Organizational networks had a strong influence on the diffusion of green knowledge within the Swedish pulp-and-paper industry from the mid-1960s to the 1980s. The environmental adaptations made by this industrial sector were not merely the result of a corporate initiative or of the response by firms or industries to environmental regulation. An examination of the innovation-system approach that was used to further the industry’s environmental goals reveals that the knowledge and technology development underpinning the project depended on a network of diverse actors. Within this network, the semi-governmental Institute for Water and Air Protection, working with a consulting company, was a critical generator and intermediary of knowledge. Thus, the success of the project was largely due to the Institute’s balanced relations with government and industry.

From the mid-1960s through the 1980s, the Swedish government supported organizational networks that were diffusing green knowledge among Swedish firms with a record of polluting the environment, such as those operating in the pulp-and-paper industry.¹ Business historians working within the tradition established by Alfred D. Chandler have hitherto given limited attention to the role of the state in shaping firms’ technological capabilities.² Moreover, for the most part,

¹We define the concept “green knowledge” as the knowledge needed to achieve deep emission reductions in Swedish heavy industry in the 1960s to the 1980s, with focus on the Swedish paper and pulp industry. It is assumed that knowledge is built up (and required) in the individual firm as well as in the related organizations and institutions that affect and assist the company in this knowledge accumulation process. These include, above all, other industrial enterprises, suppliers, consultants, industry associations, research institutions and public institutions, including environmental policy and regulation. A central assumption in this context is that the green knowledge was built up in the interaction between these institutions.

²See, for example, Kenneth Lipartito and David Sicilia, “Corporate Technological Capabilities and the State: A Dynamic Historical Interaction,” in Constructing Corporate America, ed. Kenneth Lipartito and David Sicilia (New York, 2004). Recently, a limited number of
mainstream business historians do not incorporate the environmental dimensions of business in their considerations. Christine Meisner Rosen argues that they have largely overlooked the impact of business on the environment and of environmental issues on business activities. Nevertheless, although the environmental dimension has been underrepresented in the business history literature, research on the topic has been expanding in the related disciplines of economics and business administration over the past twenty years.

Governments have influenced firms’ technological capabilities through several types of regulations over time. Recently, regulations on the environment and on safety and health have altered incentives to invest in innovation and have forced the development and diffusion of new technologies. Rosen has also suggested that an awareness of how legal and political events have induced the development of pollution-control technologies is critical to understanding the history of industrial environmental management. Environmental regulation has posed challenges to polluting and energy-intensive firms throughout the Western world during the second half of the twentieth century. It has had a far-reaching impact on both the extraction and processing of industrial materials and on the research and development activities of the affected industries. Emissions from Swedish industrial plants, such as those producing pulp-and-paper and basic metals, have been cut by up to 90 percent as a result of modern environmental regulation since the 1960s, while production has increased steadily over the same period.

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books have, however, been published on the state’s role in shaping infrastructural development. See, for example, Richard White, The Transcontinentals and the Making of Modern America (New York, 2011) and Richard R. John, Network Nation: Inventing American Telecommunications (Boston, 2010).


Lipartito and Sicilia, “Corporate Technological Capabilities and the State.”


through more efficient resource utilization and decreasing emission levels. Thus, technical progress has been an important factor of the environmental improvements made by pollution-intensive industries since the 1960s. Compliance with environmental regulations has also resulted in costs to firms that, in turn, have influenced their investment and production decisions and altered their incentives for engaging in research and development.

From the 1960s through the 1980s, the Swedish pulp-and-paper industry undertook radical environmental improvements at the same time as it was accomplishing structural rationalization and industrial renewal. The industry’s transformation was based on the development and diffusion of new knowledge concerning both its own impact on the environment and ways to improve waste management and cut emissions. Critical to the process was the decision by the pulp-and-paper producers to pool their resources in order to facilitate research and development programs that would include environmental technologies. The furthering of green knowledge was accomplished in cooperation with state agencies, particularly the state- and industry-funded Institute for Water and Air Protection (Institutet för Vatten och Luftvårdsforskning, hereafter IVL). The Institute was jointly founded in 1966 by the Swedish government and the Swedish pulp-and-paper industry in collaboration with other industrial sectors. Its primary assignment was to conduct research on the relation between industrial production and environmental problems and to identify effective solutions. Closely affiliated with the Institute was the Industry Water and Air Protection Company (Industrins Vatten och Luftvård AB, hereafter the IVL Company), a consulting company that was also established in 1966. While IVL and the IVL Company helped all Swedish industries to adapt their operations in a positive way to the environment, our focus in this article is on the pulp-and-paper industry.

The events of that industry’s history described here illustrate the important role played by state agencies in shaping the direction of Swedish technological development. The evolution of technology was driven not only by the pressure on firms to conform to emissions limits set by regulatory action, but also by the state’s willingness to fund research projects and to engage in knowledge exchanges with industry.

