older parts of industrialization did not change radically during the 1960s. Some new institutions were established to support research in large-scale companies, and funding of the public research infrastructure for small-scale industries and mechanisms for the diffusion of new technologies, also increased. But the more radical change in the public industrial R&D policy was the emergence of the idea of 'research driven industrialisation' based on emerging technologies of the 1960s. It was the emergence of the *R&D-intensive network-based* industry that made R&D a core aspect of industrial policy. R&D became a driving force for a new type of development, and a number of new institutions were established to promote the emerging technologies and the new type of industry.

In the following sections we look more closely at the development of industrial R&D policies for the three main industrial layers in the national innovation system (Wicken 2007) that emerged in the mid-1960s. Between 1963 and 1967, Norwegian governments established a number of institutions to support R&D in companies, and increased public R&D funding. Within this short period of time the technical-industrial research council (NTNF) was reorganised and new institutions for distribution of funding to companies introduced. The Development Fund for industrial policy was established in 1965, the Fund for Collective Industrial Research was established in 1967, and a subsidy system for public R&D contracts was introduced in 1967.

## Marginal innovations: R&D in large scale centralised industrialization

R&D played a marginal role in the Norwegian industrial policy for large-scale centralized industrialisation that was introduced after the end of WWII. The main industrial strategy was to transform the traditional industrial structure dominated by SMEs (small-scale decentralised industrialisation) into a more modern structure characterized by large scale and capital intensive corporations (large-scale centralised industrialisation). The Ministry of Industry was established in 1947, and the first Minister of Industry, Erik Brofoss, was the architect of the large-scale industrialisation policy. Brofoss remained the leading industrial strategist in Labour until his death in 1972. The policy sought to build up strong business organisations, particularly large-scale production units exploiting abundant energy resources (cheap electricity) and other natural resources. The Ministry of Industry focused its policy on building state-owned companies or attracting international investment in areas like metal production (aluminium and steel), energy

(electricity and coal), minerals (mining) and fishing (filet industry). The government worked closely with the management of the major state-owned companies, like Norsk Hydro and ÅSV (aluminium: see Moen 2007). The emergence of the oil sector in 1970 reinforced this policy, which focused on *capital* as the strategic input factor for industrialisation, treating R&D as an investment of marginal importance. (Jensen 1989)

A number of proposals to establish new resource-based large-scale industries linked to the steel industry, the metals industry, oil refineries, copper mining, and carbide production were discussed by governments during and after the 1950s.[6] Some of the industrial projects required public R&D investments, as was the case with proposals to exploit Spitsbergen's coal deposits for the production of coke, as well as the proposal to establish a steel works in Narvik.[7] In this industrial policy, R&D was an instrument to solve problems in production processes. Research was a "servant" that could make large-scale capital investments in process-intensive industries profitable but was not a driving force in industrialisation. Within the Ministry of Industry research policy was marginalised, and there was little if any interaction between the Ministry and the research council responsible for industrial research. NTNF was left in splendid isolation, and the research council was not part of the government's industrial policy. Still, NTNF established close relationships with individuals from various industrial companies who served on NTNF's board and committees. The main proponent for this strategy was the director of NTNF during 1946 - 1980, *Robert Major*. The Ministry of Industry, however, regarded the representatives of industry that sought to collaborate with NTNF as an

unusual group of industrial managers, interested in science and technological research, but not representatives of their companies or industries.[8]

Beginning in late 1963, the Ministry of Industry reduced NTNF's 'splendid isolation,' seeking to ensure that the research council's strategy was incorporated into industrial policy and linking NTNF more closely to demands from industry.[9] The Ministry opposed the build-up of a large research institute sector with NTNF funding, and preferred that public resources be directed towards R&D in company laboratories. The Ministry also wanted to give companies greater influence over how research programmes were defined and how funding was distributed among projects and companies.

To implement this policy, NTNF introduced a system for direct funding of R&D to companies in 1965 (PIR, Prosjekter i Industriell Regi). This became an influential part of NTNF's policy until the mid 1970s, and after 1990 was the major public program for supporting industrial R&D. *Johan B. Holte,* the research director and later the administrative director of the country's largest industrial R&D performer, Norsk Hydro, became influential in defining the main NTNF strategy for public R&D policy towards large-scale industries. He argued that a small country like Norway lacked resources for developing new large-scale processes, and that the necessary technology had to be procured from abroad. The role of public R&D funding was to improve production marginally through small-scale projects. This was the strategy of Norsk Hydro at the time, and this became the policy of NTNF in the process industries. The strategy was consistent with the longstanding Ministry of Industry characterization of R&D as a

servant or a problem-solver to support the profitability of large-scale investments in mature, process-intensive industries. (Andersen and Yttri 1997)

In parallel with the reorganization of NTNF, the Ministry of Industry established an alternative organization for funding industrial development projects, the Development Fund (Utviklingsfondet), which was established in 1965. NTNF had suggested that a separate organization be created within the council (or that an independent commercialization company be established) to ensure that new technologies developed by the research institutes were commercialized. NTNF found that existing firms were not interested in producing research-based products and technologies, and argued that Norway needed this type of organization.[10] This proposal created a strong reaction within the Ministry of Industry, which feared that the establishment of a commercialisation organisation/company would ensure that researchers and scientists remained in 'splendid isolation' from the rest of the economy. The ministry wanted an alternative strategy, in which politicians and representatives from "core" companies made decisions on public industrial R&D strategies. Erik Brofoss became the chair of the Development Fund from its inception in 1965, and the director of the Norwegian Defence Research Establishment (FFI), Finn Lied, became a board member. Other board members represented politically important industries in the resource-based sector, as well as shipbuilding. The Development Fund became an organisation for supporting research projects in industrial companies as part of a wider industrial strategy. (Sogner 1994)

The main strategy of the Development Fund was to create 'a rational industrial structure' for each industry, consistent with the ideology of Ministry of Industry that argued that Norway's industrial development was hampered by a lack of companies with financial and managerial strength. The overall strategy was to develop strong economic organisations – national champions (Sogner 1994) – in all sectors of the economy, transforming small-scale industries to support the large-scale ideal. An example was the attempt to transform the politically important ship building industry. The Aker mek. Verksted became the national champion, receiving financial support to become a dominant firm in the industry. This strategy included the establishment of corporate laboratories as well as collaboration with public research institutes on projects such as numerically controlled automation of ship navigation and operations (Andersen 1986)

The Development fund distributed most of its funding to selected national champions in shipbuilding[11], process industries, and electronics. During the 1965 - 1977 period, the Development Fund supported projects in 287 companies, of which 24 (8%) firms received half of all funding.

[FIGURE 1 ABOUT HERE]

## Diffusion of knowledge: R&D in the small–scale, decentralised industrial sector

A discussed above, the Labour governments of 1945-65 introduced a policy to transform Norway's small-scale industry into a more modern large-scale industrial structure.

Labour's industrial policy of the 1950s provided minimal support for the small scale decentralised path of industrialization, a posture that was reflected in its R&D initiatives of the 1960s. The non-socialist political parties had opposed this policy during the 1950s, although the Conservative party became more supportive of Labour's philosophy on industrial development during the 1960s.

