Manuscript submitted for publication in *Management & Organizational History* 04-07-2016. REVISED 03-10-2017. FINAL DRAFT – POST-REFEREEING

Envisioning a National Infrastructure for Science – Academic Entrepreneurship in 1890s–1950s Norway

Author: Thomas Brandt, Norwegian University of Science and Technology

Abstract

This paper investigates the importance of entrepreneurship in the establishment of institutions for scientific research in Norway from the late 19th century until the mid-20th century. By rethinking the historical development of three forms of institutionalization of scientific research – the science academy with its private funds; the central research institute; and the research council – this paper provides insights into how the entrepreneurial process worked to identify future opportunities, gather resources and legitimize ventures for the organization of science in Norway. The paper pays special attention to the role of a select group of scientists, and their inter-generational transfer of knowledge. At the same time, the paper argues for academic entrepreneurship as an inherently collective endeavor, involving also state representatives and industrialists. The methodology of the long-term historical narrative allows for highlighting the specificity of the Norwegian development, while acknowledging the importance of the shifting contexts of entrepreneurial action in a period marked by two world wars and economic crises.

Introduction

The purpose of this paper is to examine the importance of entrepreneurship in the establishment of the institutional arrangements for scientific research in Norway from the late 19th century until the early 1950s. In this period institutions for research outside academia were founded in most industrialized nations, and Norway thus followed a general pattern of growing public awareness of science as both a means for and a measure of modernity (Fox and Guagnini 1999). Norway was a young nation with relatively limited resources for science and a small scientific community. Still, like many small Western nation states in this period, Norway to a large extent mirrored, or at least echoed, international research policy trends (for a similar observation on neighboring Sweden, see Kaiserfeld 2013). Thus, focusing on Norway enables the discerning on a small scale of a general international pattern of organization of scientific institutions spurred by efforts we may term entrepreneurial.

Although my main concern is the organization of science in relation to industry – what we today would think of in terms such as research-based innovation or applied science –

my paper relates to historical developments predating the establishment of clear-cut distinctions in the Norwegian language between the equivalents of 'pure/fundamental' and 'applied' science or terms such as *Research & Development*. The situation was different in other languages. As shown by Clarke (2010), the use of distinctions such as 'pure science' and 'fundamental research' had implications for British science policy after 1916. The absence of such concepts and distinctions in late 19th and early 20th century does not entail that there was no relation between the realms of science and industry (see Fox and Guagnini 1999, 1-4). The historical actors in interwar Norway would often use science and research interchangeably and specify by adding 'industrial' or 'technical' when describing scientific research intended to be useful. Such distinctions are of little consequence in this paper, apart from in a specific situation in the immediate post-World War II period, to which I will return.

The organization of science, especially related to industrial purposes, has been a recurring topic in Norwegian historiography (Collett 1983; Sejersted 1993; Kvaal 1997; Andersen and Yttri 1997; Wicken 2009; Gulbrandsen and Nerdrum 2009). My contribution will be to highlight the importance of entrepreneurship in shaping research institutions in Norway, a perspective that so far has received little attention. An entrepreneur may be broadly defined as someone who is 'discovering, creating and exploiting opportunities to generate future goods and services, new economic activity, new organizations, etc.' (Chiles et al 2007). This definition may be criticized for being too wide, but at least it opens up for considering the entrepreneurial qualities of ventures beyond the narrowly commercial. Academic entrepreneurs are, according to Mody (2011, 9), often playing complex roles within wider research communities that are only partially oriented to commerce. Academic entrepreneurship as an activity is thus best understood, in a very general sense, as a set of processes where actors identify future opportunities, assemble resources to pursue those opportunities and seek to legitimize their ventures (See also the introduction to this special issue, Wadhwani et al 2016).

Through a re-reading and re-assessment of primary sources and the secondary literature on Norwegian scientific research organization, this paper will methodologically contribute to our understanding of academic entrepreneurship by studying a historical development in 1890s-1950s Norway. How did the actors involved in scientific research envision and identify future opportunities for organizing science on a national scale? What resources could be gathered for scientific research and how were they allocated in a period marked by economic recession, and how did the various ventures find legitimization? The long time span also allows the question of to what extent inter-generational learning occurred.

Norwegian scientists, industrialists and state representatives considered several models for organizing research in ways that would maintain the interests of science, industry and the public. To limit the scope of the investigation I will concentrate on three distinct forms of organization: the science academy with its funds; the central institute; and the research council. These are all instances of what Harwood (1994) calls 'third-sector institutions', meaning institutions devoted to research that were neither exclusively industrial nor academic in character, with funding coming from both public and private sources and located – geographically as well as institutionally – separate from both firms and universities (for a different approach, see Kaiserfeld 2013). The three institutional forms also mark a periodization as well as a development, from the academy as an Enlightenment construction set up to ensure scientific autonomy, the central institute was an early 20th century effort to create more co-operation between academia and industry, while the research council became a corporate governance vehicle for the nation in the post-war pursuit of the 'endless frontier' of science (Bush 1945).

The paper proceeds as follows: First I will provide a brief introduction to the international development of institutions for industrial research, in order to contextualize the Norwegian development. Then follows the discussion of the first of the organizational modes, the Nansen fund established by Waldemar Christopher Brøgger, after which I clarify the background for the increase in public interest in science in Norway in the wake of World War I. Next, I proceed to the presentation and discussion of the second organizational mode, the visions of a central institute, and the ensuing economic crises that hindered the realization of many plans for science before I go on to analyze the impact of the Second World War and the establishment of a Norwegian research council in 1946, also entailing the realization of the central institute.

The development of institutions for scientific research

In *The New Atlantis* (1627) Francis Bacon proposed what may be regarded as a first attempt at envisioning a science policy based on public support for a research institution. To obtain his goal of useful knowledge, Bacon outlined an integrated scheme with experimental facilities, equipment and trained personnel that he called 'Solomon's House' (Etzkowitz 1993). Although Bacon's idea indicates that public science policies are as old as modern science itself, it was only in the late 19th century that governments began to extend their involvement in science and technical matters beyond the modest contributions to universities, academies and science societies, and military research and development (Freeman and Soete 1997, 375).

Leading industrialized nations started setting up institutions that would link industrial development and public service to scientific research. These institutions were often a result of entrepreneurial initiatives by influential individuals or actor-groups.

In Germany, the Imperial Institute of Physics and Technology (*Physikalisch-Technische Reichsanstalt*), founded in 1887, became the first of several new institutions devoted to scientific research. The driving force behind this new form of institution was the industrialist and scientist Werner von Siemens, who saw the need for a research institute devoted to pure science, while also catering for the industrial demand for technological research and development (Walker [1997] 2003). This form of institutional setup, independent of both universities and industries, inspired similar arrangements in Germany and elsewhere. The National Physical Laboratory in Great Britain was established in 1900, after a campaign by British physicists fueled by public fear of the German competition (Moseley 1978). A year later, the US Congress established the National Bureau of Standards, encouraged by leading American physicists referring to the German *Reichsanstalt* as a success (Cahan [1989] 2004). Most notable of these pre-World War I institutions was the Kaiser Wilhelm Society (*Kaiser-Wilhelm-Gesellschaft*, established in 1911), which grew into a larger system of institutes devoted to fundamental research (Walker 1997/2003).

The First World War would later spawn several new research institutions due to the importance of science-based industry for warfare and the general rise in status of scientific research. The British Department of Scientific and Industrial Research (DSIR) was founded in 1916, the same year as the National Academy of Sciences established the National Research Council in the US, primarily based on private funding and with only loose connections to the federal government (Kaiserfeld 2013; Hull 1999; Kevles 1968). In the US, private foundations played an important role in science funding, with the Rockefeller and Carnegie foundations welding huge power through their research programs. In Germany, however, money was so scarce that a Public Emergency Foundation for German Science (*Notgemeinschaft der deutschen Wissenschaft*, 1920) was set up, with peer review as a new instrument for discerning between competing schemes for science (Walker 1997/2004).