Previous studies have stressed that the environmental protection system shaped in Sweden at the beginning of the 1960s was based on a policy of cooperation that fostered relations of trust and enabled knowledge to flow efficiently between the environmental agencies and the

8Ibid.
10Bergquist and Söderholm, “R&D Collaboration and Environmental Adaptation.”
regulated parties.\textsuperscript{11} IVL represented an important cornerstone of this policy setting, since it represented an impartial arena for environmental and policy discussions among parties belonging to several sectors.\textsuperscript{12} We recognize that an analysis of the knowledge base, and of the technological development underpinning the industry's environmental adaptation, will benefit from looking not only at individual firms but also at the industrial research and production facilities that were engaged in transformation.

Scholars have begun to recognize that the growing complexity, risks, and economic costs of innovation compel individual organizations to collaborate in order to obtain the information they need. Awareness of the necessity to work together arises from the growing complexity, risks, and economic costs of innovation.\textsuperscript{13} Historical studies report that collaborations on research and development ventures and production projects are inspired by incentives to share costs and lower risk.\textsuperscript{14} As technology becomes more complex, it no longer makes sense for firms to restrict themselves to in-house research and development. Instead, they seek to access knowledge created by outside firms, universities, and other knowledge-generating bodies.\textsuperscript{15} Moreover, since environmental problems typically present features that make it too difficult for single firms to find solutions, it makes sense for them to create and join networks that can handle large-scale approaches to furthering their goals.\textsuperscript{16}

The literature on innovation systems describes how the state and consultants advance innovation. In this article, we examine how IVL and the IVL Company facilitated a semi-governmental system for advancing


the green knowledge that formed the basis of the new technology and methods for reducing emissions in Swedish industries. Scholars who recognize the importance of state agencies and public policies in shaping industrial research and development write about “national innovation systems.” Kenneth Lipartito and David Sicilia emphasize that the state is a critical participant in national innovation systems and thus has become an important topic for business historians to consider if they choose to employ an innovation-system approach. They assert that public policies have profoundly shaped the relations among all the actors in the system, including policies that link firms to one another. This assertion certainly applies to the field of environmental protection. As Mikael Hildén and his coauthors observe in their comprehensive study of the Finnish pulp-and-paper and chemical industries, networks formed to encourage innovation did so in response to environmental regulatory instruments.

In brief, we employ a theoretical approach not commonly used by business historians that we believe will be useful in examining how IVL and the IVL Company facilitated innovation in Swedish industry. We focus on the pulp-and-paper industry during a period when deep emission reductions were accomplished. After surveying selected parts of the innovation-system literature, we discuss the state of the Swedish pulp-and-paper industry over the course of the twentieth century, the evolution of Sweden’s environmental protection system during this period, and the concurrent roles of IVL and the IVL company. We analyze how these two organizations promoted the knowledge and technology that underpinned the environmental adaptation of the Swedish pulp-and-paper industry from the mid-1960s until the late 1980s.

**The Innovation System Approach**

The notion of innovation systems includes both institutions whose operations are not limited by the individual firm and networks of organizations that affect the rate and direction of technological change.
Pier-Paolo Saviotti writes, “Technologies cannot exist without institutions, except possibly in their very early and emergent stages.” An approach based on the innovation system is therefore useful for interpreting the social patterns of companies and other organizations engaged in institutional innovation.

This approach helps us understand the coevolution of technology and institutions while defining environmental technology as the imposition of public institutional constraints on technology users and producers. However, the state is not limited to shaping technological capabilities through regulatory constraints, as there are various other mechanisms at hand. Lipartito and Sicilia explain that the state strongly influences the national innovation system through its actions as a rule maker, a shaper of beliefs and attitudes, a participant in the market, and a channel for funds, all of which have an effect on the technological capabilities of individual firms. In this article, we provide evidence of how the state encourages technological capabilities through its cooperation with industry. Adding to the efforts of public institutions, individual firms expand their technological capabilities by forming networks with other organizations, such as manufacturers, suppliers, and consultants, further affecting the rate and the direction of technological change.

The view that firms are embedded in broad networks of public and private organizations helps us to grasp how they learn new technology and routines. Marko P. Hekkert and his coauthors have defined several functions of the innovation system that depend on learning. The work of John Bessant and Howard Rush, examining how technology is transferred from outside sources to individual organizations or firms is,
however, more relevant to the theme of our article. Bessant and Rush suggest that, by acting as intermediaries and assisting and advising firms, consultants directly transfer specialized, expert knowledge that enables firms to operate more efficiently. By providing a single point of contact through which firms can access a wide range of specialist services, the consultant channels clients’ needs and helps them to articulate and define their goals. Consultants may also unofficially broker knowledge between firms.

