Shared problems, shared costs and common solutions

Cooperation for clean technology development in the Swedish pulp- and paper industry 1900-1990

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Abstract:

This paper deals with the importance of inter-firm and state-firm cooperation for environmental adaptation in Swedish pulp and paper industry during the time period 1900-1990. By sharing similar pollution problems within the sector, companies collectively supported projects for R&D and could thereby share cost and the economic risks for developing cleaner technologies. Of big importance was the establishment of the Institute of Water and Air Protection (IVL) in 1966 and the Forest Industry Research Foundation for Air and Water Protection (SSVL), which functioned as intermediaries of environmental technologies in the sector. We conclude that the long tradition of intra-firm cooperation for solving environmental problems within the sector, which started already at the beginning of the 20th century, facilitated the development, diffusion and adaptation of clean technologies within the sector during the 1970s and the 1980s. Simultaneously, the new environmental legislation implemented in 1969 functioned as an ultimate driver. Our findings suggest that environmental policies that support collaborative R&D activities might facilitate innovation processes of clean technologies.

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Introduction

This article deals with the development and importance of inter-firm collaboration for environmental adaptation in Swedish pulp and paper industry during the time period 1900-1990. We particularly investigate the role of collective R&D activities, and its impact on clean technology development in the sector. The history of the Swedish pulp and paper industry proves a collaborative tradition in environmental issues, which begun already in the early 20th century. We study how collective activities related to R&D facilitated the environmental adaptation process of the Swedish pulp and paper industry, before and after modern environmental regulation was implemented. By sharing many similar technological challenges related to both environmental adaptation and economic efficiency we hypothesize that cooperation lowered the information costs and economic risks related to R&D, including investments in new machineries, for environmental adaptation.

Above all, this is a historical study of how industry collectively has responded to environmental challenges, using the Swedish pulp and paper industry as a case. Previous research provides little information on how environmental problem solving within Swedish heavy industry have unfolded over time. The Swedish Environmental Protection Act (EPA) was implemented in Sweden in 1969, but its effects on the firm- and industry level is still uncertain. Further more, it is also unclear to what extent industry was restricted by environmental concerns before the 1960s. While research has shown that technological change has been important for reductions of Swedish emissions since the 1960s,[1] it is still uncertain how these changes relates to firm- and industry level activities. As found in a case study of a Swedish copper smelter, the EPA contributed to far reaching technological alterations from its implementation in 1969 and during the following three decades.[2] Thus, in this article we specifically study how emission reductions have been achieved through technological change in one of Sweden's heavy industries. The Swedish pulp and paper industry has been of importance for the Swedish economy for over a century. At the same time, the sector has faced constraints related to environmental issues on a long term basis, even decades before the modern environmental regulation was implemented.

[1] Kander, Astrid, Lindmark., Magnus., Energy consumption, pollutant emissions and growth in the long run: Sweden during 200 years, *European Review of Economic History,* Vol 8, 2005:, pp 297-335.
[2] Bergquist, Ann-Kristin.,,*Guld och Döda Skogar? Miljöanpassningen av Rönnskärsverken 1960-2000.* Umeå Studies in Economic History No 36/2007, 2007.

Environmental laws developed in western economies have since the late 1960s and 1970s placed technical restrictions on firms' activities as well as great institutional uncertainties.[3] Besides governmental pressure, also social pressure, in form of protests, negative press, diminished reputation, pressure from trade associations, competitors, investors and even insurance companies, have made environmentalism a complex issue for today's corporations.[4] While international research in business economics and management has devoted great attention to these issues, there have been few contributions from business historical studies so far.[5] This we believe is interesting since pioneering research shows that business, for instance in the United States, Germany and Sweden indeed was affected by pollution control requirements long before the 1960s.[6] We do still notice that researchers from various disciplines have paid attention to environmental issues within the Nordic pulp and paper industries. Here, important questions of today have been raised such as CSR issues and implications from environmental regulation on productivity growth.[7] Still, research lacks a historical dimension to comprehend how heavy industry have managed to cut their emissions up to 99 percent since the 1960s[8], and costs associated to these achievements. The costs for environmental measures in the Swedish pulp and paper industry accounted for 10-14 percent of total investments during the 1970s and the 1980s.[9] Thus, this article will provide a further understanding of how environmental policies have affected the Swedish P&P industry before the 1990s, and how environmental technologies were advanced. Secondly, we also provide novel knowledge on why firms on long-term basis have pooled their recourses to jointly facilitate environmental adaptation and its potential effects. This we believe will shed some

[3] Hoffman, Andrew.J., *From Heresy to Dogma: an Institutional History of Corporate Environmentalism*. San Francisco: New Lexington Press 1997. p 29.

[4] Hoffman, Andrew .J. *Competitive Environmental Strategy. A guide to the Changing Business Landscape* p 138. Washington: Island Press, 2000.

[5] Rosen; M.C., The Business-Environmental Connection, *Environmental History*, January, 2005.

[6] See for instance Rosen, M.C., Business Against Pollution in the Late Nineteenth Century Chicago, *Business History Review* vol. 69, 1995, 351-397; Uekotter, Frank., Divergent Responses to Identical Problems to Identical Problems. Businessmen and the Smoke nuisance in Germany and United States , 1880-1914, *Business History Review*. vol. 73, 1999, 641-676; Söderholm, Kristina., Environmental Awaking in the Swedish pulp and paper industry: pollution resistance and firm responses in the Early 20th Century, *Business Strategy and the Environment.* vol. 18, 2009: 1, 32-42.

[7] See for instance Mikkilä, Mirja, The many faces of responsibility: Acceptability of global pulp and paper industry in various societies, 2006. The Finnish Society of Forest Science. Brännlund, Runar, Färe, Rolf, Grosskopf, Shawna.,Environmental regulation and profitability: An application to Swedish pulp and paper mills" *Environmental and Resource Economics*, Vol 6, 1995:1, 23-36.