Smaller nations would follow similar paths of development, as science policy trends tend to transfer easily across national borders, although appropriated to meet specific needs (Ruivo 1994; Elzinga 2012). While a latecomer both in terms of industrialization and academic institutionalization, Norway also experienced the development of a national system for industrial research marked by the translation of transnational trends into a national setting. Because of the severity of the economic crises in the 1920s and 1930s, however, Norway had

to wait until after World War II before a 'national innovation system' could evolve (Wicken 2009, Gulbrandsen and Nerdrum 2009). Already in the late 19th century, however, there were pioneering efforts seeking to bring Norway up to standards in what was always already a competition in scientific progress between nation states.

In the 1890s, Norway was an emerging nation experiencing economic growth through the increased industrialization of traditional sectors such as wood and metal processing and new technology led chemical industry. Also, substantial political change was underway, especially concerning the extension and strengthening of democratic institutions, but also in terms of a growing nationalistic sentiment concerned with extending Norwegian international interests and breaking the union with Sweden. The two patriotic impulses of independence and international engagement overlapped in the much-publicized polar expeditions led by Norwegian explorers at the time.

Brøgger and the Nansen fund

On the night of 20 August 1896 a telegram created commotion throughout Norway. 'All well', it shortly stated. It was from Fridtjof Nansen and his crew on board the ship *Fram*; they had survived their expedition to the Arctic.[1] The news of Nansen's safe return to the mainland was met with a resounding, patriotic roar in all Norwegian cities. Nansen and his brave men embodied a national spirit of adventure that could easily be fueled into the political agenda of seeking independence from Sweden.

Professor Waldemar Christopher Brøgger was among the first to congratulate Nansen on his safe return. Brøgger had known Nansen since they met in Stockholm in 1887 during Brøgger's spell as professor of Geology and mineralogy at the newly established *Stockholms högskola*. Brøgger was an academic entrepreneur, always envisioning ways to improve conditions for science in the service of the nation. How could Nansen's reputation become a resource?

Brøgger had already during his stay in Stockholm demonstrated his entrepreneurial abilities. There he had managed to build up a well-working research institute, secure the support from leading industrialists and state representatives, while advancing his scientific career internationally. When Brøgger returned to the university in Kristiania (today's Oslo) in 1891 at the age of forty, he was already a leading Norwegian scientist and a prominent member of the international geological science community (Hestmark 1999, 303–335). As

[1] Already by 14 August, Nansen had sent a telegram stating he was "Home safe after fortunate expedition". The news was published worldwide, e.g. in the article "Dr. Nansen is Still Alive and Making Good Progress Toward His Comfortable Home", in *Los Angeles Herald*, Volume 25, Number 317, 14 August 1896.

Brøgger was a self-conscious national strategist his peers called him 'the Bismarck of Norwegian science' (Hestmark 1999, 15). He was for a long period the nation's strongest proponent of science, with numerous public addresses and newspaper articles to his name. Few, if any, other Norwegian academics shared Brøgger's interest and ability in forging a public science policy. As a 'public scientist' (Turner 1980; Hull 1999) he was prepared to serve the nation, provided he would retain full autonomy as a scientist. He stood almost alone in his public struggle for science in Norway until the end of the First World War (Collett 1983, 50). Then others would take up his lead.

Brøgger's immediate reaction to the news of Nansen's return in 1896 was to propose a fund for science named after the famous explorer. Brøgger was well connected to wealthy and influential people within shipping, industry and academia, and eventually managed to secure enough support to establish the *Fridtjof Nansen Fund for the Advancement of Science* already before Christmas 1896 (Brøgger 1916, 15). The Nansen fund became one of the most important sources for science in Norway in the ensuing years. Not that there was much competition: The state of public as well as private support for science remained modest in Norway throughout the first four decades of the 20th century.

Brøgger had many motives for wanting to establish a fund for science in 1896. Norwegian science was in a state of crisis in the years after the parliamentary revolution of 1884 in Norway. Scientists were seen as part of the ruling elite, or even as the educators of the civil servants ruling Norway. The legitimacy of science had to be reestablished. By strengthening scientific research through a fund Brøgger hoped to prove that scientists could make important contributions to progress and prosperity. In a newspaper article in 1904 he ensured that any nation unable to keep up on the field of science would 'inevitably be outdistanced in a material sense.' (Brøgger, 1904).

For Brøgger it was first of all paramount to prevent Norway from falling behind in the race for scientific progress, and that a promising generation of able men of science found ways to pursue their ideas. It was also important for Brøgger to make Norwegian scientists less directly dependent on the state and the impoverished university (Collett 1983, 34). Science in direct service of industry, let alone the more contemporary notion of *applied research*, was alien to Brøgger. His overarching ambition was to turn the Science Society in Kristiania into a full-fledged national academy that could ensure Norway's most prominent scientists time and resources for fundamental research. For this he needed funds.

Brøgger did not come up with his ideas *ex nihilo*; he was deeply influenced by his period in Sweden, where science had far better conditions than in Norway (a fact, as well as a

rhetoric point frequently used by proponents of science in Norway). Swedish capitalists had been relatively eager to support science, and fund-raising campaigns there had resulted in important contributions to science. Besides, Sweden had an influential science academy with tenured positions that oversaw the distribution of funds. This combination of private funds and an academy was something Brøgger thought would be a solution to the crisis in Norwegian science. With the help of Nansen's name Brøgger hoped more money could be collected for science. Nansen had a strong identity also as a scientist, and was of course eager to support science, and was willing to use his name in Brøgger's service.

At the time there was a veritable race to capitalize on Nansen's name. Brøgger had to compete against business ventures like 'Dr. Nansen cigars' and 'Nansen's polar beer' (Hestmark 2000, 18). The professor also had to use a wide variety of entrepreneurial skills to promote his fund. He set up a fund raising committee balancing political interests from left to right, religious convictions and scientific schools of thought. He used his access to the national newspaper *Verdens Gang* to publish eulogies to Nansen and his crew, and he benefitted from his network of rich men interested in science, attracting a substantial amount even from a Swedish benefactor, Alfred Nobel. In 1918, Brøgger and his allies also finally managed to convince the Norwegian Parliament to grant substantial support for the fund through a share of the revenue from the National Lottery, and was thus an embryonic case of public-private collaboration in science funding in Norway (Collett 1981, 258). Yet, Brøgger's plan held no openings for others than scientists when it came to deciding over how these funds should be spent; industrialists, politicians and civil servants were only interesting as generous patrons for science.

Although Brøgger obviously enjoyed basking in the public glory of his own achievements, it was hardly his own research or business enterprises he sought strengthening. Brøgger was a nation builder. He was convinced that Norway could become an 'Athens of the North' (Hestmark 1999, 15), provided that the young nation got around to building strong institutions and to encourage talented youth to pursue a career in science. It was thus a hallmark for Brøgger when in 1924 the Science Society was turned into a national academy for science (a name change that was of symbolic rather than substantial importance at the time). He strongly believed in science, and insisted nothing would benefit humankind more than the pursuit of scientific research. Yet, in particular he advocated science as a fundament for progress, growth and industry in a national perspective.

The Nansen fund for the advancement of science was established in 1897, and Brøgger remained chairman of the board until 1937, when he retired due to his age. He died in 1940.

The Nansen fund was, as Brøgger's biographer Geir Hestmark (2000, 25) has pointed out, 'an opportunistic masterpiece'. It was also an entrepreneurial accomplishment. Brøgger had seized the moment, captured the spirit of heroic nationalism tied to the polar expeditions, and managed to raise support for his cause while keeping at bay the volatile forces of politics. The Nansen fund remained an important source of money and academic legitimacy in Norwegian science even long after Brøgger had passed (and is still in operation). The fund also provided the Norwegian Academy of Science with enough resources so that it in 1933 rightfully could claim to be a 'central organ in Norwegian science' (Amundsen 1960, 286-7). Still, neither the Nansen fund nor the Norwegian academy became as significant as Brøgger had hoped for when he started gleaning ideas from abroad.