Thus, the literature on innovation systems describes how the flow of knowledge influenced the Swedish pulp-and-paper industry’s environmental adaptation. The production and diffusion of knowledge (both scientific and practical) were necessary components of the industry’s success in constructing and implementing green technologies at the systems level. We believe that our investigation will reveal the factors underpinning technology development that extend beyond the realm of the firm and, in the process, illustrate the complexities that have historically accompanied industrial environmental adaptation.

The Swedish Pulp-and-Paper Industry’s Relations with the Environment

The pulp-and-paper industry, which has been a major player in the Swedish economy for over a century, is not only one of the country’s largest industries but has also been one of its most polluting. There were only a few regulations in the early 1900s that allowed polluters to be prosecuted. For instance, in 1911, the Örebro paper mill was accused of being in violation of the 1874 Public Health Act, and the case was prosecuted in the Swedish Supreme Administrative Court. The Court ordered the mill to introduce several measures, such as lowering the


27 “Many user firms lack the resources or experience to understand and prioritize their problems in such a way that external resources and opportunities can be effectively utilized. Consultants can provide a valuable input to this first stage of innovation, by creating a strategic framework for change; they can also move from identifying needs in this fashion to suggesting means whereby the identified problems can be solved,” Bessant and Rush, “Building Bridges for Innovation,” 102.

28 The literature on the social constructionist approach to technology (SCOT) literature explains how this occurs. This literature typically focuses on individual consumers’ appropriation of technology (see Nelly Oudshoorn and Trevor Pinch, eds., How Users Matter: The Co-construction of Users and Technology [Cambridge, Mass., 2003]). On how firms as users can influence and get influenced by a technology, see Joanne Yates, Structuring the Information Age: Life Insurance and Technology in the Twentieth Century (Baltimore, 2005).
fiber content of its wastewater and constructing a taller smokestack. As a result, Swedish sulfate pulp producers were forced to recognize their responsibility for the foul odors emanating from their sulfate plants and to acknowledge the limitations that the release of the noxious fumes posed to industry expansion.\textsuperscript{29} Thus, early in the century, the mills jointly established and financed research to address both air and water pollution.\textsuperscript{30} This initial impetus for conducting research has altered over time in accordance with the changing regulatory framework.\textsuperscript{31}

In the early 1900s, legislation was vague and generally insufficient for managing the growing number of local conflicts over industrial pollution discharges. Eventually, the Swedish Parliament took up the issue. An ambitious legislative proposal to control both air and water pollution that included a case-by-case permit system was put forward in 1915. However, the proposal was defeated in 1921, due to the deep economic recession. In the 1930s, depression and war put enforcement of stricter regulation on hold.\textsuperscript{32} Regulation of water pollution resumed during the 1940s and 1950s, but air pollution continued to be loosely regulated until the Environmental Protection Act was passed in 1969.\textsuperscript{33}

During the 1940s and 1950s, Swedish pulp-and-paper businesses collaborated on efforts to expand environmental research and development that relied on efficient use of resources. One effort entailed improving methods of fiber extraction. The direction they followed was skewed toward certain goals: improving their use of resources, constructing methods for analyzing the composition of wastewater, and creating pollution-abatement technology. Discharges of organic materials, especially of effluents from the mills located along the coast of northern Sweden, had become a considerable problem in the 1940s.

\textsuperscript{30}Bergquist and Söderholm, “R&D Collaboration and Environmental Adaptation.”
\textsuperscript{31}Söderholm, “Environmental Awakening in the Swedish Pulp and Paper Industry.”
\textsuperscript{33}The 1942 Reform of the Water Act introduced a concession system, where those who wanted to release pollutants into water could apply to the Water Court for permission for such activities (some industries were obliged to, such as chemical pulp mills, sugar mills, and textile factories). The list of activities that required pre-investigation was extended by the Preliminary Examination Announcements of both 1946 and 1956. Also, the Water Conservation Committee was appointed in 1953, whose work resulted in a new regulatory law in 1956, meaning that the central water assessment now came to be administered by the State Water Inspection board instead of by the Fishing Authority. With the Health Care Act of 1958, local health boards were to ensure that necessary and reasonable measures were taken for the containment of water and air pollution, noise and other disturbances. See Jan Darpö, \textit{Vem har ansvaret? Rättsläget idag och förslag på framtiden: Efeterbehandling och sanering}, SNV (Swedish Environmental Protection Agency) Report no. 4354 (Stockholm, 1994); Hydén, \textit{Rättens Samhälleliga Funktitioner}. 
The practice of discharging fibers was highly inefficient, as it resulted in 15 percent waste. Increased efficiency was linked to the ability to reduce discharges of organic materials.34