[8] Bergquist, A-K (2007)

[9] Forest Industry Research Foundation for Air and Water Protection (SSVL), report No 74-85, Costs estimates for Pollution Control 1985-1991, see Appendix 20.

new light on the complexities involved in corporate strategies for clean technology development, thus enabling a link between the macro-level perspectives and industry level behaviour.

Technology development and firm cooperation

Technical change constitutes the basis for environmental improvements and economic development in general. The numbers of studies that have truly delved into the characteristics of clean technology development are few.[10] Historical in-depth studies shows that firms, in dealing with new demands for pollution control, have lacked knowledge concerning causes and effects of the emission problems and appropriate technical solutions.[11] The economic historian Nathan Rosenberg has emphasised that it is easy to overestimate the possibility to transfer knowledge or completed technical solutions into complex, factory specific conditions. Technology transfer between industries is a complex issue and cost effective solutions can take years to develop.[12] Furthermore, as also suggested by Rosenberg, technological development and technical change is a very uncertain and costly activity. Rosenberg argues that in companies' expenses for R&D, it is the development work; the 'D' of R&D that is critical in understanding the process of technical and technological change. Rosenberg states that the development process encompasses a wide range of diverse, information-acquiring activity. As companies act on the basis of restricted information they possess weak incentives to seek full information about what kind of technological achievements that could be used in their production process. Those weak incentives derive from the fact that the acquisition of information is costly. As the development of new technology requires much information, technical change is often a slow and very costly process. Mentioned also by Perry et al., long-term gains from innovation for pollution control, is bounded by the maximum reduction in abatement costs and that R&D is slow and costly.[13] For all these reasons, we believe that inter-firm cooperative strategies could be a rationale choice for polluting firms to reduce costs

[10] See Sterner, Thomas & Turnheim, Bruno., Innovation and diffusion of environmental technology: Industrial NOx abatement in Sweden under refunded emission payments, *Ecological Economics*, vol. 68, 2009: 12, 2996-3006.

[11] Bergquist, A-K (2007), Söderholm, K (2009).

[12] Rosenberg, Nathan, Exploring the black box. Technology, Economics and History. Cambridge: Cambridge University Press 1994.

[13] Parry, Ian W.H, & Pizer, William A, & Fischer, Carolyn., How Large are the Welfare Gains from Technological Innovation Induced by Environmental policies?, *Journal of Regulatory Economics*, vol 23, 2003:3, 237-255.

and risks for being engaged in uncertain activities such as pioneering development of clean technology.

The literature on firm collaboration in R&D generally suggests that firms enter into collaborative arrangements for innovation because they lack necessary resources, including know-how, and/or because they wish to reduce the risks associated with innovation.[14] A recent study by Cortat, published in *Business History,* confirm these assumptions. Cortat investigates R&D collaboration within a cartel for Swiss cable firms and concludes that the rationale behind R&D collaboration was cost sharing and risk saving opportunities related to production and research expenditures.[15] Among other things, the Swiss cable cartel established joint test laboratories, joint research laboratories and did even create a joint company to develop fibre optics.[16] The basis of cooperation can also be derived from the fact that learning-by-interaction is one of the key elements of technological learning processes at the firm level.[17] Malerba have empirically shown that the most frequent type of innovation is incremental, that in turn is related to firm learning processes.[18] Furthermore, as incremental innovation is not an event but a process of continuous improvements, it speeds up as a development trajectory as an increasing number of researchers and firms agree that a given technology is preferable to other technologies. Such a cooperative agreement lowers the uncertainties and risks related to R&D investments, as the risk that R&D projects have to be written off is minimised.

In sum, we find some clear arguments in literature that inter-firm collaboration can be cost-effective strategies in achieving technological progress, not the least for industries that are facing highly complex problems such as environmental. By pooling resources to collective R&D and perhaps other information acquiring activities, single firms could get access to technologies and know-how that wouldn't be possible to acquire by own resources. Costs for

[14] For an overview see, Un , Annique C, Martines-Romero, Ana M, Montoro-Sanchez, Angeles., Determinants of R&D collaboration of service firms,. *Service Business,* 3, 2008, 373-394.
[15] Cortat, Alain., How cartels stimulate innovation and R&D: Swiss cable firms, innovation and the cartel question, *Businnes History*, vol 51, 2009:5, 754-796.
[16] Söderholm, Kristina, *Miljöforskning inom den svenska pappers- och massaindustrin - från sekelskiftets luktkommitté till 60- och 70-talens laboratorier och forskningsinstitut*, Research report 2007:11, Luleå University of Technology.
[17] Meyer-Stamer, Jörg " Inter-Firm cooperation in Environmental management: Experience from Santa Catarina/Brazil. P3U-Working Paper No 7e, 2007.
[18] Malerba, Franco., Learning by Firms and Incremental Technical Change, *The Economic Journal*, vol. 102, 1992: 413, 845-859.

R&D is however not the only costs that firms have to bear in order to control pollution. Also investments in new capital, including process changes, purification works and monitoring technologies imposes even higher costs, and thereby also risks related to miss-guided investments. Thus, cooperation in terms of shared knowledge and experiences of preferable techniques already existing on the market, as well as other information of importance, such as environmental policy issues, could also lower the risk for miss-guiding investments. So in order to capture longitudinal dynamics between 'black box' processes of technology development and firm collaboration related to environmental adaption, it will, we believe, be necessary to use an explorative approach.