Scientific opportunities after World War I

The First World War experience created a new emergency in the discussions of science policy, also in Norway. Brøgger now became preoccupied with how the belligerent nations organized themselves to take advantage of science. In the Kristiania Science Society, he frequently referred to new initiatives and organizations he saw abroad that provided him with fresh arguments and models for building research capacity. Organizations under development in France, Germany and Britain at the time provided entrepreneurs such as Brøgger with a range of organizational options they could consider. Yet, it was the initiatives taken by George Ellery Hale and Robert A. Millikan for establishing a National Research Council in the US that caught Brøgger's attention (Collett 1983, 48–49; Kevles 1968). This form of institution was ideal, Brøgger felt, because it was controlled by the National Academy of Sciences that would ensure the support of fundamental, long-term research in every field of inquiry, with the financial and moral backing from federal government, as well as private funds. He admired the donations made by Rockefeller and Carnegie, and preferred private endowments over the public funding model he saw in Germany (Collett 1983, 45).

In 1916, shortly after Hale had presented his ideas for the National Academy of Sciences, Brøgger, and his growing number of allies within the Science Society in Norway's capital, proposed a similar design for the Norwegian government (Collett 1983, 59). The response from the authorities was rather welcoming, but the discussions about a new science institution drowned in the precarious war situation, with dramatic shortages of supplies. This heralded a myriad of initiatives to establish research collaborations between the state, industry and science in Norway (Gulbrandsen and Nerdrum 2009). It became paramount to solve the raw material shortage crisis, and the industrialists and the politicians primarily wanted

scientists to contribute with their expertise in finding short-term solutions to these problems. Brøgger passed the assignment on to his younger colleague Victor Moritz Goldschmidt, a professor in mineralogy with ties to industrial firms, who was able to come up with plans for organizing industrial research pertaining to Norway's raw material resources (Collett, 1983, 66). One of the important issues that came out of these initiatives was the question of building industrial research institutes and laboratories. Most Norwegian companies lacked the resources for setting up their own R&D departments, and many industrialists were skeptical to the use of expenditure on science and technological innovation, unless it was specifically targeted towards solving industry-related problems (Gulbrandsen and Nerdrum 2009). Put shortly, many Norwegian industrialists and politicians were eager to establish a set of institutes with laboratories for industrial, applied research targeted at some specific areas of Norwegian industry (Collett 1983, 91-94).

Within academia these plans were met with resistance. Like Brøgger, many influential Norwegian scientists believed science best could benefit society and industry if it was autonomous and oriented towards basic research (Gulbrandsen and Nerdrum 2009). The establishment of 'third-sector institutions' residing outside of academia would challenge the necessary autonomy of science. It is, however, notoriously difficult to draw the boundaries between the inside and outside the realm of science. Also, science may have many different 'insides'.[2] In Norway, this became apparent in 1910 with the inauguration of a higher engineering education in Trondheim, the Norwegian Institute of Technology – *Norges Tekniske Høiskole* (NTH) – that changed the national academic landscape (Brandt 2014).

For decades Norwegian industrialists, engineers, politicians and scientists had longed for, and bickered over, a higher engineering education institution. The opening of the NTH in the quiet town of Trondheim had meant that Norway now had a new academic community, with professors in architecture, physics, chemistry, and various branches of engineering. Although most of them had been engaged in industrial and other business activities, they had not managed to set up a joint strategy for industrial research. While historically a fertile ground for academic entrepreneurship, engineering education institutions were also marked by tensions between diverging values and cultures in business and science (Carlson 1988). With the emerging discussions of industrial research institutes from 1919 on, the leading professors at the NTH felt their position was under threat. It became part of a lasting rivalry between Trondheim and Norway's capital (Kristiania, from 1925 on named Oslo) over the

[2] I am grateful to Berris Charnley for pointing this out to me.

leadership within industrial research. In the interwar years, the Central Committee for Scientific Cooperation for the Advancement of Industry, established in 1919, became a battleground for these struggles. The Central Committee was an initiative in the spirit of Brøgger, with representatives from 'autonomous public institutions' pertaining to science, which excluded both private corporations and the government (Collett 1983 103-108).

The Mellon Institute as model

One of the leading figures at the NTH was Sem Sæland, a physics professor with limited formal scientific qualifications. Of the twelve first appointed professors only six held a doctoral degree, and Sæland was not one of them (Wittje 2003, 48). Yet, Sæland had many other qualities that made him stand out as a natural and popular leader, as a young "founding father" for a young engineering school. He served as NTH's first Rector from 1910 to 1914, a period marked by growth and prosperity both for the engineering institution and for Norway's economy. Sæland was also member of the Norwegian parliament from 1916-18, where he gained valuable experience about the political game. As an experimental physicist trained in Oslo and Heidelberg he was more of a scientist than an engineer, and his contributions to industrial development in Norway came more as a result of his efforts at institution building than from his direct engagement with industry (Brandt and Nordal 2010).

After his period as Rector at NTH Sæland's main concern was to strengthen scientific research in Trondheim through building new laboratories and institutes. Sæland was strengthened in his vision for investing in scientific infrastructure after a study trip to England and the US in 1918. He came home with ideas for an independent industrial research institute after the model of the Mellon Institute in Pittsburgh. Founded in 1913, the Mellon institute was, according to Servos (1994), the result of the 'conjunction of a chemist's dreams, financiers' money, and an educator's ambition.' The chemist was Robert Kennedy Duncan, who, after a study trip to Europe, had been inspired by how European industrialists benefitted from collaboration with scientists (Weidlein and Hamor 1936, 21-22. For a further discussion of the Mellon Institute, see the contribution by Ellan Spero in this issue).

Duncan's idea for an academic entrepreneurial venture was to set up an institution around the concept of industrial fellowships. Through the fellowship scheme American companies seeking solutions to specific problems could finance the tenure of a research fellow. In return the company would retain exclusive rights to the scientific results, while the university's chemistry department providing the fellow would get some extra hours' worth of teaching (Duncan 1909). In this way, promising researchers could be lured out of their

laboratories to collaborate with industrial firms that in turn had money and specific problems to be solved. Duncan, after having made a trial of his fellowship arrangements at the University of Kansas, eventually found the necessary resources for his venture in Pittsburgh, with the Mellon brothers as investors, and the University of Pittsburgh as provider of qualified researchers.

Sæland was enthusiastic about the Mellon model, and in 1920 he helped bring it into the Norwegian debate on the organization of industrial research in the wake of World War I. Sæland was not the first to point out the Mellon institute as a potential model for Norway. Already in 1918 his colleague at the NTH, professor in mining engineering and respected industrialist Alfred Getz, had described the Mellon institute as one of several international organizations that could serve as an example for Norway (Getz 1918). Sæland, however, provided a more elaborated discussion of how an industrial fellowship system based on Duncan's ideas could be institutionalized in a Norwegian setting.

Sæland was arguing against the proposals of establishing industry-specific laboratories or institutes that were prevailing in parts of Norwegian industry at the time. Rather, Sæland argued, scientific research for industrial purposes had to be conducted under the supervision of leading scientists. The autonomy of science was thus as important to Sæland as it was for Brøgger in legitimizing academic entrepreneurship ventures. Further, in order to provide a truly scientific environment for industrial research, the institution would benefit from being closely linked to the NTH in Trondheim, which in turn would be able to grow by having access to industrial partners, financial support, research facilities and scientific talent (Sæland 1920). Sæland thus realized that the resources necessary for this venture were not only a question of money, but also of providing talented scientists and engineers with state-of the-art research laboratories to solve industrial problems.