Effective collaboration in environmental research and development became more important in the mid-1960s. The advent of stricter regulation increased the costs and risks of environmental adaptation. At this time, the industry was undergoing structural change leading in the direction of larger units with the potential to cause the kind of serious local environmental damage that was not allowed under the new regulation. The industry therefore intensified its collaborative efforts. Research and development activities and two new platforms were established: the state industry–funded IVL in 1966, and the Forest Industries’ Water and Air Pollution Research Foundation (Stiftelsen Skogsindustriernas Vatten- och Luftvårdsforskning, hereafter SSVL) in 1969. In addition, the pulp-and-paper producers recognized that pollutants had to be tackled through internal process measures, not simply through end-of-pipe treatments that reduce emissions after pollutants have already been formed.35

After establishing SSVL, the Swedish Pulp and Paper Mill Association commissioned it to conduct comprehensive environmental protection projects. The SSVL projects consisted not only of a broad set of representatives from private companies, research institutions, and industry interest groups, but also of consultants, equipment suppliers, and research institutions outside the immediate sector. Of about one hundred participants in the first SSVL project undertaken between 1970 and 1973, ten were representatives from IVL. IVL’s participation in a project conducted in the late 1970s was closer to 30 percent, and it grew slightly in another project that took place in the late 1980s. The proportion of equipment suppliers and consultants ranged from 10 percent to 20 percent over the 1970s and 1980s. Only a small number of researchers from Swedish universities who specialized in animal physiology, zoology, and environmental chemistry were represented.36 This assemblage of contributors who represented different skills and interests led to the establishment of an appropriate infrastructure for technology development and diffusion, and SSVL projects became central to the industry’s environmental adaptation during the 1970s and 1980s. The intense participation of IVL representatives in these projects reflected their high level of business leadership in environmental knowledge.

34 Bergquist and Söderholm, “R&D Collaboration and Environmental Adaptation.”
35 Ibid.
In the 1970s, SSVL projects focused on measuring and assessing discharges and developing methods to monitor the environment. The economic frameworks of these projects generally did not allow for the development of new technology. Still, over 500 million Kronor (SEK, in 2000 prices), roughly 60 million U.S. dollars (USD), was invested in the projects from 1970 to 1997. The largest sums were invested in the early 1970s. Individual firms, however, supplemented the projects on a large scale and, together with equipment suppliers, provided access to factory floors, machinery, and personnel. In this way, they contributed to meaningful technological development. The most prominent focus in the 1980s was on the environmental impact of chlorinated organic substances, nitrogen oxide, and sulfur dioxide. From 1970 until the late 1990s, the paper-and-pulp sector cut its emissions of sulfur dioxide by 97 percent, and those of chlorinated organic substances by 95 percent.

The main force behind pollution reduction in Swedish industry during the 1970s and 1980s was the Environmental Protection Act, which formed the basis of Swedish environmental efforts. The act was based on case-by-case judgments of every production unit, and its creators envisaged a licensing system that covered all use of property that could cause environmental disturbances. Paralleling the Act’s emergence as a potent force was the establishment of the quasi-judicial Franchise Board of Environmental Protection (hereafter, FBEP), which was empowered to grant the required permits. After considering statements submitted by the Swedish Environmental Protection Agency (hereafter SEPA), the FBEP could prescribe protective measures or standards that demonstrated “technical and economic feasibility.” Before knowledge about the environment began to be developed at Swedish universities in the 1980s, SEPA, founded in 1967, represented the only state organization gathering up-to-date information about the environment.

The Environmental Protection Act was designed to accomplish the two main goals of achieving the maximum possible pollution abatement and controlling the emissions of individual plants. It represented the first uniform framework for regulating not only air and water pollution but also noise and other disturbing activities caused by Swedish industrial plants. All production units that engaged in polluting activities, as

38 Ibid.
40 See Lundqvist, The Hare and the Tortoise.
well as those planning to do so, had to submit their plans for constructing or altering plants, factories, and other installations. Assessment of the plans was based on several criteria specified in the Act, and rejection led to the activity’s being closed or the proposed initiative canceled.

Sweden, together with Japan and the United States, is regarded as a pioneer in environmental protection. Sweden led the way with the establishment of the environmental protection agency in 1967. Political scientist Martin Jänicke has suggested that Sweden’s cooperative approach to environmental protection was more successful than the United States’ confrontational strategy for improving environmental quality. Swedish environmental regulators relied on a policy style that emphasized cooperation and consensus. They based their methods on the view that rational and balanced decisions could only be reached when each party knew and understood exactly what the other wanted. The Swedish system was based on direct intervention as well as on precautionary principles. While firm managers perceived the system as overly stringent, they acknowledged that under its rules they were given discretion in identifying the most cost-effective compliance strategies. Another feature of the system was that changes in internal processes designed to reduce emissions were favored over end-of-pipe solutions.