Nevertheless, a substantial infrastructure of research institutes designed to support individual industries was established after 1950. At the technical university (NTH), the research council (NTNF), and at the industry level, initiatives were taken to establish laboratories for research directed towards industries in which company-funded R&D was non-existent or marginal. These included construction[12], shipping and shipbuilding,[13] and electricity production.[14] NTNF also supported research projects organised by industrial associations for industries with low R&D intensities, and conducted analyses of R&D strategy in individual industries, such as textiles and clothing. (NOU 1971)

In 1965, a non-socialist government consisting of four parties entered government, promoting a more positive attitude to small-scale industrialisation. The government introduced a policy for R&D support for this type of industries. Since the inter-war period, some industries had established collective or collaborative laboratories to solve industry-wide problems. Most of these labs were financed by specific taxes that the Storting had introduced (export tax, etc.). The early labs of this type were canning and paper industries, and during the post-WWII period additional collective labs were established at the initiative of companies or industrial associations. The new government

introduced a specific funding system (Bransjeforskningsrådet, Collective Industrial Research Council) to support collective industrial research for industries with limited in-house R&D. The classic collective research laboratories focused on problems and challenges that were common to all or many of the companies in the industry, and normally avoided projects that favoured one company at the expense of a competitor in the same industry.

By contrast, the industrial institutes controlled by NTNF or linked to NTH were to a larger extent consultancy companies that undertook contract work to solve problems of individual companies. Many of them became part of Norway's knowledge-intensive business services sector. Examples of these organizations include Norges Geotekniske Institutt (NGI) and Vassdrags- and Havnelaboratoriet (VHL) which performed consultancy analysis linked to construction works. (Gulowsen 2000)

A core part of R&D strategy for small scale decentralized industry was public support for the diffusion of science-based knowledge or technology. In particular the primary industries (fishing, seafood, agriculture, forestry) had long-established systems for collective research and for diffusion through education, consultancy organisations, seminars and conferences, training programmes etc. The Marine Research Institute and the higher education institutions and agricultural research institutes played a core role in linking industry to science and research. Nevertheless, science and technology played a modest role in technological and economic dynamics of these industries. Instead, capital-goods suppliers, importing agencies, and consultancies constituted the main aspects of

the knowledge infrastructure. Except for primary industries, the contributions of public support for R&D in the small-scale decentralised sector remained marginal until the 1980s.

### Path creation: R&D-intensive, network-based industries

The new industrial policy instruments of the 1960s became closely linked to R&D–intensive, network-based industries (see Wicken 2007 description of this sector). An increasing share of public R&D funding controlled by the research council, the Development Fund, and the Public R&D contracts was allocated to areas later defined as ICT during and after the 1960s. Many of the selected national champions were companies from this sector. Simrad, the major producer of maritime electronics, received significant funding through all of the programs established to support R&D in industrial companies. Norsk Data, Kongsberg Våpenfabrikk and Noratom-Norcontrol also received funding from these sources. The emerging ICT technology became a central focus of Norwegian industrial research policy, and significant resources were used to support the development of high-tech companies. The state also invested substantial resources in a public research infrastructure, developing research institutes and university research directed towards this industry, and expanding education in the area. The research-driven strategy to build up a new path of R&D intensive companies became the core of Norwegian industrial R&D policy from the mid 1960s. (Wicken 2000)

### *The role of defence in industrial research strategy*

The emergence of this strategy in Norwegian policy was closely linked to the international defence challenges of the late 1950s. The Norwegian Defence Research Establishment (FFI) had since its establishment in 1946 collaborated closely with British and American authorities. The new emphasis on science and technology in Western defence put FFI in a central position in the transfer of knowledge from the USA and led to expanded financial support from the USA and NATO. National defence also provided a strong argument for building up Norwegian national research capabilities. During the 1960s FFI and the affiliated Institute for Nuclear Energy Research became the largest research institute in Norway. FFI became closely liked to the NATO and American defence research communities, and the institute developed technologies important for the new arms race, including sub-sea detection systems for submarines, long range telecommunication, fire control systems, electronic intelligence, etc. The main representative of the new approach of the FFI was *Finn Lied* who became director of FFI in 1957 and remained in this position until 1982. (Njølstad and Wicken 1997)

NATO defence policy in the late 1950s sought to build up a scientific basis for defence related issues and to build up an independent defence industry in Western Europe. Norway had a very limited defence industry during the 1950s, consisting mainly of three state-owned companies (one for shipbuilding, one for ammunition, and one for general weapons production). The defence minister of the first post-WWII governments, *Jens Chr. Hauge*, supported the modernisation of the defence companies with NATO funding. A powerful member of the board of Kongsberg Våpenfabrikk (KV), Hauge argued in

favour of turning the old workshop into a modern high-tech defence company, and in 1957, appointed *Bjarne Hurlen* as a director of the company. (Wicken 1987a) Hurlen and Hauge remained the key managers of KV until 1986, and Lied was on the KV board for most of this period. Finn Lied became the main industrial policy strategist in Labour from the 1960s to the 1980s. Together these three representatives of the Norwegian industrial-technological system became strong proponents of science-based industrial policy. (Wicken 1994) The group connected to FFI and KV became core players in the introduction of the ideology 'technology as the driving force' in society and politics.

A technology-driven system for defence industry development was established during the mid-1960s. The core organisations were FFI and KV, and they succeeded in getting support from the Ministry of Defence (FFI's owner) and the Ministry of Industry (KV's owner). In late 1950s, FFI began to receive substantial financial support from the USA for the development of a ship-to-submarine missile system (Terne III) and long-distance detection systems for submarines (Bridge). The missile system was produced by KV and the Ministry of Defence became the sales organisation for the system within NATO. The increased defence investment budget created new opportunities for national production of defence equipment. The largest investment was the construction of a modern navy (Flåteplanen 1963), a plan that for the first time involved Norwegian companies in large-scale sales to Norwegian defence forces. Hauge, Lied and Hurlen turned KV into an instrument for industrial policy, arguing that the company should improve its product and production technologies, and diffuse the resulting ideas and practices to other parts of the economy. (Wicken 1984, 1987) For a quarter of a century KV took on production of

technologies that had been developed in Norwegian research institutes, most frequently in FFI. The technologies included computers, numerical control machinery, fire control systems, gas turbines, and weapons systems (the Penguin), as well as sub sea equipment and other products. (Njølstad and Wicken 1997, Wicken 1988)

FFI and KV became leaders within Norway in defining a new type of production where science and research played a core role for success. To a large extent the processes of establishing a defence industry from the early 1960s created a path for policymaking and direction of this type of industry that remained influential in the following decades. Hauge-Hurlen-Lied represented a tradition in social democracy in supporting the importance of state-owned production units and public control of core knowledge bases. They tried to monopolise Norway's emerging high-tech industrialisation by making KV the core player in technology-driven or research-driven industrialisation.[15]

The alliance between FFI and KV influenced a wider policy system supporting a science- and technology-driven policy strategy. FFI established in 1960 a Systems Group introducing systems evaluation techniques for assessing new technologies, a type of analysis introduced by the RAND organisation in the USA a few years earlier. Systems analysis became an instrument for planning future investments and measuring the efficiency and performance of different types of technologies and weapons systems. (Njølstad and Wicken 1997). Its reliance on systems analysis helped FFI to become an important instrument for defence planning. In 1963 Jens Chr. Hauge chaired a committee planning a re-organisation of national defence. In the committee served also Finn Lied

(director of FFI) and *Håkon Kyllingmark* (from 1965 minister of transport and telecommunications). The report argued that the Chief of Defence should have two equal advisory systems, one focused on military issues and the other on scientific and technical concerns. The committee recommended that FFI should be responsible for the latter advisory role, and should apply its scientific and technological expertise to decision making processes in defence (Njølstad & Wicken 1997) The idea that all aspects of policymaking should be based on scientific and technological expertise was incorporated into Labour's political programme for the 1965 election, based on recommendations from a planning committee headed by Jens Chr. Hauge and with Finn Lied as a member. But Labour lost the election, forcing the party out of government for the first time since 1935, and the science based policy making system was not introduced.