Firm cooperation in environmental R&D before the 1960s

Inter-firm collaboration in environmental issues was initiated for the first time in the Swedish pulp and paper industry in the early 20th century. This was a response to increasing local criticism against pollution, where the pulp and paper industry was particularly in the limelight. In some areas, firms, with reference to e.g., the so-called Public Health Act, were imposed to rather far-reaching and costly measures. In the case of Örebro Paper mill, this included the construction of an exceptionally high chimney aiming for the dilution of the typical sulphate odor.[19] The pollution problem was at the same time discussed in the Swedish Parliament, and an ambitious proposition for a new bill against the pollution of water and air, including a case by case permitting-system, was suggested in 1915 by a committee appointed by the government.[20] As a response to the rising environmental issue, the majority of the Swedish sulphate pulp producers met in Stockholm in 1908 to form the "Sulphate Pulp Committee" to voluntarily and jointly find measures against the nuisances stemming from sulphate pulp production. Collective efforts were established as the pollution problems, and especially the odor problem, became acknowledged as a threat for industrial expansion. One of the initiators of the committee, the chief editor of the "Swedish Paper Journal" (Svensk Papperstidning), Alvar Müntzing, stated that the industry, by joint efforts and costs would get

[19] Söderholm, Kristina, *Tekniken som problem och lösning – Föroreningsmotstånd och teknikval i 1900-talets svenska pappersmassaindustri*, Phd thesis, Lulea university of technology 2005:34, 2005; and, Söderholm (2009).

[20] In the end (in 1921) the proposition was declined due to the high unemployment rate and the industry-friendly government policy of the 1920s (Lundgren, Lars, "Från miljöproblem till miljövård" in Teknik som kultur – Tekniska museet 75 år, Höjeberg, Ed., *Daedalus*, 1999, Vol. 67).

the environmental problem, i.e., the odor problem, scientifically and technologically investigated in the best possible way. The Sulphate Pulp Committee met for at least five times in 1908 and 1909, while it is uncertain if it ever continued. It was nevertheless financed by, at the time, all 19 Swedish sulphate pulp producers, and did focus on activities like gathering information, elaborating knowledge and diffuse applicable knowledge of importance for the industry, as well as engaging in experimental activities.[21] The Sulphate Pulp Committee can therefore be seen as the first joint effort to approach environmental problems common for the pulp producers, even though its activities yet had marginal impact on the business activity.

However, collective R&D on other issues besides purely environmental started on small scale even earlier. The otherwise purely economically oriented (cartel-like) Wood Pulp Association, Paper Mill Association and Pulp Association, all established in the 1890s, did then for example give scientific lectures on topics like basic process technology and new machines.[22] In 1908, the Swedish Pulp and Paper Engineer Association (SPCI), principally a society of fellow engineers, were established with the articulated aim of facilitating technical development.[23] In 1931, the first department in pulp technology and wood chemistry was founded at the Royal Institute of Technology (KTH) with a state-funded professorship and industry-funded building.[24] The same building also hosted a number of central laboratories, one for every economic association mentioned above.[25] The purpose with these laboratories was to address timely technical problems and to follow up the development of international research. The pulp industry established the first central laboratory in 1936, with research primarily focusing on improved pulp extraction. The laboratory personnel did also work directly with experimental activities in existing plants and did engage about 70 individuals in the 1960s.[26] So, in practice, the development work (the D of R&D) for these collective projects did actually take place at the private mills.

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[21] About the Swedish Sulphate Pulp Committee, see *Svensk papperstidning* 1908 (Nos. 4 and 9); Söderholm (2005); and, Söderholm (2007).

[22] *Svenska Pappersbruksföreningen 1923-1948: Minnesskrift vid 50-årsjubileet*, Stockholm, 1948.

[23] SPCI is still active and meets up continually at the production sites with the most modern technology (.Interview with Folke Burstrand, Piteå, 23.09.2009).

[24] There was also some state-funded research on wood chemistry carried out at the Royal Institute of Technology (KTH), in front by Peter Klason, professor in chemistry and chemistry technology between the years of 1890-1913. About Klason, see Sundin, Bosse, *Ingenjörsvetenskapens tidevarv*, Umeå Studies in the Humanities 42, Umeå University, 1981.

[25] They, together with a number of individuals, funded the building. See Rydberg, Sven, *Papper i perspektiv – Massa- och pappersindustri i Sverige under hundra år*, Skogsindustrierna, Stockholm, 1990.

[26] Rydberg (1990).

In the mid 1940s, the first central research organization for wood product research, the state-industry jointly financed[27] Swedish Pulp and Paper Research Institute (STFI), was founded with the original idea to pursue research in close cooperation with KTH on forest products and to advance methods for their rational refinement and exploitation.[28] Eventually, in the 1970s, the R&D activities in STFI became directed on improved material and energy utilization from the wood, as well as on developing new systems of process control and more environmentally friendly bleaching methods.[29] So even though STFI wasn't established to specifically deal with pollution issues, it ended up doing so, as improved material utilization and process control became an important strategy to combine pollution reduction with production expansion from the late 1960s.

However, concerning environmental issues, in 1936 another governmental committee was appointed by the Swedish government to propose legislation for air- and water pollution. This resulted in the establishment of a Fishing supervising authority in 1937 and the Water Act was implemented in 1941.[30] As a response to the again rising environmental issue, the Central laboratory of the pulp mills established the *Water pollution committee* in 1945[31], to examine the pollution of watercourses. And in only a few years, the committee became a joint organ for the whole forest industry, with representatives from the different branches and thus declutched from the Central laboratory of the pulp mills.[32]

In the 1940s, the discharges of organic dissolvable materials had become a real problem-area; especially from the mills along the coast of northern Sweden. The discharges of fibers were in some areas so enormous that dredging was needed in order to get company

[27] The Swedish state did already partly fund the Swedish Institute for Metals Research, founded in the 1920s. According to Sundin (1981) this type of industry-state collaboration was typically an expression of the Swedish view on state-industry cooperation as an advantage in reforming the Swedish society, a tradition established in the early 20th century..

[28] From the 1940s to the 1960s, research performed by STFI was mainly focused on the reactions of the wood components at pulp production and bleaching, and new analytical and sampling methods were developed (Rydberg, 1990).

[29] Rydberg (1990).

[30] Hydén, Håkan, *Rättens samhälleliga funktioner*, Report series 1978:4, Department of Sociology of Law, Lund University, 1978; and, Darpö, Jan, *Vem har ansvaret? Rättsläget idag och förslag för framtiden – efterbehandling och sanering*, Report No. 4354, Statens Naturvårdsverk, Stockholm, 1994.