In conclusion, it can be said that members of the Swedish pulp-and-paper industry pooled their resources to facilitate environmental research and development even before the passage of modern Swedish environmental legislation in the late 1960s, although their cooperation intensified in the 1970s. To gain a full picture of this development, we must look beyond the industrial organizations. When the Swedish government founded IVL in 1966 in conjunction with the pulp-and-paper mills and several other industry sectors, it created an arena filled with opportunities to generate and diffuse new knowledge. This arena benefited from the dual participation of government and industry. The knowledge that was necessary for carrying out industrial environmental adaptation was no longer limited to a few contexts, but could be generated and diffused throughout the industry, conferring great benefits to large parts of Swedish society.

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43 Lundqvist, *The Hare and the Tortoise*.
Institute for Water and Air Protection and Industry Water and Air Protection Company

The Institute for Water and Air Protection (IVL) was formed as a single organization combining a wide range of specialist services for industrial environmental adaptation that could be accessed by both industry and government. A number of industry groups joined the forest products industries to form IVL, including the mining and utility industry associations and Sweden’s chemical industry office. Many water- and air-quality problems were common to different business sectors. Thus, by coordinating specialized research programs, they were able to accommodate several business interests simultaneously. Access to in-house specialists enabled these industries to assess their environmental problems and to participate in developing solutions.47

Closely tied to IVL was the Industry Water and Air Protection Company (IVL Company), which was also established in 1966. The two organizations shared facilities and were jointly administered. However, the IVL Company was not in any way governed by the state. While IVL’s primary task was conducting research on the relation between industrial production and environmental problems in order to find effective solutions, the IVL Company supplied consulting services, reports, analyses, and evaluations, and advised and assisted negotiations between industry and government agencies.48 Figure 1 illustrates the positions of both organizations in relation to the environmental authorities and industry.

IVL acted as a springboard for generating and diffusing the knowledge that Swedish heavy industry required in order to adapt to the shift in environmental policy, particularly during the 1960s and 1970s. The Institute supported basic and applied research on the quantity, content, and environmental impact of emissions like mercury, sulfur dioxide, and, not least, the wastewater produced by the forest industry. IVL moreover developed technical measures for lowering emissions and helped to standardize analytical methods and measurement instruments.49 The ability to reliably measure the scale and the impact of emissions was critical to developing efficient pollution-abatement technology. This knowledge was equally important to industry representatives and environmental authorities.

48 See, for instance, IVL verksamhetsberättelse 1980/81, archive of Swedish Environmental Research Institute (IVL), Stockholm.
Besides acquiring information about pollution, IVL performed more broadly as an organization of national experts. IVL was acknowledged outside Sweden for its unique expertise on, for instance, the effects of oil spills and mercury. In the 1970s, IVL was employed by international organizations, such as the World Health Organization and the United Nations Educational, Scientific and Cultural Organization. Today, as a limited company owned by a trust composed equally of government and industry members, it has added a subtitle: the Swedish Environmental Research Institute. In 2009, IVL had an annual turnover of 200 million SEK (about USD30 million) and 180 employees and is engaged in both research and consulting activities.

IVL and the IVL Company: Important Knowledge Intermediaries

The rationale behind IVL’s founding was the formation of a pool of financial and human resources housed under one roof for the purpose of developing and diffusing the knowledge and technology required to solve industrial pollution. During its first year, 1966, the Institute’s twenty employees worked in a leased laboratory and office space at the Royal Swedish Academy of Engineering Sciences (Kungliga vetenskapsakademien, IVA) in Stockholm, where it shared facilities with the IVL.
Company. The number of employees expanded to 44 in 1970 and to 150 in 1979; the Institute and the company moved to larger facilities in 1974. In the late 1960s, an air-pollution control division of IVL (which had its own consulting company) was set up in Gothenburg, and in the late 1970s, IVL had come to establish subsidiary experimental and research stations in various parts of Sweden. In the Stockholm laboratory, industry and government collaborated to identify and look for solutions to the most acute problems. The research and development agendas were also affected by changing societal norms and values, and policies were adjusted to make them consistent with the latest technological insights.52

Initially both IVL and the IVL Company focused on creating technologies that would measure and assess the quantity, content, and environmental impact of industrial emissions.53 In the late 1960s, most of IVL’s and the IVL Company’s operations, identifying the flow and amount of contaminated discharges, were carried out at individual mills. Arne Jernelöv, IVL’s research manager at the time, described what they did:

The consulting department of IVL identified the emissions for much of the cellulose industry. It is hard to imagine today, but when we arrived at the old mills, it could be a total jumble of old pipes. There were seldom any drawings to speak of that could give us information about what was running in the pipes, in which direction, and where, it was not at all clear. Usually, the best way to get information was to call in some old retired foreman who had worked there for 40 years. So, we spent a lot of time at the mills.54