Lied and his colleagues were more successful in influencing strategic planning in the technical-industrial research council (NTNF) . Lied was at this time a member of NTNF's executive board and therefore a member of the group that during 1963-4 undertook an evaluation of NTNF. The ministry of industry intervened and demanded that three more persons should be part of the evaluation committee. Two of them were Jens Chr. Hauge and Bjarne Hurlen. The military-industrial system (Wicken 1990) thus had a lot of influence on the emerging R&D industrial policy.

### *A research driven strategy*

The 1964 NTNF evaluation report argued that Norway's future welfare could not depend solely on resource-based industries. To ensure continued growth and improved welfare,

Norway had to develop new industries based on new technologies, and R&D played a crucial role in such a strategy. This argument was consistent with the thinking of the representatives of the military-technological system that emerged in the late 1950s, and it soon became widely accepted by scientists and research engineers in Norwegian universities and research institutes. The ideology positioned this social group and their knowledge as core agents for a wider modernisation of society and in the future welfare of the nation.

Norway lacked research-based industries and had very few R&D-intensive companies in 1963. The main exceptions to this characterization were firms with strong historical links with defence activities. Simrad was started by Willy Simonsen, who used his experience in UK defence laboratories during WWII to set up a company producing walkie-talkies and later, sub-sea detection technology for fisheries and shipping. (Sogner 1997) Nera started producing radiolink systems that also were based on know-how from British war laboratories, and marketed its products to NATO forces. (Njølstad and Wicken 1997) There was also a small company directed towards marketing technology for nuclear energy market (Noratom), but other than these firms, research-based industry in Norway was almost nonexistent.

Beginning in 1964/65, Norwegian industrial R&D policy promoted this type of production, and the FFI-KV alliance was a core part of the strategy. The state-owned production company KV became the major engineering company and the national commercialisation company for products developed by researchers and scientists.

However, the Norwegian military resisted pressure from the FFI-KV interests to define the weapons systems and technologies that the military should choose, often preferring to procure systems and technologies from abroad, rather than getting involved in local development projects. (Wicken 1987) To overcome this resistance from the military users of domestically developed products, the Ministry of Defence (headed by the industrialist Grieg Tiedemand) developed regulations for procurement practices in the defence system that forced the military procurement agencies to consider the industrial implications for Norway of their investment programmes. The nonsocialist government supported the introduction of a subsidy system for public R&D contracts that encouraged public users to pursue development projects with Norwegian industry. The system for public R&D contracts became in many ways an instrument for the promotion of high-tech or research-based industrialization, especially for the ICT industry. Almost all contracts went to companies in this sector. (Wicken 2000)

The industrial research council, NTNF, also became a strong promoter of industrialization based on emerging technologies such as electronics, computers and telecommunication (ICT). NTNF allocated a growing share of its budget towards these technologies, and the research council established large projects that involved the newly established companies of the research-driven path as well as older companies that were national champions. The automation-computing committee became a particularly strong supporter of research-based industry, and companies like the mini computer producer ND, the defence system provider Kongsberg, the automation company Norcontrol and the maritime electronics company Simrad were the primary recipients of NTNF funding

in this area. The public support system also supported the entry of national champions like Aker (numerically controlled machinery and semiconductors) and Hydro (ship automation) into publicly funded automation research projects. (Wicken 2000)

Not all supporters of a research or technology driven strategy for industrialisation supported the strong role of defence, especially the strong role of Hauge, Hurlen and Lied, and two controversies erupted in 1967. A group of researchers at FFI had developed a prototype of a minicomputer and wanted to leave FFI to set up a private company to produce computers commercially. Lied objected and transferred the prototype to KV for production. The young researchers challenged Lied with support from within FFI and from NTNF, and their departure from FFI created the basis for the establishment of Norsk Data, a symbol of research-based industrialisation and an alternative to the state-driven strategy of KV-FFI. A similar development took place in 1967 within telecommunications research. FFI initiated the establishment of a national research laboratory for telecommunications (TF), supported by the Minister of Transport and Telecommunications Håkon Kyllingmark.[16] But the director of TF, Nic Knudtzon, did not support the state-driven strategy of FFI-KV, and TF chose to collaborate with both national (Nera) and international companies (EB controlled by Ericsson and STK controlled by ITT).[17] (Collett and Lossius 1986)

The establishment of industrial instruments for R&D during the 1960s was closely connected to political support to specific types of industrialization. Most of the system was introduced to promote research-driven or R&D-intensive industrialization as part of

a wider ideology of support for research and new technologies in social and economic development that was influential in Western policymaking at the time. The research council, the public R&D contracts, the buildup of KV as a commercialization company, the development of a telecommunications R&D system, and other instruments supported a research-driven industrial strategy. Norway's strategy was similar to those of other European economies, but the military-technology system shaped the structure of the support system to an unusual degree. KV-FFI, under the supervision of Hauge-Lied-Hurlen shaped how the policy systems functioned, emphasizing state or national ownership and control. Over time, however, parts of the public support system broke away from this ideology and promoted a more liberal strategy based on private ownership of companies.

By the late 1970s, a substantial policy structure had been established to promote the emergence of a new path of Norwegian economic development that relied on R&D–intensive, network-based companies. A significant number of new companies had been established and some of the old companies had entered high-tech industries. The main companies were Kongsberg Våpenfabrikk, Norsk Data (computers), Simrad (marine electronics), Norcontrol (automation systems), and AME (semi conductors). By this time Norway had a large number of small high-tech companies, and some observers found Norway to be the most dynamic of the Nordic countries.

These emerging industries were supported by a substantial knowledge infrastructure. In addition to the national industrial research council (NTNF), both the defense sector (FFI)

and the telecommunication sector (TF) purchased research services from companies, research institutes, and universities. A significant research base within ICT developed and many research institutes expanded their capacity and competence within this area. FFI, TF, IFA, CMI, Sintef (for example Elab), SI, Norsk Regnesentral, and others developed wide competences in regulation technology, communication, computing, semiconductors, etc.

Public procurement also promoted R&D in companies through public R&D contracts between a companies and public agencies. This type of arrangement was particularly linked to emerging technologies, and mostly to ICT. This connected company R&D to market demand, and to large public users. The most frequent users of public R&D contracts for high tech industries were the defense and the telecommunication sectors.