Like many of his professor colleagues at the NTH, Sæland was concerned about the future development of the new engineering education institution in Trondheim, where important infrastructure in terms of laboratories and buildings were missing due to the public parsimony (e.g. Heje 1920). A central institute in Trondheim along the lines of the Mellon system could help concentrate the nation's sparse resources in terms of laboratories, man-power and funding, and thus buttress Trondheim as the hub of Norwegian industrial research and development (Sæland 1920).

Campaigning for Trondheim was, however, not the only motive legitimizing Sæland's vision of a central institute. The physics professor was convinced that industrial research, like any other kind of research, had to be directed, supervised and conducted by scientists with

freedom to pursue unexpected problems and explore new avenues. Such an approach to industrial research and development departed quite drastically from the plans for industry-specific laboratories located in the vicinity of the manufacturing plants, as the Norwegian canning industry in the Stavanger area had envisaged. Sæland referred to the director of the Mellon institute, who he claimed had warned against the dangers of introducing 'the factory spirit' into the institute's research. Rather, Sæland insisted, the 'research drive' or the 'scientific spirit' ought to be guiding the work at such an institution (Sæland 1920).

What Sæland had not noticed, or failed to report, were the growing difficulties facing the Mellon institute. Lauritz Jenssen Dorenfeldt, a Norwegian engineer visiting the Mellon institute in the same period, had found that the contact between the institute and the university was far from as close as Sæland claimed, and that the professor clearly was 'on the wrong track' when he suggested a scheme like this for the NTH in Trondheim. In Dorenfeldt's experience, the Mellon institute hardly contributed to the university, and he advised against spending public money on an organization that only catered for the private interests of individual industrialists unwilling to share the results of their investments in science (Dorenfeldt 1921). Dorenfeldt was no neutral observer; since 1919 he had been chairing a state department committee set up to investigate the potential for a paper industry research institute, which alongside the canning industry institute, were the only industrial research cooperatives established in interwar Norway (Gulbrandsen and Nerdrum 2009; Kaldal 2009). As noted by Servos (1994), the Mellon Institute model had indeed run into difficulties due to disagreements between university faculty and the institute. The university, especially the Department of Chemistry, was hostile to the institute because it provided next to nothing in return for the benefits of having access to the best students. They paid no rent for being placed on campus, and shared none of their revenues.

The objections voiced by Dorenfeldt did not prevent Sæland from using the idea of an institute co-located with the academic institution in Trondheim. Still, there was a conspicuous discrepancy between the rosy image of academic freedom painted by Sæland and the sobering account of the Mellon Institute presented by Dorenfeldt for the Norwegian parliament.

The discussions about industrial research took place in a period marked by political and economic turmoil in Norway. The immediate post-war years of 1918 and 1919 were prosperous and the surplus of money also found their way into several new funds, private and public, for scientific research (Collett and Skoie 1981, 97). Then the Norwegian economy went through three major setbacks in the period between the two world wars. The crisis following the First World War was due to the international post-war depression, but it hit

harder in Norway due to a monetary policy bent at restoring the Norwegian currency to the pre-war gold standard. From 1920 to 1921 the GDP fell by 9.6 per cent (Central Bureau of Statistics of Norway 1969, 350). The sustained deflationary policy resulted in a new recession in the mid-1920s, and in the early 1930s the international Great Depression also hit Norway. Although there was glimpses of upturns, the decades between the world wars were marked by high unemployment rates, low rates of investment, a large amount of bankruptcies and stagnation in public expenditure (Grytten 2002).

For a newly founded academic institution like the NTH the economic situation in the 1920s was stifling. The graduates had a hard time finding jobs, and the number of enrolled students plunged. Investments in new buildings and laboratory facilities dried up almost completely, and the institution struggled to fill vacant positions. Also, the decline in industrial development had severe repercussions, as there were fewer commissions and R&D projects. In this situation, more than becoming a lever for modernization, industrial and economic development, the NTH by and large became an insulated academic institution (Hanisch and Lange 1985, 89). The professors felt that the pressure from the industry to establish independent research institutes outside of Trondheim was threatening to undermine the institution.

Although the politicians generally welcomed the proposals put forward by Sæland and the NTH, they ended up with supporting the alternative ideas of industrial laboratories outside of Trondheim. Sæland, it turned out, was unable to muster the necessary resources for his entrepreneurial vision of a central laboratory in Trondheim. Yet, although the central institute plans were temporarily postponed, mainly due to the precarious economic situation after 1921, Sæland's ability to seek out important international developments and appropriate them into a Norwegian context demonstrates his position as one of the foremost academic entrepreneurs in early 20th century Norway (Brandt and Nordal 2010, 155).

While Sæland, with the support of his colleagues, managed to secure the establishment of a physics laboratory amidst Norway's enduring economic crisis before he moved on to execute the grand scheme for a new campus at the University of Oslo (Fure 2011, 109), his ideas for a central industrial research institute did not come to fruition during his lifetime. He died in 1940, the same year as Brøgger. Sæland's vision of a research institute modeled on the Mellon Institute, located on the campus of a higher education institution, was however sustained. It became one of the main points of contention in the immediate post-war.

Fredrik Vogt and the research council[3]

The idea of a research council had surfaced several times during the interwar years in Norway, after Brøgger had brought it up in 1916, with reference to the National Research Council in the US (Kvaal 1997, 75). A first attempt had been a follow-up of the growing governmental interest in organizing science after World War I, but this effort dwindled away during the 1920s. In 1935, the Norwegian state nourished a hope that scientific industrial research could ensure job creation in a time of severe unemployment. Again, Sem Sæland had been instrumental, he had worked behind the scenes to make sure this new initiative would be on the terms of science, not the industry (Kvaal 1997, 180). His position was here as adamant as Brøgger's. The result was The Council for Technical Industrial Research, established as part of the state administration, and with a mandate to make assessments and provide policy recommendations for public funding of science. It ended up as many of the other Norwegian science policy initiatives from the 1920s and 30s: with the best of intentions, but without necessary resources and support. After the Second World War this research council was sidetracked, and new impulses dominated, with new people to support them.

On October 12, 1945 a group of ten men met in Oslo at the Ministry of Trade. They were the members of the newly appointed Committee for the organization of technical research. They were scientists, industrialists and state representatives. Fredrik Vogt, Rector of the NTH, had already been selected as the chair of the research committee (Kvaal 1997, 319). Vogt had just returned to Norway after two years in British exile during the war and was now in charge of rebuilding the engineering education at the NTH in Trondheim. During his years in the UK he had been chairing another committee, the so-called Norwegian industry committee responsible for gathering as much information as possible on British and American military-industrial build up (Brandt and Nordal 2010, 228).

The lessons learned by the industry committee during the war were profound for Norwegian decision makers: Industrial capacity could be built fast and strong enough to win the war if only science, state and industry collaborated. Further, science-based industrial development was profoundly a team effort, and could therefore not be left to individual inventors or scientists. Teams of engineers, scientists and industrialists working together – often supervised by military interests – were behind many of the efforts observed by the industrial committee. This committee was therefore also a joint effort, made up of members

[3] For this section I rely on Stig Kvaal's collection of archival material from the establishment of the Royal Norwegian Council for Scientific and Industrial Research.

from industry, the state and science. The reports from the wartime industrial committee gave the Norwegian politicians in exile clear arguments for the necessity of a large-scale, systematic approach to science-based technological and industrial development. From another important group, the Norwegian Defense Supreme Command's technical committee (FOTU), came similar recommendations. Norway needed to establish a research facility for developing military defense technology as a national security measure. These recommendations resulted in the expedient creation of the Norwegian Defense Research Establishment (FFI) immediately after the war in 1945 (Forland 1988).