Toxic mercury emissions, which can damage the nervous system, especially of small children, were an early focus of IVL. In 1966, in a joint project with the trade association of the chlorine industry, IVL and the IVL Company investigated the presence of mercury in lye and sediments in the immediate vicinity of chlorine mills across the country. In the course of these investigations, IVL developed methods for determining mercury levels and examined the tendency of oxidized mercury to bind chemically to different kinds of sediments.55 In separate operations, it developed and installed methods for treatment of industrial waste, especially of wastewater. Other IVL activities entailed restoring the receiving water body, developing standards for methods of routine

52 Bergquist and Söderholm, “Miljöforskning i Statens och Industrins Tjänst.”
53 Ibid.
54 Interview with Arne Jernelöv, Stockholm, 2010.
analysis, and creating instruments for measuring the character, extent, and impact of emissions.56

IVL, in conjunction with the IVL Company, developed basic knowledge and technology.57 As a result of their combined efforts, no individual firm had to assume the costs and risks of developing such knowledge. The fact that a semi-governmental institution took on this task underlined the willingness of both government and industry to accept the legitimacy of the knowledge and technologies that emerged from their efforts.58 Individual firms had access to a single connection that they could contact in order to benefit from a range of specialist services.59 Through their work in the individual mills, IVL and the IVL company not only diffused new knowledge and technologies but also gained practical knowledge that helped them to identify development needs.60

At IVL, the various departments, which became research groups in the mid-1970s, were populated by both natural scientists and engineers. These researchers regularly presented proposals to the IVL expert committee, outlining their views on the direction that the research to be conducted should take within the co-funded framework. The committee consisted of about twenty representatives from industry, mainly leaders, and a slightly larger share of representatives from government agencies, such as the Swedish Environmental Protection Agency (SEPA), universities, and other research institutes. A proposal was subsequently endorsed by the IVL board, which was made up of ten representatives, five state agency officials, such as the general director of SEPA (from 1971), and five industry representatives.61 The direction of the research to be undertaken within the framework of IVL programs was thus decided by state agency officials and industry representatives from different business sectors in concert with various natural scientists and engineers. In the late 1960s, these collaborations identified a number of projects, such as “the determination of hydrogen sulfide and sulfur dioxide in smoke gases” and the “cleaning of surface water.”62

Basic research on the environmental damage caused by specific pollutants expanded during the 1970s, a shift that was reflected in the growing number of natural scientists employed by IVL.63 It made sense

57 As entrepreneurial activities suggested by Hekkert et al., “A New Approach for Analysing Technological Change.”
58 Ibid.
59 See Bessant and Rush, “Building Bridges for Innovation.”
60 Interview with Arne Jernelöv; interview with Stig Freyschuss.
to assess the effects of emissions before developing measures to reduce the most damaging effects. IVL’s activities grew to an extent that could not have been foreseen at the time of its founding. These activities were funded by grants from both research councils and industry. However, the number of commissions grew rapidly and, by the late 1970s, accounted for more than half of IVL’s operations. The research manager noted, “When we had got the first results, it was much easier to get research funded [from] other environmental research-supporting organizations.” The statement indicates the importance of IVL and the partially government-funded framework in supporting and helping to initiate the basic research activities that would have been too costly and risky for individual firms to carry out.

In the 1960s and 1970s, IVL received funding from special research grants and commissions from industry, particularly the pulp-and-paper sector, but it also received backing from government agencies, such as SEPA, and local and regional authorities. In the early 1980s, SEPA commissioned IVL to investigate the possibility of using household waste-disposal sites as anaerobic filters for purifying leach water. In a parallel project, IVL worked with SSVL to investigate the possibility of using bark for the same purpose. Such efforts illustrate how IVL simultaneously explored similar solutions to problems, but in widely diverse sectors. SEPA and industrial entities also co-funded special projects to develop methods for assessing the impact of emissions from specific industries. The large number of commissions and research projects carried out at this time reflects the gap in Swedish specialist knowledge that IVL was created to fill. Before environmental research gained a place in the curriculum of Swedish universities, IVL was the country’s only organization with the requisite knowledge and research capabilities to operate within the environmental field.

IVL became a central resource for Swedish authorities to consult on a wide range of environmental issues, and it also organized and contributed many environmental courses at Swedish universities. These activities highlight the Institute’s important role as a mediator of environmental knowledge in the public sphere. Its broader societal role

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64 During the same period, the total turnover increased from 44 employees and 2.4 million SEK in 1970 to over 150 employees and 30 million SEK in 1979 (about 16 million USD in today’s money). In current prices, the activity of IVL grew by an average of 30 and 45 percent annually during the 1960s and the 1970s, respectively. See Bergquist and Söderholm, “Miljöforskning i Statens och Industrins Tjänst.”