### *Research driven re-industrialisation strategy (c.1978 – 1990)*

During the 1980s the research-driven industrial policy reached its peak. The renewed interest in this type of industrial policy was reflected in a 1978 report by a committee headed by Finn Lied that presented ideas for a new industrial policy. (NOU 1978). This document followed up some of the ideas from the 1960s, emphasising the role of emerging technologies for future industrial development. The ideas had by this time been widely circulated in international analyses of the economic recession of the 1970s. There were two main interpretations of the wider change in international economy during the 1970s. One interpretation was that the economy had entered a radical transformation from industrial to post-industrial society. (Bell 1976) Another group of scholars argued

that we were in the middle of a new Industrial Revolution characterized by the emergence of new growth sectors based on radical technological innovation. (Mensch 1979, Freeman & Soete 1982)

Interpreting the socioeconomic changes of the 1970s as a Third Industrial Revolution suggested the possibility of *re-industrialisation*, based on emerging technologies that could become the basis for the next long-term growth period. In the terminology used in Wicken (2007), the policy was a strategy for an industrial path creation process. Modern economies moved away from the old manufacturing sectors to new 'high tech' industries. Future growth was dependent on a successful transformation of the economy that relied on the growth of new sectors based on new technologies.

The role of new technologies in the re-industrialisation process made R&D a core element in the emerging policy. Technological development was regarded as closely linked to science, research, and development – concepts that in policy-making became incorporated into the R&D concept. There was a strong belief that what was later labelled as information and communication technologies (ICT at the time involved different technologies like telecommunication, computers, control technology and professional electronics ) would play a decisive role in the transformation of the economy, and therefore was important to long term economic growth and welfare. In short, Europe should put resources into the development of ICT and create strong industrial sectors within this group of technologies.

In many ways this re-industrialisation strategy based on new technologies and investment in R&D resembled the ideas of the Norwegian modernisers of the 1960s. There was, however, a major change in the political context that influenced the conditions under which new industries could be established in the 1980s and contrasted with the 1960s. Although Hauge-Lied-Hurlen had proposed a state-driven policy during the 1960s, the Lied committee in 1978 argued that the international context had changed significantly, making a more liberal policy necessary for a research-driven industrial strategy. The more liberal views were supported in a 1981 policy paper on national R&D policy (NOU 30: 1981) that advocated a liberalisation of the research system in order to improve interaction between the large industrial research institute sector and companies, and to increase industrial R&D. With the support of nonsocialist governments during 1981-1986 (Willoch I and II), Norway adopted a more liberal industrial ideology.

Industrial R&D benefited during the 1980s from increased public spending. During 1983 - 1993, public R&D spending increased from 5500 to 9000 mill. NOK in fixed (2000) prices, i.e. more than 80 per cent. The growth in public R&D during the second half of the 1980s was linked to the decision of the Brundtland government to increase public R&D by five per cent as part of the Technology Targeted Area (TTA) policy. (St.prp. 1, 1986-87) The TTA strategy was a technology- and R&D-driven policy in which the main instrument to promote new industries was R&D, and a substantial part of the funding increase was linked to industrial R&D.[18]

[FIGURE 2 ABOUT HERE]

## Implementing a research-driven re-industrialization strategy

Like its predecessors during the postwar period, the new Norwegian policy was part of a wider international trend in industrial policymaking. During the mid-1980s, many OECD countries introduced programs that were similar to the Targeted Technology Area (TTA) policy, based on the idea that governments should select potential growth sectors and move resources to these industries. The main areas selected by European countries were linked to emerging technologies like IT, biotechnology and new materials. The background for the re-industrialisation strategy in Europe was rapid de-industrialisation (reduction in manufacturing-industry employment) during the 1970s. In contrast to much of Western Europe, however, Norway experienced declines in employment in manufacturing industries somewhat later, in the late 1970s.

The policy of a research-driven industrial strategy during the 1980s achieved wide political support from both the nonsocialist governments (Willoch I and II 1981-86, Syse 1989) and the Labour government (Brundtland I, 1986-1989). New technologies and research had achieved a dominant ideological position in industrial policy making that they have had before or since. This wider political consensus supported public industrial R&D funding and made R&D the core element of industrial policy. All governments during the 1980s planned and implemented a research-driven industrial strategy, concentrating national R&D resources on specific sectors and technologies. The Ministry of Industry started to plan the strategy in 1982 and presented a plan for expanding industrial public R&D funding in 1984. The plan suggested that industrial policy should give priority to the three new technology areas that internationally were accepted as

important; information technology (IT), biotechnology, new materials. However, the government also decided that Norway should support the development of two industries which were nation specific: fish farming and offshore technology.[19]

This policy framework reflected the existing economic realities in Norway, and also the influence of various types of industry in the political system. Expanded support for emerging technologies was well received in large parts of the research communities and in Norway's small but rapidly expanding high tech industry. The government wanted to strengthen the development of a *R&D-intensive, network-based* industry as a new dynamic element in the economy. But the older sectors of the economy remained influential, and developments during the 1980s proved that opportunities for new industries based on natural resources were significant. The highly technical offshore sector represented opportunities for industrial growth within the *large-scale centralised path*, while the emerging fish farming sector represented the long tradition of the *small-scale decentralised* form of industrialisation. All the main paths of Norway's economic development were represented in the new policy; and no type of industrialisation was excluded.

### *Re-industrialisation strategy for small-scale industry: fish farming*

Systematic experiments in farming of salmon and trout had started during the 1970s and by the 1980s, this sector was regarded as a potentially important small-scale industry that could be incorporated in the existing local economies along the coast. The development of the new industry was closely linked to the traditional fishing sector. Most of the

involved actors came from fisheries, both regarding capital, technology, and knowledge. The technology of using nets for growing fish was an extension of methods used to catch and keep fish alive for shorter period of time. Most of the fish farmers had backgrounds in the coastal or ocean fisheries, and most innovations were the outcome of close interaction between local fish farmers, mechanical workshops, banks and other knowledge sources. (Berge 2006)

Research played a marginal role in the early developments of the new industry, but some scientists were interested in the new field and started up research projects. Projects linked to biology and medicine (fish health, diseases) were established in research communities traditionally linked to agriculture and fisheries. When a political plan for the emerging industry was discussed 1972-77, research was regarded as a servant, support function or problem solver for the industry. (Mariussen 1992)

During the early 1980s the role of R&D in fish farming policy changed. The ideological change was initiated at the industrial research council; NTNF. Fish farming now became redefined from small scale local production of salmon and trout to the basis for establishing industrial food production in the ocean. The industry was redefined from aquaculture to mariculture (*havbruk*), the concept used in American documents with similar ideas in the 1970s.[20] The scientific and research communities promoted this interpretation of fish farming, and in a short period of time the industry was redefined as a future potential growth sector and a targeted technology area.

As part of this process the industry became part of a controversy of definition. Was 'fish farming' to be regarded as fishing, farming or manufacturing industry? Three ministries and three research councils competed to control the development of the new industry. In addition to the industrial research council, NTNF, there was also a research council for agriculture (NLFR) and one for fishing (NFFR). This created a diverse system for funding of fish-farming research. Researchers could apply for resources from multiple sources, and fish farming became the second largest of the targeted technology areas of the 1980s.