The committee for the organization of technical research, chaired by Vogt from October 1945 on, had to deal with the complex issue of creating an institutional framework for industrial and scientific research in Norway. The two terms 'industrial research' and 'technical research' were used interchangeably in relation to the committee's work, which hinted at a small unresolved difference between the involved actors regarding the focus and scope of the entrepreneurial venture: To what extent should the organization of research be directly targeted towards industrial needs? While the negotiations in the committee were set up as a balancing act between the interests of the state, industry and science, the mandate given by the government was to ensure that the benefits for industry from scientific research should be the main priority. While the interwar public interest in finding ways to organize research had been motived by pressing, short term needs for new raw materials and job creation, the post-war discourse had a broader scope: 'In order for our nation to be able to participate in the strong industrial competition one currently is facing', the government mandate stated, 'it is of the utmost importance to ensure an increased and more targeted work in the field of technical research. Given the small size of the Norwegian scientific community – with less than 70 professorial chairs within science and engineering at three separate academic institutions and a public expenditure on technical research of 13.5 million NOK – the committee was facing a daunting task in fulfilling this mandate. [4]

The committee was considering several models for organizing research for industry. This time, the entrepreneurial efforts were not based on a specific model from abroad, but rather on an assessment of a broad range of international options. Vogt was especially focusing on the institutions for science in Scandinavia, and on the British Department of Scientific and Industrial Research that he knew well from his time in London during the war. The representatives from Norwegian industry, most notably Alf Ihlen, were more preoccupied

[4] Norwegian Royal Decree, September 28, 1945, «Komité til å fremkomme med forslag om den tekniske forsknings organisasjon».

with ensuring that the public effort this time would be of a sufficient scale. Already in the first committee meeting Ihlen suggested the amount of 30 million NOK as a suitable level of funding for the new organization, a number way beyond anything previously invested in Norwegian science funding.[5] Ihlen could not find immediate support for his proposal, but it served as a demonstration of a sense of urgency among leading Norwegian industrialists for establishing a large-scale national science operation.

While the question of funding remained unresolved, the issue of finding a suitable organizational model for scientific research dominated the discussion among the committee members. Three alternatives were put on the table; an academy for science; a research council within the department of trade; or an independent organization governed by a research council with board members from science, the state and industry. The academy model was similar to the Swedish Engineering Science Academy. Also, Brøgger, as shown above, had been a strong proponent of the academy model, and his ideals of scientific autonomy in the governance of research funding had several proponents. After the war, however, the academy model was considered to 'lack the necessary public status for a national coordinating organ of science'. (Vogt ed. 1946).

The other alternative discussed was a research council organized as part of the Department of Trade. The deputy chair of the Vogt committee, Einar Slåtto, representing the department, backed this proposal. Slåtto had been instrumental in forging the mandate for the committee and was well connected with leading figures in the dominating Labor Party, and thus for him it was logical to propose an organizational solution as part of the state apparatus. The leading industrialists in the committee were however opposed to the idea of placing a research council within a state department. Instead, the committee began discussing another option, a research council of a 'freer kind', placed outside the departments of the state, and funded jointly by public and private money.[6] This was an innovative model for scientific research in Norway, and it was proposed by Alf Ihlen. He was wary of any arrangement that smacked of governmental control, as he assumed that the industrialists would be reluctant to participate. Instead, he wanted to organize the research council more like a private corporation, with an executive director supervised by a board, and with the authority to forge national strategies for R&D. Committee chairman Vogt, who had thought the state department model proposed by Slåtto to be more in line with similar arrangements he admired, like the

[5] Minutes from the constituting meeting in The Committee for the Organization of Technical Research, October 13, 1945.
[6] Minutes from The Committee for the Organization of Technical Research November 12, 1945.

British DSIR, was initially reluctant to back the idea of an independent research council. What eventually made Vogt budge is not clear, but may have been related to the funding of the new council: If the industry wanted an independent research council they would have to pay for it. Ihlen conceded, and promised he could rally financial support from the Norwegian industry.

The Vogt committee's final report then ended up with recommending the establishment of an independent research council for science and technology. It started out with painting a picture of how the recent war had demonstrated the decisive effect of coordinated research and technological development. It would be just as decisive in the ensuing peaceful competition between nations. 'Those not up to standard will inevitably fall into economic dependency', warned the committee, echoing the voice of Brøgger from 42 years earlier (Vogt ed. 1946, 5). Every nation of 'culture' was energetically pursuing scientific research. It was as if technological modernization through scientific research was the ultimate 'measure of men', to paraphrase Michael Adas (1989).

The Vogt committee spent only a few months preparing their report, and in July 1946 the Norwegian Parliament unanimously voted for the establishment of a Royal Norwegian Council for Scientific and Industrial Research – the official translation into English, suggesting a closer tie to industry than the Norwegian name did (*Norges Teknisk Naturvitenskapelige Forskningsråd*, NTNF). In October 1946 the 24 members of the council, representing industry, the state and the science institutions, were appointed. Alf Ihlen, a Norwegian engineer educated in the US and owner of a mechanical workshop, became the first chairman, ensuring continuity from the Vogt committee along with several of the other members. The balance between representatives from science, industry and the state was also maintained. Although this solution was meant to bring about the autonomy of the research council, and ensure democratic representation in a corporative fashion typical of Norwegian governance at the time, the research council was very much in the hands of a small, tightly knit group of men from the elite.

While Norwegian scholars previously have pointed to the importance of various actor groups in the establishment and development of the research council system in Norway, they hardly recognize the entrepreneurial efforts that paved the way for the creation of this powerful scientific research organization (Skoie and Collett 1981, 104; Slagstad 1998, 350; Kvaal 1997; 713–14; Nygaard 2014, 115–116). There is a clear line from Brøgger, who almost singlehandedly raised the issue of organizing science in Norway and through his efforts was making scientific research a matter of public importance, via the like-minded

Sæland who set a course for research institute building, to the work of Vogt, Slåtto and Ihlen. Although Ihlen eventually sidetracked the representatives from science and the state in his quest for an industry-minded research council, they all collaborated on envisioning a possible future for Norwegian scientific and technological research. The Vogt committee report is a hallmark of collective academic entrepreneurship in that it created an innovative model for public-private collaboration on industrial research. While unique due to the distinct nature of any national setting, similar acts of entrepreneurship aimed at building institutions for science took place in other Scandinavian countries, resulting in the establishment of research councils, although with important differences due to the more prominent role of academies, private funds and the greater number of large firms investing in R&D (for Denmark, see Knudsen [2005], for Sweden Pettersson [2012]).

The success of the research council model was by no means a given, even in the post-war drive for modernization through science. The German Research Council, established in 1949, became a short-lived failure. According to Carson and Gubser (2002), it was based on 'generic, ill-informed comparisons with British and American models' with inadequate concern for the specific challenges facing science in the new Federal Republic. The German Research Council was working under the conviction that research policy should be decided by scientists, but in the end it 'failed to persuade industrialists or economics officials of this.' (Carson and Gubser 2002).

In Norway, the issue of creating a central research institute was eventually solved as a result of the new research council, albeit not without conflict. Again, the main point of contention were the consequences for NTH in Trondheim. The visions of a central institute catering for the R&D needs of small and mid-sized Norwegian firms had lived on throughout the 1930s and 40s. In 1947 the question was brought up again within the NTNF council, at the initiative of the industry. The research council drew up a plan for funding and organizing an institute, with explicit reference to a 'Mellon-department' (Kvaal 1999, 6). Early on it became clear that Sæland's vision of locating the institute in the vicinity of NTH would not be fulfilled.