66 Interview with Arne Jernelöv.

67 IVL verksamhetsberättelse 1980/81.


Green Innovation Systems in Swedish Industry

is further reflected in the research it directed toward the environmental effects of emissions caused by consumer products, such as sulfur dioxide, a byproduct of residential heating oil, petroleum spills, and detergents.70

The IVL Company’s operations for addressing the environmental impact of wastewater systems were driven largely by industry and, to a lesser extent, by local authorities. The company’s tasks included identifying industrial emissions; developing proposals for actions, programs, and processes that would reduce emissions; overseeing the construction of external purification plants; participating in, or carrying out, industrial research, development, and redevelopment projects; and advising and assisting negotiations between industry and authorities. Initially, identifying industrial emissions represented most of its activities. During the 1970s, and as an outgrowth of its early efforts, control of purification plants became a growing business. Designing these plants and participating in (or enforcing) industrial development projects accounted for an expanding part of its activities. In 1977, the IVL Company was engaged as the main consultant to an expanding pulp mill in northern Sweden. The number of employees grew from the initial twenty to eighty by 1971, and its budget increased during the 1970s to about twenty million SEK (approximately two-thirds of IVL’s turnover).71

The growth of the two organizations in the 1960s and the 1970s reflected the great demand from both industry and government for basic research and technology development on industrial pollution. Their joint mobilization to measure the scale and impact of emissions formed the basis for industrial adaptation to take place. Another critical feature of IVL and the IVL Company was that the knowledge they gathered on industrial water and air pollution formed the basis of the emission permits that were granted by the FBEP.72 IVL represents the cross-pollination and transfer of knowledge that has been described by Bessant and Rush. Meetings between government and industry took place in boardrooms, within the expert groups, in the laboratories, at individual firms, and jointly with the IVL Company. Communications among the groups did not always proceed smoothly, however, and IVL managers continuously discussed how the Institute could improve interactions with its users, particularly firms.73 In 1966, IVL began to hold annual conferences that were attended by industry and government authorities from Sweden and other Scandinavian countries in order to encourage communication among all interested parties.74 In the 1970s,

71 Ibid.
72 Bergquist, Guld och Gröna Skogar?
IVL intensified its efforts to become more inclusive by engaging IVL Company representatives in its management.75

The IVL Company represented the most direct link between IVL and individual firms. While it worked closely with IVL, it was entirely private. The company was hired to conduct fieldwork for IVL and, in turn, it hired IVL experts to conduct investigations and perform assessments. The IVL Company not only transferred IVL's experience and expert knowledge to individual firms but also assumed the entrepreneurial task of developing and implementing new technology. The IVL Company furthermore communicated the experiences of mills to others and sometimes even encouraged sharing between different lines of business, while bringing information about industry needs back to IVL.76

The flow of information between IVL and the SSVL projects was critical to the transformation of the environmental knowledge generated at IVL into practical solutions. One outcome was the development of cleaner technologies at mills. The Environmental Protection Act pressured larger factories to become more productive and to operate in a cleaner way. SSVL was more focused on changing internal processes than IVL; it was concerned exclusively with the pulp-and-paper industry. Nor did it engage in exchanging information with authorities to the same degree. As information about SSVL projects was elaborated by representatives of private companies, research institutions (in many cases, IVL), consultants, and equipment suppliers, it often overlapped the information gathered by IVL's network.77

Since the authorities were kept informed about the research projects being overseen by IVL and SSVL, the FBEP could sometimes stipulate conditions based on technology that was not yet fully developed as a way of encouraging progress. A franchise board member explained how this worked:

The Franchise board listened eagerly to the results of the investigations made by both authorities and industry and if we could see the prerequisites for a certain technological development, we ordered probation periods and stipulated conditions based on expected technological development and thus in fact stipulated technological development.78

76 Interview with Arne Jernelöv; interview with Stig Freyschuss; interview with Björn Lundberg, president of IVL in the 1980s and 1990s, Sollentuna, 11 May 2009.
77 Bergquist and Söderholm, “R&D Collaboration and Environmental Adaptation.”
78 Interview anonymous Franchise board official with experiences of pulp and paper licensing processes of the late 1980s and onwards, Stockholm, 8 June 2010.
The strong agreement between the government and industry on IVL’s value conferred legitimacy on the knowledge and technology developed by the institute. In the late 1970s, however, IVL and the IVL Company began to encounter difficulties in balancing the interested partners, and they severed their connection in 1981. By that time, their activities had grown increasingly distinct as IVL became engaged in natural-science research connected to the universities, while the IVL Company concentrated on activities related to industry. Arne Jernelöv, IVL’s research manager, further noted that the IVL Company’s practice of representing individual firms while they were being licensed was considered problematic by IVL. He thus explains the separation of the IVL Company from IVL as a natural outcome of the sharply divergent direction their activities were taking. IVL soon relaunched a consulting department, which received growing numbers of assignments. Its operations continued to focus on measuring and assessing industrial pollution and on external treatment measures.
Conclusions