Competition among the three research councils for control of the emerging industry produced rapid growth in public R&D funding. In 1973 research relevant for fish farming had a cost of c. 1,5 million NOK. In 1984 the three research councils alone supported R&D for fish farming for 17 million NOK, and this increased to 31 million in the following year. In 1988 they financed research for 75 million NOK, and in the period 1988-1992 the average funding for R&D for fish farming was c. 125 million NOK. (Mariussen 1992)

During this period also some large companies became involved in research-driven fish farming (Aslesen 2007). The most important actor during the 1980s was Norsk Hydro which had decided to pursue a research-driven diversification strategy that relied on R&D to establish future productions sectors. This strategy was the company's parallel to the national TTA policy, and Norsk Hydro selected biotechnology, fish farming, and new

materials as their main areas. (Andersen & Yttri 1997) Hydro established R&D strategies and organizations for fish farming, and became a driving force for research in the area.

By the late 1980s fish farming had been defined as the future basis for food production and therefore a potential growth industry. Political documents argued that success in the sector depended on R&D, and public investment in R&D a view that was also reflected in some of the major industrial companies. The research-driven strategy had become a basis for the establishment of a new small scale coastal industry. However, the belief in research-driven innovation in fish farming did not last long. By the early 1990s, Norsk Hydro had abandoned its research-based diversification strategy and had reduced its involvement in fish farming. When the industry experienced a downturn during the early 1990s, skepticism grew concerning the role of research in the future development of the industry. The evaluation of the TTA of fish farming argues that public funding of research was reduced because politicians no longer believed in a research-driven strategy for industrialization – at least not for this type of industry (Mariussen 1992:12) Research once more was reduced to being the servant of industry.

### *Re-industrialisation strategy for R&D intensive industries: IT*

Information technology (IT) was a core technology in research-driven industrialization. This area received by far the largest public subsidies, and a large share of Norway's public R&D funding was directed towards this group of technologies. This is also reflected in the funding of the research council, NTNF. Among technological fields, IT received by far the largest share of NTNF funding during the latter part of the 1980s,

accounting for more than 50% of total funding allocated to targeted areas, and the sector's share was especially high during 1986-88. (NHD 1990)

Policymakers' optimism over the prospects for this emerging technology was linked to the IT sector's rapid growth and the economic success of a number of Norwegian companies. Two of these high-tech companies became symbols of the Norwegian re-industrialization process of the 1980s. Kongsberg Våpenfabrikk (KV) became one of the country's largest manufacturing companies and a leading high-tech company dominated by engineers and people with advanced degrees in technical fields. KV became a symbol of Labour's strategy through the 1970s of developing new industries with state ownership and control. Norsk Data (ND) also grew rapidly during the 1970s and 1980s, and was by the mid 1980s a leading European producer and exporter of minicomputers. As a private company registered on the stock exchange in both Oslo and New York it symbolized the entrepreneurial opportunities of the more liberal economy of the 1980s. A large number of other Norwegian ICT companies also enjoyed substantial growth until 1987. (see Sogner 2007)

During the 1980s, the system of public R&D funding for companies favoured a select group of national champions. The tendency to concentrate R&D resources among a few selected companies is apparent in the statistics on NTNF funding of companies' R&D during the research driven industrial strategy. Between 1978 and 1987 NTNF distributed 50 per cent of its total funding for corporate R&D to just 13 companies (figure 2).

[FIGURE 3 ABOUT HERE]

As was noted earlier, the ICT industry itself received more than 50 per cent of the total funding for corporate R&D from NTNF during the 1980s, with particularly strong position for this industry during 1987-88 [redundant with earlier statement]. The five largest projects in NTNF's corporate programme during the 1980s were all in the IT sector:

[TABLE 1 ABOUT HERE]

It is not surprising that Norsk Data (ND) achieved a strong position in the Norwegian R&D support system. Along with KV, the company was the main national champion in the ICT sector, receiving substantial funding from public R&D institutions during the 1980s in addition to indirect subsidies through high prices on computer systems sold to public administration and other public organisations. The company enjoyed strong support in political institutions and in procurement agencies, and until the late 1980s had a near-monopoly on computer sales to public sector. The other main national champion, KV, received annual operating subsidies from the government to cover its financial deficits, a signal of the continuing strength of the military-technology system within Norway in the 1980s.

NTNF's strong support for Autodisplay signifies the dominant ideology of the 1980s. The project was based on a plan by an entrepreneur with visions of a future technology that would result in large-scale growth, and was organized by a company established in

1985 to develop a new intelligent automobile instrument panel that would collect a large amount of data for the car driver. The plan called for the establishment of a large plant in Sandefjord in 1991 in collaboration with an Italian producer of car instrumentation that could make Norway a more important player in the European and international car industry. It was the largest project ever supported by the research council, and was also part of the Eureka project Prometheus. It failed and production never started.

Other projects, including SensoNor, Norcontrol and Dolphin, were based on proposals for new technologies that would support the establishment of substantial new industries. This ideology was strong in Norway during the 1980s, based on the success of Norsk Data. ND's development illustrated the opportunities created by the emerging technologies. Even in small countries entrepreneurs could establish new companies with substantial growth potential.

The belief that IT research projects could develop new technologies that would form the basis for long term growth of new or old companies was the main driving force the attempt to use public R&D to create a new industrial path in the economy.[21] This ideology dominated NTNF and was the basis for the strategies for defense-related R&D (FFI) and the telecommunication R&D (TF). In addition, most public R&D contracts remained directed towards IT projects. The emerging technologies achieved strong political support from governments and from industrial associations and the large industrial companies.

In spite of this ideology and support policy for R&D intensive industrialisation, the most important influence on high-tech industrial development in Norway during the 1980s was the growth of offshore oil and gas production. Beginning in the late 1980s, Norwegian policy mandated the creation of links between international oil companies and national R&D organisations. This policy strongly shaped the direction of the IT/ICT industry.

*Re-industrialisation strategy for large scale technologies: R&D in offshore sector*

The development of a petroleum sector in Norwegian economy was not based on the idea of a research-driven industrial expansion. Here, production came first, and strategies for R&D followed only when the industry was well established. The introduction of R&D as part of oil policy emerged at the end of the 1970s.[22] The new policy was introduced in 1978 when the government introduced the Technology Agreements.[23]

The new policy embodied in the Technology Agreements was based on the Norwegian government's power to hand out or deny concessions for permission to drill for oil and gas on the Norwegian shelf. (see Engen 2007) The government developed a system of criteria to guide the granting of concessions to applicants, and an important criterion established in 1978 was investment by foreign oil companies in R&D in the Norwegian economy. The Goodwill Agreements involved R&D contracts between oil companies and Norwegian companies, universities and research institutes. (Wiig 1993) Along with public R&D contracts, the Goodwill Agreements were important elements in a shift in policy during 1978-93 to make R&D more market-oriented and for science to become more involved with technological problems of industry.

The Goodwill Agreements (GWA) became very influential instruments in increasing industrial R&D. Oil companies paid around 80 per cent tax on the revenues from the North Sea, and the companies' investment in Norwegian research was therefore indirectly paid for by the state. The oil companies' collaboration with Norwegian companies and research institutes had a great impact on the research system. Companies and research institutes turned towards the demand (and profit) in the offshore sector, as is apparent from R&D spending data. The oil and gas sector rapidly increased its procurement of R&D from external sources, and reached a volume of 700-800 million NOK during the first half of the 1980s. By comparison, all manufacturing industry procured R&D services from external organisations for c. 250-450 mill NOK. (Statistics Norway) The surge in demand for R&D from the oil and gas sector had a crowding-out effect, as the expansion in petroleum related R&D corresponded with a period of reduction of industrial R&D. (Smith and Wicken 1991) The GWA strongly influenced industrial R&D in the longer term as well, as oil companies reported that they invested 5.800 million (1990 NOK) NOK through approximately 1500 different projects during 1979-91.