The NTH was in a poor state after the German occupation, overcrowded with students returning to finish their studies, with several vacant professor chairs and a dilapidated campus containing laboratories no longer up to date. Vogt, although no longer at the NTH, fought vehemently against the plans for an institute outside of Trondheim. It was of little use, as the industrialists, among them Ihlen, had lost their patience with NTH. Therefore, the Research Council instead decided to establish a research institute on the campus of the University in

Oslo, with the idea of taking up research problems common for many industrial companies in Norway. The professors at the NTH strongly opposed this idea. They had so far not been in the habit of working collectively towards a common goal, but the situation called for entrepreneurship: They rallied support and organized a local fund-raising for an alternative research institute in Trondheim. The result was the industrial research foundation SINTEF, established in 1950. The institutional symbiosis of SINTEF and NTH became a highly successful institutional innovation, an act of entrepreneurship born out of the pressure of competition. SINTEF soon became Norwegian industry's favorite partner for applied research, while also engaging in long-term fundamental science. Sæland's vision was finally brought to fruition (Brandt and Nordal 2010, 249–251).

Conclusion

The actors involved in the creation of institutions for scientific research in Norway during the first half of the 20th century used a variety of strategies and practices that are recognizable as entrepreneurial. For analytical purposes they may be categorized as the ability to identify future opportunities, gather the necessary resources to pursue those opportunities and find ways to give legitimacy to the entrepreneurial venture.

In order to identify the future societal opportunities attainable through the organization of science, the Norwegian academic entrepreneurs to a large extent relied on transferring concepts, models and ideas from abroad. The circulation of ideas, people and scientific artifacts such as books, journals, specimens and instruments is a well-known feature of modern science, dating back to at least the 17th and 18th centuries and the 'Republic of letters' with its cosmopolitan ideals and universalist ambitions for scholarship. Albeit vitiated by narrow-minded views of science that frowned upon experiments and fieldwork, the Republic of letters ensured networks of knowledge production that allowed for rapid and far-flung spread of information (Mayhew 2005). While the nationalist fervor of the 19th and early 20th century bridled cosmopolitan ideals, the established transnational, border-crossing practices of science meant that drawing ideas, designs and models for organizing scientific research was ingrained in the academic entrepreneurial mindset. In late 19th and early 20th century Norway, the transfer of models across borders was key to the academic entrepreneurial processes of envisioning as well as creating a future organization of research.

Brøgger was initially looking to other Scandinavian countries for inspiration for his vision of a large national science fund. Eventually he was however more intrigued by the initiatives taken in the US to create a national institution to support scientific research based

on a combination of private endowments and federal governmental support, yet under the auspices of the National Academy of Sciences. In terms of financial resources for the Nansen fund, Brøgger was initially relying on private benefactors to step up, but when this proved insufficient public money through the National Lottery saved the venture (Collett 1981, 258). Money was, however, not the only resource Brøgger made use of; unlike most of his peers in academia, Brøgger was able to create publicity for his schemes through media; he also had access to the nation's political and financial elites; as a prominent member of a first generation of modern scientists he could engage his younger colleagues in his struggle for achieving a broad scientific program in Norway.

Sæland would follow Brøgger's lead in envisioning a model for Norwegian scientific research with scientists at the helm. Sæland also looked to the US for inspiration, with the Mellon Institute as a model he deemed suitable to cater for a national effort for science-based industry, while at the same time strengthening the newly founded Norwegian Institute of Technology in Trondheim. Sæland had access to some of the same resources as Brøgger had, but the economic recessions between 1921 and 1936 curtailed his plans. In the new situation after 1945, Vogt and his fellow members of the committee for the organization of technical research made a broader assessment of international models, but with a more explicit intention of using these as raw material in the assembly of an institutional arrangement suitable for the Norwegian post-war situation, which entailed a substantial scaling up of the public financial engagement in science.

While the resulting institutions for research were innovative, even unique, they should not be understood in terms of exceptionalism. Instead of flagging the historical development in Norway as a *Sonderweg* (Sejersted 1993), it would be more worthwhile to consider the entrepreneurial processes of creating institutions for research as 'junctures where the nation-state's permeability might be brought into view' (Rodgers 1998, 2). Especially for small countries like Norway in the allegedly 'periphery of science' (for a discussion, see Gavroglu et al. 2008) the transnational transfer of knowledge, experience and schemes concerning how to organize industrial research was a concomitant of the entrepreneurial practice.

One of the most striking effects of adopting a long time span is the demonstration of entrepreneurial collaboration across generations. The paper demonstrates that visions, ideas and specific organizational designs were transmitted through time periods as a form of cultural memory residing within the scientific community. While beyond the scope of this paper, it is at least worth pointing out that there seems to be an untapped potential for combining historical studies of organizational change with the theoretical frameworks of

memory studies (Booth and Rowlinson 2006). The ideas and processes put forward by Brøgger and Sæland in the early interwar years transmuted into a full-fledged system of research institutions in the post-war period. What was the 'learning outcome' from this inter-generational transfer of visions, ideas and solutions for organizing resources for science? Most prominent was the realization of the importance of involving all stakeholders in industrial research in the process of creating a viable organizational framework that would balance the integrity of science with its relevance for society. The interwar visions of scientists in control of substantial resources was, especially in the field of industrial research, replaced by a post-war corporate model. In other words, bringing people together was an indispensable resource for the entrepreneurial venture.

Bringing stakeholders together to form communities around the endeavors of scientific research was thus crucial, and it involved overcoming differences of interest that were ingrained in science. One of the key issues here are related to the changing power-relations between the stakeholders of science. This has to do with a recurring issue in the history of science policy; in what Elzinga (1990) has described as the 'triangular drama' of science policy, involving science, industry and the state, the question of 'epistemic drift' looms large. That is, to what extent should forces outside of science be allowed to influence the definition of scientific problems, the solutions of these problems and the value of research results (Elzinga 1984, Kaiserfeld 2013). The organization of resources for science on a national level was a result of the negotiations within this triangular field of interests. Through the establishment of the Royal Norwegian Council for Scientific and Industrial Research in 1946 as an independent entity, a form of 'trading zone' (Galison 1997, 783-4) was created where various actors from industry, science and public administration could interact. The 'triangular drama' was by no means put to an end by this, but it was given a well-defined arena held up by institutional 'rules of the game'.

When it comes to understanding the legitimization of the various entrepreneurial ventures, a salient feature of the creation of institutions that becomes apparent from these Norwegian examples is the importance of historical and geographical context. Nations, nationalism and international competition were important determinants of the entrepreneurial visions in various ways. Baumol (1990), with a keen eye for the importance of historical perspectives in the understanding of entrepreneurship, reminds us that entrepreneurial activities sometimes are 'unproductive', even 'destructive'. While Brøgger's staging of the competition with Sweden may have had productive effects, enabling the capitalization of the scientist-explorer Nansen as a resource, the national perspective also proved unproductive,

especially in the interwar years, simply because it impeded the flow of talent, material resources and ideas that is so important for science.

Like in most other countries, the prominent scientists in Norway were nation-builders, and this paper demonstrates that their efforts at organizing resources for science also were state-building contributions. Yet, it is worth noting that these efforts were not always of a unifying nature, consolidating a national research community. At times their initiatives were just as much aimed at local interests, as part of strategies for strengthening their own scientific disciplines or as measures in the inter- or even intra-university competition. In other words, academic institutional entrepreneurs have crossing identities that enable them to be pivotal in both concerting and conflicting schemes for organizing resources for research. In the specific case of industrial research in Norway in the first half of the 20th century, the cagey relationship between Oslo and Trondheim was especially challenging. This may serve as a reminder of the importance of being sensitive to 'the historical geography of scientific knowledge', as recommended by Finnegan (2008).