[31] The Swedish Pulp Mill Association had actually already in 1937 appointed a committee to examine what the pulp industry could do to lessen its waterborne pollution and to solve related problems. The committee was, however, in economic distress after only a few years (and WW2 started) (See Söderholm, 2007).

[32] Skogsindustriernas vattenskyddskommitté, *Meddelande*, Nos 9 and 12, Stockholm, 1954.

ships in to the quays of the mills.[33] Above that, lakes smelled of hydrogen sulphide and could be completely oxygen-free. At the same time, discharges of fibers were indicating great inefficiency, as important prospects for earnings, up to 15 percent of all fibers, were actually wasted away. Therefore, the Water pollution committee expanded with a full-time employee service engineer in 1948. The engineer functioned as technical assistant at mills aiming for fiber recycling and machine investments. Interestingly enough, this joint financed engineer also made questionnaires to locals, and not surprisingly, it was concluded that the public indeed was troubled by the odor from sulfate mills and fermented fiber piles.[34] Because of a rather intense activity in the Water pollution committee, it grew to become the Water Laboratory of the Wood Industry (SIV) in the mid 1950s.

If the activity during the 1940s had been directed towards information, service and consultation, outlines for the now five employees at SIV concerned to a greater part actual R&D. On the whole their tasks was to examine possibilities of recycling byproducts of the wastewater, but also to examine the composition and effects of wastewater, develop methodology of water analysis as well as to develop measures against pollution. In 1956 the activities of the laboratory was reformed into a research department and a self-supporting service department, which from the very start had about 60 assignments and 40 different clients.[35] Demand continued to be high for the service department and in the 1960s the number of employees rose to about 10.[36] Alongside with the service department the research department grew steadily, and employed about 10 individuals in the early 1960s. R&D activities at SIV was directed foremost on biological, but also chemical treatment of the

[33] This was reported to be the situation around the pulp mills near cities Timrå and Sundsvall, cited at the coast around 500 kilometres north of Stockholm (Interview with Stig Freyshuss, Lidingö 08.10.2009, president of SIV, 1958 -1964 and IVL 1966 -1982.

[34] Interview with Stig Freyshuss 08.10.2009.

[35] The service-department usually was assigned in connection to license-trials in the Water Court, to carry out maps, flow charts and water-court examinations, as well as to give general advices and to suggest and assist in the adaptation of measures against pollution. The service-department further came to accomplish a growing number of watercourse examinations in cooperation with the National Water Inspection as the Water courts to an ever increasing extent demanded the state of the watercourses to be monitored in connection the permitting process.

[36] In focus of the time was typically the oxygen-supply of the watercourses as well as the treatment of condensates. The condensates of the pulp industry were both directly poisonous to fish and contributed heavily to the sulphate odor, however, had not yet constituted real matters of treatment by the industry.

wastewater, effects of wastewater in the water courses and methods of analysis and sampling technology. [37]

The research department of SIV was fully financed by the Wood pulp, Paper mill- and Pulp associations up to 1958, where after the possibility came up to receive means from the State fund for price equalization charge means.[38] The fund, however, came to an end in the mid-1960s and the laboratory established the need of financial support for the research department (the service department was self-sufficient due to its many assignments). It was not an option to cut down the activities of the research department given that the work on the Environmental Protection Act already was in full progress.[39]

The pulp and paper industry – by arrangements through its collective organs – frequently, i.e., once a year, arranged colloquiums with representatives from both the Swedish and other Nordic forest industries. This activity started already in already in 1949. The meetings were also joined by people from the Federation of Swedish industries, as well as from a number of public institutions, such as the Water courts, the National institute for public health and the National board of fisheries. At the colloquiums and in the "letters" frequently handed out to the individual mills, topics ranged from general water protection[40], to technical measures[41], and to fiber recycling and methods of analysis. The colloquiums were further in general concluded with open discussions were the participants tended to be rather generous in informing about purification measures and methods of analysis. The "letters" further informed of study trips made by SIV employees to, for instance, a number of North American mills.[42] Thus, these colloquiums functioned as an important intermediary of information to the firms, both concerning technology advanced in the collective industry laboratories, as well as technology generated abroad.

In sum, we find that the collaborative arrangements for environmental R&D grew steady during the 1940s and 1950s, however with a clear focus on efficiency aspects, such as improved fiber extraction. We find that path of the technology development in both general

[37] Söderholm (2007). See also Skogsindustriernas vattenskyddskommitté, *Meddelande*, Stockholm, 1954 – 1956; Skogsindustriernas vattenskyddsråd, *Meddelande*, Stockholm, 1957 – 1964; and Interview with Stig Freyshuss 08.10.2009.

[38] Wohlfart, Go□ran (Ed.), *Svensk skogsindustri i omvandling*, Skogsindustriernas samarbetsutskott, Strukturutredningen, 1971.

[39] Interview with Stig Freyshuss 08.10.2009.

[40] Especially the composition and effects of the waste water of the pulp and paper industry.

[41] Such as biological purification, filters, and sedimentation basins.

[42] Söderholm (2007).

and environmental R&D had a bias towards rational resource utilization. Important to acknowledge in this respect is that Swedish forest industry, particularly the pulp producers generally feared a future shortage of timber during the studied period[43], which likely had a significant impact on these R&D priorities. So in this respect, striving for increased economic efficiency by improved fiber extraction worked hand in hand with lowering emissions of chemical oxygen demanding (COD) substances. Still environmental R&D was not only directed on resource utilization, but foremost analysis of waste water composition as well as finding methods for pollution purification. In connection to this, also effect studies i.e. how wastewater actually affected the recipient became an important area for methods and analysis. The Water Laboratory of the Wood Industry (SIV), was the most important platform for environmental R&D, while the Swedish Pulp and Paper Research Institute (STFI) was directed on issues related to processes for improved resource utilization.