The rapid increase in procurement of R&D services in the offshore sector that began in the late 1970s influenced the development of universities, research institutes, and much of Norway's emergent high-technology industrial sector, especially in ICT. Norway's ICT industry found a lucrative market for technology development in the large oil and gas sector, and a substantial part became incorporated as problem-solvers into the large technological system developing in the North Sea.

The demand for R&D from the offshore sector was introduced just a few years before a more market-oriented policy was introduced for the research institutes. The new policy mandated that institutes should become independent organisations and receive a part of their income as basic funding from the research council. Most of the remainder of their income should come from projects from private and public sector. The new policy encouraged research institutes to seek new markets for their services in, for example, the offshore sector. Three institutes became closely linked to strategy of the Oil Directorate (OD) (which became a new *de facto* "research council"): Rogalandsforskning in Stavanger, Institute for Energy Technology at Kjeller outside Oslo, and Sintef in Trondheim. These institutes, and SINTEF in particular, became closely incorporated in the ministry's and directorate's strategy which focused on increasing revenues from the oil fields. . The most important part of the programme was to improve knowledge regarding flows of gas and oil in pipes, and how to increase the percentage of the reservoir that could be exploited.[24]

The R&D strategy introduced through the Technology Agreement policy between 1978 and 1993 heavily influenced the development of the Norwegian R&D system. It directed large parts of Norway's national research and knowledge infrastructure towards the large and profitable domestic market, strengthening a Norwegian development trajectory (see Engen 2007) with specific knowledge demands and characteristics.

## *The breakdown of the research driven industrial strategy*

The hegemony of the research-driven strategy in public industrial policy broke down during the early 1990s. The change in political thinking took place inside the Labour government of Gro Harlem Brundtland as she became prime minister for the third time in 1990. The 'research-driven strategy' for industrialisation was abandoned in favour of a 'user-driven strategy' for industrial research and development. Existing industry became far more influential in industrial R&D policy making, and representatives of R&D-intensive, network-based industries became less influential.

The breakdown of the research-driven strategy resulted from changes in different parts of industry during the economic crises of 1987-93, as well as learning from the experience of the policy instruments introduced during the late 1980s. The evaluations that were undertaken of the "Targeted Technology Areas" were rather critical to the implementation of that policy, particularly the lack of good instruments for realizing the objectives, and this obviously made a strategic policy change politically feasible. However, the main factor behind the breakdown of the research-driven industrialisation strategy was the difference in development among the three main layers of the innovation system. (See Wicken 2007) In particular there was a change in the relative political influence of the *large scale centralized* and *R&D intensive network* industry sectors between 1986 and 1993, and this strongly influenced policymakers' thinking about future growth opportunities.

The most important factor in the breakdown of the research-driven strategy was the severe problems experienced by the R&D-intensive industries during 1987-88. The two major national champions in ICT entered into economic crises, and Norsk Data went bankrupt. This was a shock to many as ND had been the model company in the research-driven industrial strategy of the 1980s. In a surprisingly short period of time, the vast network of organisations and individuals around ND disintegrated and very little of the computer industry survived. Kongsberg Våpenfabrikk (KV) had lost money almost every year since the beginning of the 1970s, and the Labour government (Brundtland 2, 1986-89) finally broke with the core group of modernisers from the 1960s. Hauge-Hurlen-Lied lost control of KV, and the company became involved in an international scandal over the use of KV technology to produce silent propellers for strategic Soviet submarines.[25] (Wicken 1988) KV was divided into a number of companies and privatised; only the defence part of KV remained state-owned. The KV privatization symbolized a shift in Labour policies towards a more market-oriented industrial strategy, and a clear signal that the KV model for research-driven industrialisation was no longer viable. The weakening of the network around KV and the breakdown of the network around ND weakened the position of R&D-intensive industry in Norwegian politics. When the national telecommunications industry collapsed in the early 1990s, (see Sogner 2007) the ideology that future industrial growth would come from public support for R&D in emerging technologies lost support, and the research-based industries became a much weaker player in the political system.

In this critical period of collapse in several emerging industries, Norway had an alternative potential industrial strategy. The offshore oil and gas sector had been selected as a major growth industry in the 1970s and was subsequently selected as a targeted technology area. The fall in petroleum prices in 1986 created uncertainty over the future profitability of the industry, but by around1990 the industry was again profitable and crucial for state income. The state-controlled companies Stat oil and Hydro, the strong engineering companies (Kuærher and Aker), supply industries, and other parts of the large scale technological system of the oil industry became the focus of policy. The strong position of the offshore oil and gas sector effectively displaced the research-driven strategy that had been directed towards emerging technologies. Public policy followed the change in the strategies of the largest resource-based companies. Norsk Hydro abandoned its R&D-driven diversification strategy, focusing instead after 1990 on improving production in 'core activities.' Norsk Hydro focused on three sectors; fertilizers, aluminium and oil/gas, and R&D related to other product areas decreased. The government followed suit, focusing on the same 'core activities'. Norsk Hydro, Statoil and a few others became the new 'national champions'. Within this industrial policy, R&D was no longer a source of economic transformation, and public R&D spending instead supported problem-solving activities in existing production systems.

The offshore oil and gas sector had by 1990 become a major part of Norway's economy. It shaped politicians' policy debates, as well as the behaviour of R&D performing organisations and other sectors of the economy. The ability of the oil and gas sector to attract attention away from the research-driven strategy is illustrated by the careers of the

promoters of the research-based strategy of the 1960s. Beginning in the early 1970s, Jens Chr. Hauge and Finn Lied turned their political interest towards the emerging offshore sector, emphasising institution building for a state-owned and nationally controlled system for exploiting the new natural resource. Hauge became the first chairman of the core political instrument, Statoil, and Lied soon followed him as the chair of the board. (Hanisch & Nerheim 1992) In a similar way the political system from the first half of the 1990s chose to focus on the resource based industries. There was less political interest in industrial R&D in general and in research-driven strategies in particular. (see Gulbrandsen and Nerdrum 2007)

The build-up of the large technological system around offshore production also attracted large parts of Norwegian industry seeking to exploit this lucrative market. Norway's industrial policy for the offshore sector ( Engen 2007) and the large scale of investment in the sector influenced the development of the Norwegian R&D infrastructure, the structure of Norwegian manufacturing industry, and some parts of the Norwegian service sector. The sectors of Norway's economy that supplied offshore production activities grew to constitute a significant part of the economy, a reality that influenced the behaviour of companies and policymakers. Norway's industrial R&D strategy became focused on the problems of the resource-based industries, particularly oil and gas. The large investments in the offshore sector during the early 1990s drew research institutes, universities and R&D-intensive companies into deeper involvement in Norway's oil economy. In this economy R&D intensive-industry was only one (of many) support

industries for the resource based industry. The R&D driven strategy for industrialisation based on emerging industries had come to an end.