Finally, one of the overarching frameworks for legitimizing the entrepreneurial ventures of both Brøgger and Sæland had been the importance of maintaining an idea of scientific autonomy. This idea had been productive insofar as to establish the authority of science as a vehicle for modernization in Norway. As in most industrialized nations, Norwegian industrialists and politicians held great hopes for how scientists and their research would result in progress also within the sphere of production. Many university professors did contribute in highly profitable ways to Norwegian industry in the years before World War II. Yet, the scientists were often reluctant of letting commercial or political interests into deciding over the direction of science. There were exceptions to this, but for academic entrepreneurs like Brøgger and Sæland the autonomy of science was a central prerequisite in legitimizing the venture of erecting institutions for research. Only scientists could decide over matters pertaining to scientific research. For Brøgger, with his idea of a science academy with a substantial fund, this attitude served him well, while Sæland never got to test his central institute plans due to the overall lack of funds in interwar Norway.

What happened to this idea of a clear-cut division between science and society during and after World War II in Norway? Obviously the distinction was blurred, the autonomy of science was no longer a primary reason for legitimizing institutional ventures within scientific research related to industry. The observations made by Norwegians in exile in the allied nations during the war had made clear that great industrial productivity could be

achieved through the collaboration between scientists, engineers, industrialists, civil and military authorities. After the war, a general spirit of common purpose in the reconstruction of the country after years of German occupation, combined with a democratic corporative ideology were among the factors explaining how industrialists, state officials and scientists realized they should sit around the same table to make decisions about the future direction of Norwegian research. The establishment of a national council for scientific and industrial research as an independent institution allowed for a rethinking of the limits of scientific autonomy. As pointed out by Guston (2000, 9), a recurring issue concerning public policies for science since the late 1880s has been how to maintain the integrity of science while also ensuring its accountability and productivity. Here, the research council of 1946 turned out to be a viable solution that also became a very fertile ground for academic entrepreneurship with a number of ensuing institutional establishments.

References

Adas, Michael. 1989. *Machines as the Measure of Men: Science, Technology, and Ideologies of Western Dominance*, Ithaca, N.Y: Cornell University Press.

Amundsen, Leiv. 1960. *Det Norske videnskaps-akademi i Oslo 1857-1957: 2*. Oslo: Aschehoug.

Andersen, Ketil Gjølme, Gunnar Yttri, and Kjell Wiedswang. 1997. *Et forsøk verdt : forskning og utvikling i Norsk hydro gjennom 90 år*. Oslo: Universitetsforlaget.

Baumol, William J. 1990. "Entrepreneurship: Productive, Unproductive, and Destructive." *Journal of Political Economy* 98 (5):893. doi: 10.1086/261712.

Booth, Charles, and Michael Rowlinson. 2006. 'Management and organizational history: Prospects', *Management & Organizational History*, 1: 5-30. doi: 10.1177/1744935906060627

Brandt, Thomas, and Ola Nordal. 2010. *Turbulens og tankekraft. Historien om NTNU*. Oslo: Pax Forlag.

Brandt, Thomas. 2014. "1968 as a turning point in Trondheim's university history." In *University Jubilees and University History Writing – A Challenging Relationship*. Leiden: Brill Academic Publishers.

Brøgger, Waldemar Christopher. 1904. “Videnskaben og det praktiske liv.” *Aftenposten*, 164 (March 20):1.

Brøgger, Waldemar Christopher. 1916. *Fridtjof Nansens fond til videnskapens fremme: 1896-1916*. Kristiania: Brøgger.

Bush, Vannevar. 1945. *Science – The Endless Frontier*. Washington: United States Government Printing Office. http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm#transmittal

Cahan, David. [1989] 2004. *An Institute for an Empire: The Psysikalisch-Technische Reichsanstalt, 1871–1918*. Cambridge University Press.

Carlson, W. Bernard. 1988. "Academic Entrepreneurship and Engineering Education: Dugald C. Jackson and the MIT-GE Cooperative Engineering Course, 1907–1932." *Technology and Culture* 29 (3):536–567. doi: 10.2307/3105273.

Carson, Cathryn, and Michael Gubser. "Science Advising and Science Policy in Post-War West Germany: The example of the Deutscher Forschungsrat." *Minerva* 40 (2):147–179. doi: 10.1023/a:1015708903590.

Central Bureau of Statistics of Norway. 1969. *Historical Statistics 1968.* Oslo: Central Bureau of Statistics of Norway.

Chiles, Todd H., Allen C. Bluedorn and Vishal K. Gupta. 2007. "Beyond Creative Destruction and Entrepreneurial Discovery: A Radical Austrian Approach to Entrepreneurship." *Organization Studies* 28(04): 467–493. Doi: 10.1177/0170840606067996.

Clarke, Sabine. 2010. "Pure Science with a Practical Aim – The Meanings of Fundamental Research in Britain, circa 1916–1950." *Isis* 101, 285–311.

Collett, John Peter. 1983. *Videnskap og politikk: samarbeide og konflikt om forskning for industriformål 1917–1930*. Oslo: J.P. Collett

Collett, John Peter and Hans Skoie. 1981. "Teknisk-industriell forskningsorganisasjon i Norge 1945–1980. Prinspiell debatt og hovedlinjer i utviklingen." In Appendix to *Forskning, teknisk utvikling og industriell innovasjon: en vurdering av den offentlige støtte til teknisk-industriell forskning og utvikling i Norge*. Official Norwegian Report (green paper) NOU 30 B. Oslo: Universitetsforlaget.

Dorenfeldt, Lauritz Jenssen. 1921. "Foreløbig innberetning fra ingeniør L. J. Dorenfeldt vedrørende de studier av industrielt-videnskabelige forskningsinstitusjoner, som han i 1920–21 efter Industriforsyningsdepartementets opdrag foretok på reiser i U.S.A, Canada og Tyskland." In *Om utnyttelse av innenlandske råstoffer til oprettelse av industrielle forskningsinstitutter*. Royal Norwegian Proposition 84 Appendix 2. Oslo.

Duncan, Robert Kennedy. 1909. "Industrial Fellowships." *Science* 29 (749):736–738. http://www.jstor.org/stable/1635028 .

Elzinga, Aant. 1984. "Research, bureaucracy and the drift of epistemic criteria." In *The university research system: The public policies of the home of scientists*, edited by

Björn Wittrock and Aant Elzinga, 191–220. Studies in Higher Education in Sweden No 5. Stockholm: Almqvist & Wiksell.

Elzinga, Aant. 1990. "Triangeldramat bakom forskningspolitiken." In *Makten över forskningspolitiken: Särinteressen, nationell styring och internationalisering*, edited by Wilhelm Agrell, 41–60. Lund University Press.

Elzinga, Aant. 2012. "Features of the current science policy regime: Viewed in historical perspective." *Science and Public Policy* 39: 416–428. doi: 10.1093/scipol/scs046

Etzkowitz, Henry. 1993. "Redesigning 'Solomon's House': The University and the Internationalization of Science and Business." In *Denationalizing Science: The Contexts of International Scientific Practice*, edited by Elisabeth Crawford, Terry Shinn and Sverker Sörlin, 263–288. Dordrecht: Springer Netherlands.

Fagerberg, Jan, David C. Mowery, and Bart Verspagen, eds. 2009. *Innovation, Path Dependency, and Policy: The Norwegian Case*. Oxford University Press.

Finnegan, Diarmid A. 2008. 'The Spatial Turn: Geographical Approaches in the History of Science', *Journal of the History of Biology*, 41: 369-88. doi: 10.1007/s10739-007-9136-6.

Forland, Astrid. 1988. "Atomer for krig eller fred? Etableringa av Institutt for Atomenergi 1945–48." *Forsvarsstudier* 2.

Fox, Robert and Anna Guagnini. 1999. *Laboratories, workshops and sites. Concepts and practices of research in industrial Europe, 1800–1914*. Berkeley: Office for History of Science and Technology, University of California, Berkeley.

Freeman, Christopher, and Luc Soete. 2004. *The economics of industrial innovation*. 3rd ed. London: Thomson.

Fure, Jorunn Sem. 2011. *Universitetet i Oslo 1811–2011. Bok 3: 1911–1940: Inn i forskningsalderen*. Oslo: Unipub.