In this article, we have described how organizational networks have influenced the diffusion of green knowledge within the Swedish pulp-and-paper industry from the mid-1960s to the late 1980s. Our study confirms several findings reported in the literature on innovation systems, such as the role of core systems in generating and diffusing knowledge and the benefits of intermediaries in accomplishing these goals. In addition, we have illustrated the importance of the state as both a regulator and a supporter of knowledge-generating organizations through funding and information. During the period covered here, the Swedish pulp-and-paper industry underwent a period of rapid environmental improvements based on new knowledge and the development of clean technology. Underpinning this process was interfirm collaboration on environmental research and development, complemented by knowledge diffusion on the measurement and impact of industrial emissions through the semi-governmental Institute for Water and Air Protection (IVL). The Institute was established in 1966 and was jointly funded by industry and government that operated as equal partners.

It was the pulp-and-paper industry’s initiative to establish IVL as a proactive measure to comply with the environmental regulations that were anticipated in the late 1960s. However, the action was also a sign of its willingness to regulate itself, as the industry had established and funded research activities to address both air and water pollution problems since the early 1900s. Those earlier acquired knowledge and research traditions were usefully applied to both air and water pollution during the 1960s. Complementing IVL’s activities, the industry expanded its research and development in the late 1960s by engaging in projects proposed by the Water and Air Pollution Research Foundation (SSVL), whose exclusive concern was to change the internal processes of the pulp-and-paper industry and thereby solve environmental problems faced by the sector.

Our account demonstrates that the environmental adaptation that the pulp-and-paper industry undertook from the mid-1960s to the 1980s cannot be understood by adopting a corporate focus alone—as an accomplishment by single firms or industries responding unilaterally to environmental regulation. By employing an innovation-system approach, we found that the knowledge and technology development underpinning this industry’s environmental adaptation involved a national network of diverse actors representing different, but complementary, functions. This semi-governmental system embraced private companies, consultants, equipment suppliers, and the government itself. IVL and its consulting company performed important intermediaries of knowledge that also embraced other manufacturing industries.
IVL’s central functions were mobilizing and pooling resources (thereby dispersing the risks of misguided investments), developing and diffusing knowledge, and guiding search efforts, all within a hybrid space shared by government and industry. The consensus about the value of IVL that existed among state and industry representatives created legitimacy for the knowledge and technology that it developed. All the involved parties agreed, at least until the second half of the 1970s, that basic research on measuring and assessing the environmental impact of industrial emissions was needed. IVL also functioned as an arena where different types of business exchanged knowledge, technology producers met technology users, and, not least, industry and researchers met government. Moreover, we found that the IVL Company not only transferred IVL’s specialized expert knowledge to individual firms but also developed knowledge about how new technology functioned under different circumstances. The IVL Company transferred experience from one mill to another, and sometimes across different business sectors, while bringing information about industry needs back to IVL. The rich store of knowledge that IVL, the IVL Company, and SSVL built up formed a network of support for industrial environmental adaptation that benefited not only individual firms but also the state.

The state was central to Swedish industry’s environmental adaptation. In our article, we report that environmental regulation was a driving force behind the development of technological capacities within the pulp-and-paper industry. The Environmental Protection Act, which was implemented in 1969, forced the sector’s producers to undertake all protective measures and impose all limitations on pollution that were considered technically and economically feasible. In so doing, it triggered a massive search for environmentally related knowledge. By continuously defining stricter emission standards for different pollutants, the state, through the environmental authorities, influenced the direction and extent of technological development.

Not only did the state influence the innovation system by issuing regulations; it also reflected and supported certain beliefs and attitudes. A central element of the Swedish environmental protection system that emerged in the late 1960s was the emphasis on cooperation and consensus seeking. The innovation system that emerged reflected and symbolized this ideology. Information generated at IVL partly formed the basis for the individual emission permits that the Franchise Board of Environmental Protection began granting to polluting plants in 1969. IVL thus served a broader role as a national expert organization.

The integration of environmental perspectives with business history provides many opportunities to shed light on how businesses have
interacted with their external environment. Our case represents a multifaceted picture of intensive research and development activities diffused through networks as a response to institutional change. The pulp-and-paper industry case highlights the complexities of corporate environmental adaption and supports the rationale for sharing resources and competence to accomplish technological change. The case also demonstrates how the state can shape firms’ technological capacity. A challenge for future research would be to compare how different national institutional settings have shaped the formation of “green” innovation systems. Such a project could be usefully amplified by including national features of corporate stakeholder relations, as such features influence how firms interact with other companies and groups.

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