The breakdown of the research intensive strategy for industrialisation created a path for Norway's industrial R&D investment and innovation system that contrasted with those of neighbouring economies such as Sweden and Finland. In these countries the R&D-intensive industries remained success stories (or were strong enough to survive), and the national policies remained focused on research-driven industrial strategies directed towards R&D-intensive industries like ICT, pharmaceuticals, aerospace, and biotechnology. Sweden and Finland stand out internationally as very R&D-intensive economies. Norway focused on developing resource-based industries in which R&D is not the sole driving force, but instead supports industry performance, acting as a servant in solving problems in large technological systems or as part of wider knowledge flows in the economy. One result of this trajectory of development is the persistently lower level of R&D investment in Norway by comparison with its Nordic counterparts.

## Notes

[1] At the Labour Party's 1963 annual conference, Wilson made possibly his best-remembered speech, on the implications of scientific and technological change, in which he argued that "the Britain that is going to be forged in the white heat of this revolution will be no place for restrictive practices or for outdated measures on either side of industry".

[2] S. Zuckerman ”Linking science with industrial growth”; Financial Times 7.11

[3] OECD published the first report on science policy, the Piganiol report, in 1963 and organized the first ministerial meeting on Science Policy the same year.

[4] Cuttings in the archives of the Ministry of Industry from Financial Times 7.11 ”Government drive to modernise Britain” and 15.11., on “Getting ready to push research” and S. Zuckerman ”Linking science with industrial growth”; “Three new bodies should take over from DSIR”, NOE-RA, VI, Boks 59, Utvalg i forbindelse med opprettelse av et utviklingsselskap.

[5] The director of the research council (NTNF), Robert Major, played an important role in drawing the attention of OECD policymakers to R&D policy. The 1963 OECD analysis was probably ordered by NTNF in order to bring industrial research into the realm of industrial policy. (Interview Robert Major)

[6] The main policy making organisation within the ministry was the Negotiation Committee (Forhandlingsutvalget or Gøtheutvalget) headed by the *statssekretær Odd Gøthe* from 1955. This committee discussed new ideas for establishment of new industry and came up with proposals to be discussed by the government. Næringsdepartementet, Utredningsavd, VI, 40; Forhandlingsutvalget for nye industritiltak, *Mappe 1 1955-6,6* Notat MM 29.11.63.

[7] NOE-RA, VI, Boks 59: Utvalg i forbindelse med opprettelse av et utviklingsselskap, April 1962: PM om et utviklingsfond

[8] This was the perception of the ministry of industry: ”NTNF is today primarily an advisory body for researchers, not for industry. The industrialists that participate in the NTNF do so in their private capacity and this does not guarantee close contact with industry” NOE, VI, Boks 59: Utvalg i forbindelse med opprettelse av et utviklingsselska7.3.64

[9] The Labour government intervened in the evaluation process and asked Hurlen, Hauge and also the representative of large scale industrialisation, nn, to be part of the evaluation committee.

[10] KV became this type of organisation between 1963 and 1987.

[11] Shipping and shipbuilding also played a central role in the strategy of NTNF. There was a build-up of the research infrastructure for these industries in Trondheim, and NTNF also assigned a high priority to this cluster when handing out R&D support to companies. The ship classification company, Det norske Veritas (DnV), was crucial in the strategy for developing technological competence within this part of the economy (Andersen and Collett 1989), and DnV alone received 17% of all money distributed from NTNF to companies during 1967-1977. In addition companies like Aker, Moss Rosenberg Verft, Ankerløkken, Bergen Mek Verksted, Wickman motorfabrikk and Norcontrol all received substantial support.

[12] Byggforskningsinstituttet, Norsk Geoteknisk Institutt, Vassdrags- og havnelaboratoriet

[13] Skipsmodelltanken, Skipsteknisk Forskningsinstitutt, from 1972 Norges Skipsforskningsinstitutt

[14] Elektrisitetsforsyningens forskningsinstitutt

[15] With the exception of one year KV never made a surplus. Every year it received (substantial) subsidies from the ministry of industry. It was more a technology-industrial policy instrument than a ordinary industrial company (NOU 1988)

[16] Kyllingmark was closely linked to Defence, and was a former member of the Hauge committee which discussed the future management of the defence sector in 1964.

[17] The specific direction of Norway research-based policy strategy became evident in the 1970s when Jens Chr. Hauge made an attempt to reorganise the IT industry which had emerged from the mid 1960s. Hauge followed up the idea which was developed in the Development Fund, that policy should encourage development of strong and large organisations. (Sogner 1994) From the 1960s different companies had been defined as 'key companies' who should receive public R&D support, while others were more or less excluded from the subsidy system. Hauge's effort failed and the research intensive industry remained small scale with a few exceptions, KV, ND and the two major international telecommunication, STK (ITT) and EB (Ericsson, Norwegian owners from 1974).

[18] This is based on NIFUSTEP Statistikkbanken for studies of R&D funding in the yearly state budget, defining the following categories as 'industrial R&D': primary industries, manufacturing, energy, transport- and telecommunication, space and defence. State funding in 1983 was 1189 mill NOK, increasing to 3034 mill NOK in 1993. In nominal prices the increase 1983 to 1993 was 155%.

[19] The targeted technology areas were introduced for the five years period 1986/87 to 1990/91.

[20] Project 'Mari Culture' by National Oceanic and Atmospheric Administration Sea Grant Office 1970, publication J. Hanson (ed.), Open Sea Mariculture, Dowden, Hutchinson & Ross, 1972. Based on Mariussen 1992.

[21] Pharmaceutical industry was traditionally weak in Norway. However, during the 1980s the small company Nyco made a break through in radiocontrast agent production, becoming a leading international producer of the field. (Amdam and Sogner 1994) The company's growth and profitability supported the idea that R&D could lead to new growth opportunities within research based industries. However, this sector was much weaker in Norwegian politics and science, and was not able to create the same type of support as that of the ICT sector.

[22] NTNF established a R&D programme for the emerging offshore sector during the 1970s, mainly directed towards development of production technology for the sector. It was part of the research council's wider strategy for promoting industrial development. However, the programme was rather limited and not incorporated into a wider strategy for the development of the new industry.

[23] The TC consisted of three types of regulations called '50% agreement', technology agreements, goodwill agreement. The latter represents 77% of all R&D funding of the system. Data on the Goodwill Agreements based on Wiig (1993).

[24] In the 1970s it was expected to harvest app 20 % of the total oil in the reservoir, while the percentage was app 50 at the turn of the century.