The big Environmental breakthrough

> At first, the motives behind […] [the environmental protection activities of the Swedish pulp and paper industry] were foremost economic in that large amounts of chemicals and fibers were lost through discharges. […] A more resolute work aiming for decreased discharged began in the 1960s. Large-scale reductions of fiber and oxygen-consuming materials were achieved through production process alterations. This "spring-cleaning" ended in the 1970s by continued process improvements and by the installation of different kinds of purification works. Environmental protection requirements further made it economically impossible for some mills to continue operating and many small mills chose to shut down. Thus, also contributing to the decreased discharges of the line of business was a structural rationalization." (authors' translation)

The citation above is the Swedish pulp and paper industries own short summary of its environmental protection activities up to the 1980s.[44]

As have already been noticed, R&D related to environmental protection measures were to some degree driven by efficiency reasons before the 1960s, but also by environmental

[43] Sjögren, Hans., *Den uthålliga kapitalismen. Bolagsstyrning i Stora Kopparberg Bergslaget AB, Astra och Svenska Tändsticksbolaget.* Stockholm: SNS:s Förlag, 2005 see chapter 5.
[44] *Miljö 90, Slutrapport*, Stiftelsen Skogsindustriernas Vatten- och Luftvårdsforskning, SSVL, Stockholm, 1991, 38.

demands stemming from both locals and the authorities. With the implementation of the Environmental Protection Act in 1969 however, more far-reaching and profound measurements were required. The magnitude of pollution control that the new regulation implied made the pulp and paper producers concluded that it was only through reconstructed and new plants embodying the latest techniques that the discharges could be substantially reduced.[45] One implicating factor for improved pollution control was the ongoing trend towards concentration of pulp and paper production into larger units. In the 1960s, the Swedish pulp and paper producers realised that their production levels had to increase in order to keep up with the international competition. This also included shut downs of inefficient plants, mostly cited in interior areas. In the year of 1960 there were totally 110 pulp plants in Sweden and 20 years later, in 1980, there were only 35 pulp mills still producing 74 percent more then in the year of 1960. The need for structural change towards larger units in the 1960s entailed a potential risk of more serious local environmental damages, which the new regulation in 1969 wouldn't tolerate. The pulp and paper producers therefore concluded that pollutants had to be dealt with "inside the mills" by process alternation, and not simply by end-of-pipe treatments.[46] Furthermore, the new stricter demands for environmental protection also contributed to a phase out of sulphite pulp mills in Sweden. Calcium based sulphite mills which were rather common had many environmental disadvantages as regards of discharges of BOD, lignin, gases and dust that demanded radical external purification works. Therefore, the business sector strategically aimed for production expansion based on the adoption of sulphate processes which both had the potential to profitable burn black liquor and recycle chemicals.[47] In the period 1966-1989, the production of sulphate pulp was doubled whiles the production of sulphite pulp decreased by almost 50 percent.[48] Nevertheless, structural rationalisations would only mitigate some parts of the environmental problems, as there were still great problems also related to sulphate pulping and paper production. Undeniably, as indicating in table 1 below, both Swedish pulp and paper industry had to invest heavily to curtail pollution problems. During the 1970s and the 1980s the costs for environmental investments accounted for 9-14 percent of all investments. The pulp producers accounted for

[45] Skogsindustrierna (1971b), p 320.
[46] Skogsindustrierna (1971a) p 432.
[47] Wohlfart, Go□ran (1971).
[48] *Miljö 90*, 1991, 38.

the main part where the share of environmental investments accounted for 17.5 percent of the total investments during the period 1985-1988.[49]

Table 1. Costs for environmental investments in the Swedish pulp and paper industry 1968-1988 (current prices)

Categories of producers		68-70	71-75	76-79	80-84	85-88	Total
(I) *	Unintegrated sulphate plants, unbleached	-	-	-	-	-	-
II	Unintegrated sulphate plants, bleached	25	167	295,2	272,9	505,3	1265,4
III*	Integrated and integrated sulphate plants, unbleached	47	249	188	301,4	591,4	1376,8
IV	Integrated sulphate plants,bleached	22	131	172,7	291,9	900,9	1518,5
(V)**	Unintergrated sulphite plants, unbleached	4	35	3,1	-	-	42,1
VI***	Unintegrated sulphite plants, bleached	-	-	-	-	-	-
VII**	Intergrated sulphite plants, unbleached	5	10	5,9			20,9
VIII	Intergrated and sulphite plants bleached	18	183	58,5	170,4	175	604,9
IX	Unintergrated production of mechanical pulp (inc.CTMP)	4	8	19,6	17,8	62,7	112,1
X	Intergrated production of mechanical pulp	5	67	27,9	14,6	50,2	164,7
XI	Journal and paper journal plants	42	144	140,3	225,7	224,8	776,8
XII	Free standing fine paper mills	3	13	16,1	20,5	14,1	66,7
XIII	Other free standing paper mills	1	27	16,8	27	47,9	119,7
XIV	Fiber board production	5	35	6,3	1,5	13,9	61,7
Total		181	1069****	950,4	1344	2586,2	6109,4
Percent of total investments		6	14	10	9	12	11,6

* Group I is merged with group III.
** No mills could currently been placed in group V or VII.
*** Group VI had previously merged with group VIII
**** Including 300 million SEK from governmental subsidies

Source: Forest Industry Research Foundation for Air and Water Protection (SSVL), report No 74-85, Costs estimates for Pollution Control 1985-1991, see Appendix 2 and 20. The estimates are based on questionnaire data collected by SSVL during the periods 1968-1970, 1971-1975, 1976-1979, 1980-1984, 1985-1988.

[49] Forest Industry Research Foundation for Air and Water Protection (SSVL), report No 74-85, Costs estimates for Pollution Control 1985-1991, see Appendix 10.