Galison, Peter. 1997. *Image and Logic: A Material Culture of Microphysics.* University of Chicago Press.

Gavroglu, Kostas, Manolis Patiniotis, Faidra Papanelopoulou, Ana Simões, Ana Carneiro, Maria Paula Diogo, José Ramón Bertomeu Sánchez, Antonio García Belmar, and Agustí Nieto-Galan. 2008. "Science and technology in the European periphery: Some historiographical reflections." *History of Science* 46 (2): 153–176. doi:10.1177/007327530804600202.

Getz, Alfred. 1918. *Forskningsinstituter: Foredrag holdet i Trondhjems tekniske Forening 22. Oktober 1918*. Trondhjem.

Grytten, Ola Honningdal. 2002. "Norwegian policy response to the international economic

disintegration during the inter-war years." Discussion Paper 23/02. Bergen: Norwegian School of Economics and Business Administration.

Gulbrandsen, Magnus and Lars Nerdrum. 2009. "Public Sector Research and Industrial Innovation in Norway: A Historical Perspective." In *Innovation, Path Dependency, and Policy: The Norwegian Case*, edited by Jan Fagerberg, David C. Mowery and Bart Verspagen, 61–88. Oxford University Press.

Guston, David H. 2000. *Between politics and science: assuring the integrity and productivity of research*. Cambridge: Cambridge University Press.

Hanisch, Tore Jørgen, and Even Lange. 1985. *Vitenskap for industrien : NTH – en høyskole i utvikling gjennom 75 år*. Oslo: Universitetsforlaget.

Harwood, Jonathan. 1994. "Institutional Innovation in Fin De Siècle Germany". Review essay. *The British Journal for the History of Science* 27 (2): 197–211. http://www.jstor.org/stable/4027435.

Heje, Kolbjørn. 1920. "Norges tekniske Høiskole. Ved 10-aarsdagen." *Teknisk Ukeblad* 35: 442–443.

Helsvig, Kim. 2009. "Fortidslevning eller moderniserende elite? Det Norske Videnskaps-Akademi etter 150 år." In *Kunnskapens betingelser. Festskrift til Edgeir Benum*, edited by John Peter Collett, Jan Eivind Myhre and Jon Skeie. Oslo: Vidarforlaget.

Hestmark, Geir. 1999. *Vitenskap og nasjon: Waldemar Christopher Brøgger 1851–1905*. Oslo: Aschehoug.

Hestmark, Geir. 2000. *Fridtjof Nansens fond til videnskabens fremme: grunnleggelsen : Nansen minneforelesning 10. oktober 2000*. Oslo: Det norske videnskaps-akademi.

Hull, Andrew. 1999. "War of words: the public science of the British scientific community and the origins of the Department of Scientific and Industrial Research, 1914–16." *The British Journal for the History of Science* 32 (04):461–481.

Kaiserfeld, Thomas. 2013. "Why New Hybrid Organizations are Formed: Historical Perspectives on Epistemic and Academic Drift." *Minerva* 51 (2):171–194. doi: 10.1007/s11024-013-9226-x.

Kaldal, Ingar. 2009. "Lauritz J Dorenfeldt." In *Norsk biografisk leksikon*. Accessed March 31 2016. https://nbl.snl.no/Lauritz_J_Dorenfeldt.

Katzenstein, Peter J.. 1985. *Small States in World Markets: Industrial Policy in Europe*: Cornell University Press.

Kevles, Daniel J.. 1968. "George Ellery Hale, the First World War, and the Advancement of Science in America." *Isis* 59 (4):427–437.

Knudsen, Henrik. 2005. "Konsensus og Konflikt. Organiseringen af den tekniske forskning i

Danmark 1900–1960." PhD. Diss. Steno Instituttet: Aarhus Universitet.

Kvaal, Stig. 1997. *Janus med tre ansikter: om organiseringen av den industrielt rettede forskningen i spennet mellom stat, vitenskap og industri i Norge, 1916–1956*. Trondheim: Historisk institutt, Det historisk-filosofiske fakultet, Norwegian University of Science and Technology.

Kvaal, Stig. 1999. *Realiseringen av en gammel kongstanke: etableringen av SI og SINTEF*. Trondheim: Senter for teknologi og samfunn, Norges teknisk-naturvitenskapelige universitet.

Mayhew, Robert. 2005. 'Mapping science's imagined community: geography as a Republic of Letters, 1600–1800', *The British Journal for the History of Science*, 38: 73-92. doi: 10.1017/S0007087404006478

Mody, Cyrus C. M.. 2011. *Instrumental Community. Probe Microscopy and the Path to Nanotechnology.* Cambridge, Mass.: The MIT Press.

Moseley, Russell. 1978. "The origins and early years of the National Physical Laboratory: A chapter in the pre-history of British science policy." *Minerva* 16 (2):222–250. doi: 10.1007/bf01096015.

Njølstad, Olav. 1999. *Strålende forskning: Institutt for energiteknikk 1948–1998*. Oslo: Tano Aschehoug.

North, Douglass C.. 1990. *Institutions, Institutional Change and Economic Performance*: Cambridge: Cambridge University Press. *Cambridge Books Online.* Web. 04 April 2016. http://dx.doi.org/10.1017/CBO9780511808678

Pettersson, Ingemar. 2012. *Handslaget: Svensk industriell forskningspolitik 1940–1980*. PhD diss. 2065. Stockholm: Kungliga Tekniska Högskolan.

Rodgers, Daniel T.. [1998] 2009. *Atlantic Crossings*. Cambridge, MA: Harvard University Press.

Ruivo, Beatriz. 1994. "'Phases' or 'paradigms' of science policy?" *Science and Public Policy* 21 (3):157–164. doi: 10.1093/spp/21.3.157.

Sæland, Sem. 1920. "De industrielle Forskningsinstitutters Forhold til vore øvrige videnskapelige institusjoner." *Teknisk Ukeblad* 17: 229–233.

Sejersted, Francis. 1993. *Demokratisk kapitalisme*. Oslo: Universitetsforlaget.

Servos, John W.. 1994. "Changing Partners: The Mellon Institute, Private Industry, and the Federal Patron". *Technology and Culture* 35 (2): 221–57. doi:10.2307/3106301.

Slagstad, Rune. 1998. *De nasjonale strateger*. Oslo: Pax forlag.

Turner, Frank M.. 1980. "Public Science in Britain, 1880–1919". *Isis* 71 (4): 589–608. http://www.jstor.org/stable/230502.

Vogt, Fredrik. ed. 1946. "Innstilling fra Komiteen for den tekniske forsknings organisasjon." In *Om Opprettelse av Norges Teknisk-Naturvitenskapelige Forskningsråd*. Royal Norwegian Proposition 65 Appendix. Oslo.

Wadhwani, R. Daniel, Joris Mercelis, Anna Guagnini and Gabriel Galvez-Behar. 2016. "Introduction." *Management & Organizational History* 11 (4) PAGES DOI:

Walker, Mark. [1997] 2003. "Twentieth-Century German Science: Institutional Innovation and Adaption." In *Companion to Science in the Twentieth Century*, edited by John Krige and Dominique Pestre. London: Routledge.

Weidlein, Edward R., and William A. Hamor. 1936. *Glances at Industrial Research During Walks and Talks in Mellon Institute*. New York: Reinhold Publishing Corporation.

Wicken, Olav. 2009. "The Layers of National Innovation Systems: The Historical Evolution of a National Innovation System in Norway." In *Innovation, Path Dependency, and Policy: The Norwegian Case*, edited by Jan Fagerberg, David C. Mowery and Bart Verspagen, 33–60. Oxford University Press.

Wittje, Roland. 2003. *Acoustics, Atom Smashing and Amateur Radio: Physics and Instrumentation at the Norwegian Institute of Technology in the Interwar Period*. PhD diss., Norwegian University of Science and Technology.