[25] KV exported numerical control systems for machinery to Toshiba, and Toshiba re-exported the systems to the Soviet Union. This created the deepest crises in Norway's relationship with USA since WWII. The government decided to get rid of the Kongsberg name and renamed the company to Norsk Forsvarsteknologi (Norwegian Defence Technologies)

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**Table 1: The five largest projects in NTNF's corporate programme during the 1980s**

| Company | Project | Details |
|---|---|---|
| Autodisplay | Instruments for car industry | 25 M NOK |
| Norsk Data | Software | 22 M NOK |
| Dophin Server | Orion superserver | 14 M NOK (the follow-up of ND) |
| Sensonor | Integrated sensors (inl. Car industry) | 9 M NOK |
| Norsk Data | Archival programmes | 4 M NOK |
| Norcontrol Simulation | | 2 M NOK |

(Source: NHD 1990: 106)

**Figure 1: Cumulative distribution of funding from Utviklingsfondet (Development Fund) 1965-1977**

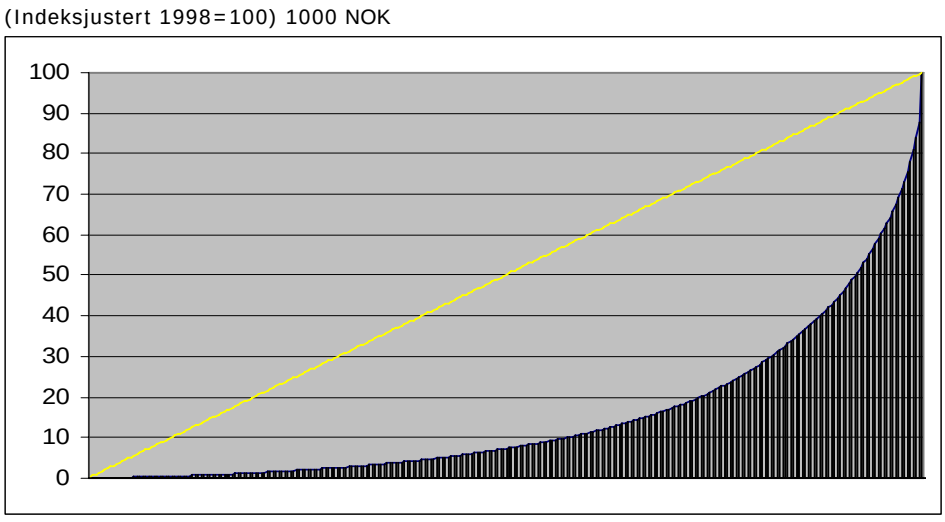



Figure 1 shows cumulative distribution between companies receiving support from Uviklingsfondet for the period 1965-77. The figure shows that 60% of total number of companies received app 10% of total funding, while 24 companies received 50% of total funding.

**Figure 2: R&D by funding, million NOK (fixed prices, 2000)**

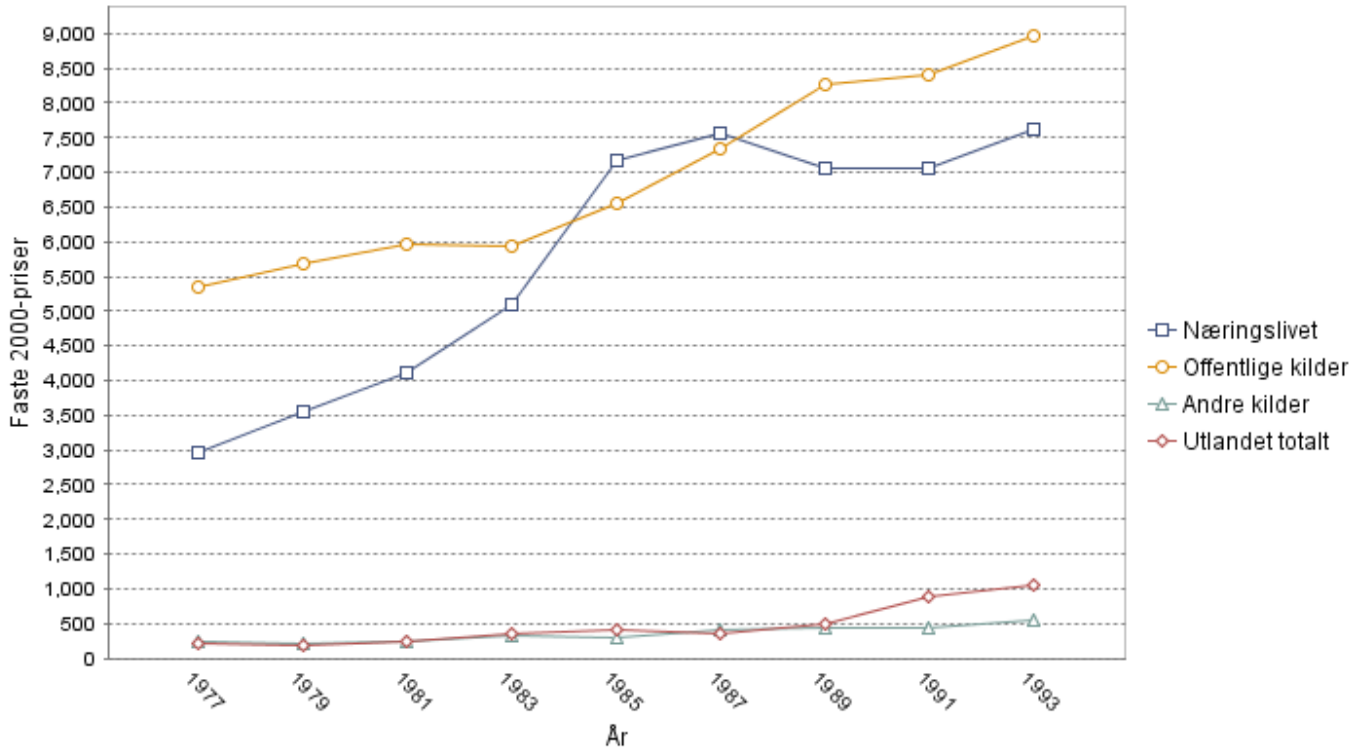
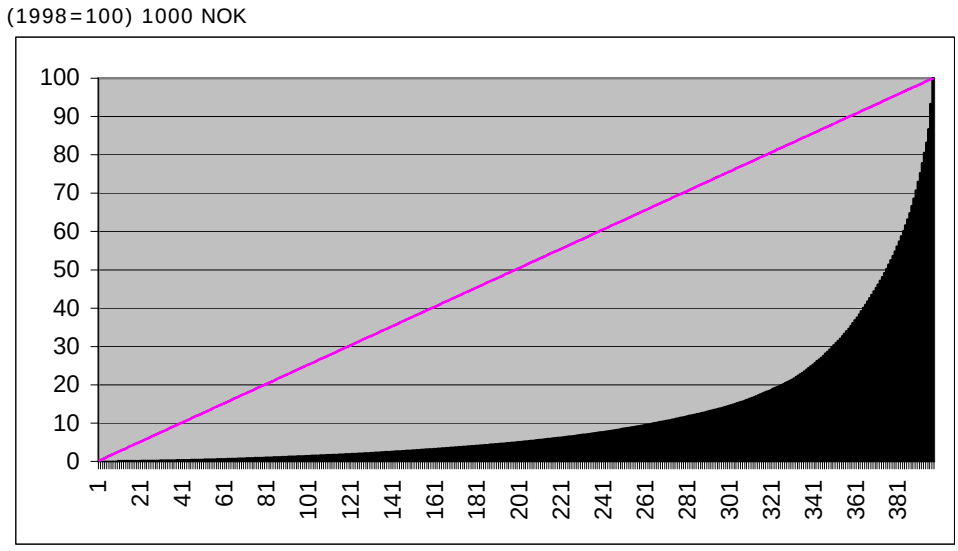



**Figure 3: Distribution of funds from NTNF (Nyskaping I næringslivet/Innovation in industry) 1978-1987**




The figure suggests that 13 companies received 50 per cent of total funding by NTNF 1978-1987