The environmental investments undertaken by the Swedish pulp and paper producers also rendered significant emission cuts. One example is that emissions of Chemical Oxygen Demand (measured as BOD) decreased from 800 000 tons annually in the early 1960s to 100.000 tons at the beginning at the 1990s at the same time as production more the doubled.[50] It should however be added that the capital costs for environmental protection increased even more among bleached pulp producers at the beginning of the 1990s, as cause of the discovery of dioxin related to chlorinated organic substances (AOX) in the mid 1980s.

As costs related to pollution control became considerable, the industry early recognized that the investments had to be cost effective, i.e. the highest possible emission reduction had to be achieved per invested Swedish crown. There was certainly a high risk related to investment strategies as miss-guided investment on the environmental area could, in a worse case scenario, force companies out of business. Effective collaborative efforts in R&D therefore became increasingly important as the costs and risks related to environmental adaptation increased from the late 1960s and onwards. Important platforms related to environmental R&D was STFI already mentioned, whereas two new organizations was established in the 1960s, the state-firm financed *Institute for water and air protection* (IVL) and *The Forest Industry Research Foundation for Air and Water Protection* (SSVL).

The Institute for Water and Air Protection (IVL)

The need for specialist knowledge on environmental adaptation grew also in other industry branches at the beginning of the 1960s. Besides the pulp and paper industry, also the mining industry as well as metal smelters, the petroleum industry, the food industry, the chemical industry and more, all contributed to increasing environmental disturbances. Already in 1952, the *Federation of Swedish Industries* (Industriförbundet) established a Water and air protection committee with five representatives from the forest industry and eight from five other branches (tannery, 3, textile, 2, mining, 1, oil, 1 and food, 1). In 1959, also a special section for environmentally related questions was founded. This section, however, focused on raising environmental issues on company's agendas and on giving advices rather than to take any interest in R&D.[51]

The services and support of the Federation of Swedish industries was not extensive and substantial enough for the forthcoming challenges of the Swedish industry on the

[50] *Miljö 90*, 1991, 14.
[51] Söderholm (2007). See also Vattenföroreningskommittén, *Meddelande*, Stockholm, Nr. 5, 1953.

environmental field. The Swedish heavy industry shared the need for both relevant information and technical support in the field and could with appropriate research organisation pool resources and effective solve common problems. Thus, the president of SIV, Stig Freyschuss, and the president of the Federation of Swedish Industries, Axel Iveroth, put forward a proposal to the Minister of Finance, Gunnar Sträng, of a jointly financed research institution. The purpose of the institute would be to conduct research on water and air protection issues. The question was investigated by Olof Palme, who arrived in suggesting the formation of a half state/half industry supported research institute, the *Institute of Water- and Air protection* (IVL), and of an industry administered, non-profit driven service institution, the *Water- and Air protection of the Industry AE* (IVL AB). The Swedish government thus came to financially support, and to some degree govern (see below), inter-industry research cooperation on environmental adaptation through IVL from the mid 1960s and onwards.[52] Internationally, this was a unique set up of organisation and building of competence on the environmental field in the mid 1960s. IVL therefore became engaged in several international projects, such as in clearing sediments from mercury in Minamata, Japan, in the late 1960s.[53]

The IVL-board of directors constituted of five state and five industrial representatives and had access to an expert committee/research council of about 20 members managing the manifold interests of the institute.[54] Valfrid Pålsson, president of the Swedish Environmental Protection Agency (SEPA), was represented in the board together with representatives from the different lines of businesses. The head of the research department of SEPA was further represented in the IVL research council in order to avoid collisions. Annual research programs were thus made up within the research council in close cooperation with representatives from SEPA. According to Stig Freyschuss, president of IVL from 1965/66 to 1982, the cooperation with the "industry people[55]" at SEPA was fruitful.

> "One can say that we [the industry] did not keep any of the actual problems as secrets. Authorities, such as SEPA, in turn gave industry time to fulfil the

[52] Interview with Stig Freyshuss 08.10.2009.
[53] Interview with Björn Lundberg, president of IVL (1988-2008), Sollentuna 11.05.2009.
[54] Söderholm (2007). See also *Svensk papperstidning*, "Ny centralorganisation för industrins vatten- och luftvård", Stockholm, 1966, 250-52.
[55] With "industry-people", Freyshuss refer to SEPA-employees former employed by industry; SEPA is organized differently today.

requirements, i.e., to renew the processes and rebuild the mills. It was a very good cooperation."[56]

The trustful and pragmatic view mediated by Freyshuss represents a typical example of the spirit of Swedish environmental policy in the late 1960s and 1970s.[57] Among many aspects, researchers have especially argued that the Environmental Protection Act of 1969 was a typical expression of the tradition of consensus-seeking solutions, often vaguely but commonly referred to as the 'Swedish Model'.[58] And as suggested by Linderström, IVL became a cornerstone in the Swedish cooperative mode of environmental protection.[59]

The forest industry had a big interest-share in IVL, 50 percent of the industry-shares was in the possession of the *Forest Industry's Air and Water Pollution Research Foundation* (SSVL)[60]. The big interest share of SSVL in IVL was perhaps natural since the initiative to IVL came from the forest industry in the first place. Even more important was perhaps that the forest industry caused massive environmental destruction, essentially through waterborne emissions. Those, together with municipal discharges, probably were responsible for about 70-80 percent of the total organic discharges in Sweden in the mid-1960s.[61] While IVL had the commission to engage in fundamental research activities, IVL AB had the commission to "work inside the industry gates". The forest industry was for long the major client of IVL AB, which therefore became specialized on issues related to the pulp and paper industry.[62] IVL AB mediated important knowledge between industry and IVL (the institute), partly by mediating research results from IVL to the industry but also by mediating the problems formulated by industry back to IVL (as well as of course knowledge and technology among

[56] Interview with Stig Freyshuss 08.10.2009.
[57] Lundqvist, Lennart, *Miljövårdsförvaltning och politisk struktur*, Uppsala: Verdandi, 1971.
[58] Lundqvist, Lennart, "Sweden", in *National Environmental Policies. A comparative Study of Capacity Building*, Jänicke, M & Weidner H (eds.), Berlin: Springer, 1997; Rothstein, Bo, *Den Korporativa Staten*, Stockholm: Nordstedts Juridik, 1992.
[59] Linderström, Magnus., *Industrimoderniteten och Miljöfrågans utmaningar. En analys av LO, SAF, Industriförbundet och Miljöpolitiken 1965-2000*. Linköping: Linköpings Studies in Arts and Science, 2002.
[60] The *Foundation for water protection research of the wood industries* up to 1963, which was what the Water protection committee of the forest industries and the Water protection council of the forest industries had transformed into in 1956 (Svensk Papperstidning, 1966).
[61] Interview with Stig Freyshuss 08.10.2009.
[62] The pulp and paper industry mostly engaged the laboratory of IVL AB for the mapping of total discharges and section currents of individual mills. IVL AB also offered physical-chemical and bacteriological water analyses, as well as developed an automatic sampler aiming for wastewater from the forest industry. Also IVL paid in its first few years a lot of attention to research on the development of methods of measurement, sampling and analyses as well as on the development of mainly chemical, but also biological, sedimentation of the wastewater (Söderholm, 2007).

the individual mills). IVL AB therefore functioned as an important intermediary of information and technology which likely speeded up the environmental adaptation process in the pulp and paper industry. Another important platform for knowledge exchange was the annual conferences held by IVL with start in 1966. As been described by Söderholm, these conferences functioned as arenas for inter-industry respectively industry-state knowledge exchange.[63]

Through organized international knowledge exchange, foremost with industrialists engaged in environmental issues within the pulp and paper industry, IVL-representatives experienced how they, at least in the 1960s and 1970s, knew much more on those matters than representatives from other countries. IVL was further rather well-known within Europe also for people outside the pulp and paper industry, especially after the arrangement, in which IVL was deeply engaged, of one of the first international, i.e., European, meetings on industrial pollution in Stockholm in 1970.[64] The knowledge of IVL was in turn spread, not only within Sweden, but also internationally by consult firms engaged by mills both in Sweden and at other places. The most prominent example is Jaakko Pöyry, which was frequently engaged to carry out the changes proposed by IVL and IVL AB at Swedish pulp and paper mills. At the same time the firm also was engaged by mills in e.g., North America, Norway and Finland.[65]

In sum, we conclude that the establishment of IVL reflected the environmental breakthrough in the Swedish industry in general, but the initiative came from Swedish pulp and paper producers. The collaborative form of organisation was also based on experiences gained by the pulp and paper producers. Below we present an organisational overview of the different platforms where collective environmental R&D was achieved.

[63] Söderholm (2007).

[64] The conference was formally arranged by *The International Union of Pure and Applied Chemistry* (IUPAC). About 100 lectures were given at the conference, of which almost one fourth (each) dealt with the water pollution problems within the pulp and paper industry and the food industry, whereas the oil, coal, mining, metal and chemical industry each was processed to a lesser extent (Söderholm, 2007).

[65] Interview with Stig Freyshuss 08.10.2009.

Table 2: R&D cooperation of the Swedish pulp and paper industry 1890-2000

Organization/institute	Time period
Royal Institute of Technology (KTH)	1890--1913 (Klason) 1931 (Department of Pulp technology and Wood chemistry)
Swedish Association of Pulp and Paper Engineers (SPCI)	1908
Sulphate Pulp Committee	1908-1909 (?)
Swedish Pulp and Paper Research Institute (STFI)	1945
Central Laboratory of the Pulp Industry	1936 (ascended into STFI in 1968/69)
Water Pollution Committee	(1937-)1945 (divided into SIV and SVSK in 1953/54)
Water Laboratory of the Wood Industry (SIV)	1953/55-1964
Water Protection Committee of the Wood Industries (SVSK)	1953/54- (changed into SSVL in 1963)
Swedish Forest Industry's Air and Water Pollution Research Foundation (SSVL)	1963
Institute for Water and Air Protection (IVL)	1966 (today IVL Swedish Environmental Research Institute)
Water and Air protection of the Industry AE (IVLAB)	1966 (acquired by the ÅF-Group in 1982)
ÅF-Group	1895

Source: Söderholm (2007).

The Forest Industry's Air and Water Pollution Research Foundation

With the implementation of the Environmental protection act in 1969, it was recognised by the Swedish Pulp and Paper Mill Association that the pollution problems of the pulp and paper industry were to big to be handled merely within IVL/IVL AB or STFI. As previously mentioned, STFI focused on improved material and energy utilization from the wood, and in the 1970s, also new systems of process control and more environmentally friendly bleaching methods became priorities.[66] These efforts together with parallel collective engagements in general R&D had a strong bias towards rational resource utilization. Thus, a new project organisation was built up by SSVL with the commission to conduct comprehensive environmental protection projects. The organisation consisted of representatives from a number of private companies, research institutions (IVL and STFI), consultants (IVL AB, Jaakko Pöyry and Ångpanneföreningen, ÅF) and equipment suppliers.[67] By this construction,

[66] Rydberg (1990).
[67] Söderholm (2007).

an appropriate infrastructure for technology development and diffusion were set. The guiding principle for the development projects was to identify and/or develop technical solutions that enabled emission reduction *with* increased production levels. For this goal, internal process changes became a prerequisite. The development work became mainly focused on technology that was pollution preventive, i.e., on process changes keeping emissions low, even though end-of-pipe technology also played an important role.

The first environmental protection project of SSVL was carried out between the years of 1970-73 and focused on both internal process changes and external waste-water purification methods, i.e. end of pipe technology. The project was to about 75 percent, i.e., 20 million SEK (about 14 million EUR in today's money value), financed by the forest industry and to about 25 percent by the state funding.[68] The first project was in turn followed by two to three main projects/decade[69] in the 1970s to the 1990s. Project costs increased over the years: they roughly doubled between the periods of 1970-1981 and 1981-1994, from about 90 to about 176 MSEK in running costs which in total was about as much as the forest industry contributed to IVL and STFI in total in that same period.[70] Between the years 1970-1997, the forest industry invested 535 million SEK in SSVL projects (See Table 2 below).

The environmental investments in the Swedish pulp and paper industry in the 1970s and 80s consisted to over 60 % of internal process-measures aiming for decreased waste water and improved chemical and fibre recycling, to about 14 % of external waste-water purification measures, and to about 15 % of air-purification measures.[71] This figure contrasts in many parts from the established view that end-of-pipe treatments were the main business strategy to curtail pollution problems in the 1970s. The share of public funds differed over the years, from about 15[72] to 40 %.[73]

As was the case with the first SSVL-project, also following projects in the 1970s to the 1990s were generally conducted in close cooperation with research institutions such as IVL,

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[68] State funding came from the Board for technical development (Styrelsen för teknisk utveckling, STU), See *Skogsindustrins miljövårdsprojekt: Teknisk sammanfattning*, Stiftelsen Skogsindustriernas Vatten- och Luftvårdsforskning, SSVL, Stockholm, 1974, 7-10.

[69] The main projects were in general simply named "Environment of the North 80" (Nordmiljö 80, in cooperation with industry, research institutions and authorities in Finland and Norway); SSVL 85; Environment 90, 93, 95/96 (Miljö 90, 93, 95/96) etc., however, some of the main projects in the 1970s were specialised on chloride (1974-76), respectively on greener production of bleached pulp (1978-81).

[70] *Miljö 93*, Repoprt No 79, Slutrapport från delprojekt 1, Miljöeffektforskning, Stiftelsen Skogsindustriernas Vatten- och Luftvårdsforskning, SSVL, Stockholm, 1995, 10.

[71] *Miljö 90*, 1991, 93.

[72] *Miljö 93*, 1995, 10.

[73] *Miljö 90*, 1991, 330.

STFI and ÅF, but also with universities. SEPA representatives were also partly involved in the project work by participating in consulting and working teams.[74] Project results were in turn communicated, generally continuously, to both authorities (SEPA) and industry, through reports and articles in business journals (Svensk Papperstidning) and in connection to SPCI-meetings and the like.[75]

The role of SSVL was foremost to deliver ecological background-material, to invent and evaluate accessible environmental-protection technologies and to support the introduction of new technology. It was in general not possible to actively develop new technology within the economic frames of the SSVL-projects. Individual firms did, however, supplement the projects on a large scale and did, together with suppliers, contribute with technological development.[76] Individual mills were on the whole contributing to the projects on a large scale by their openness and by making knowledge, both technical and waste-related data, accessible to the projects and, at the same time, the entire line of business.[77] The outcomes of this way of organising the projects, i.e., leaving a substantial part of the development work to the level of application, i.e., to the floors of the mills, are expressed in the technical summary (1974) of the first project;

> "by locating the development work to mills with existing problems, the project has effectively been able to attach to development in progress and make it common for the line of business."[78]

Looking closer to the focus of the projects we find that the first project focused on essential points of discharges in the production processes, where after a number of sub-projects was formed. These partly concerned critical sections of the processes, such as bleaching, evaporation and condensate-treatment as well as mud-treatment, and partly process-overarching questions, such as occasional discharges and system closure. The sub-projects also concerned biological-chemical wastewater purification and air protection issues. The first

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[74] See e.g., *SSVL 85: Sammanfattande rapport*, Stiftelsen Skogsindustriernas Vatten- och Luftvårdsforskning, SSVL, Stockholm, 1984; *Miljö 90*, 1991; and *Miljö 93*, 1995.

[75] *Skogsindustrins miljövårdsprojekt: Teknisk sammanfattning*, 1974; *Klorid i återvinningssystem: Slutrapport*, Stiftelsen Skogsindustriernas Vatten- och Luftvårdsforskning, SSVL, Stockholm, 1977; *Nordmiljö 80: Slutrapport*, Stiftelsen Skogsindustriernas Vatten- och Luftvårdsforskning, SSVL, Stockholm, 1979; *Miljövänlig tillverkning av blekt massa: Slutrapport*, Stiftelsen Skogsindustriernas Vatten- och Luftvårdsforskning, SSVL, Stockholm, 1982; *SSVL 85*, 1984; *Miljö 90*, 1991; *Miljö 93*, 1995.

[76] *Miljö 90*, 1991, 40.

[77] *Skogsindustrins miljövårdsprojekt*, 1974; *Klorid i återvinningssystem*, 1977; *Nordmiljö 80*, 1979; *Miljövänlig tillverkning av blekt massa*, 1982; *SSVL 85*, 1984; *Miljö 90*, 1991; *Miljö 93*, 1995.

[78] Skogsindustrins miljövårdsprojekt, 1974, 7.

SSVL-project did further also focus on how older mills could find economically justifiable measures to lessen discharges radically.[79]

Table 3: Collective environmental research projects

Year	Project	Costs (MSEK)
1970-73	The environmental care project	27
1974-76	Chlorides in recovery system	4
1975-78	Nordic Environment 80	12
1978-81	Environmentally harmonized production of bleached pulp	40
1981-85	SSVL 85	32
1986-90	Environment 90	67
1989-94	Enviroinment 93	70
1974-85	Other SSVL projects	14
1979-93	Grants for IVL	55
1970-93	Grants for STFI	200
Total		521

Source: Swedish Forest Industry Federation, file: Montreal, September 24-26, 1990.

Over time, some new critical sections of the processes were added as focus-areas within the SSVL-projects, such as added chemicals. The focus in general was, though, directed towards more process-overarching questions, such as increased system closure, high and even production levels and, not the least, discharge control. On the whole, especially in the 1970s and the 1980s, there was a constant and rather extensive focus on measuring, describing and valuing of discharges, respectively on programs of control and methods for environmental supervision.[80] This indicates that there was a general lack of tools for measuring and monitoring within the national environment protection system of the 1970s and 1980s. It further indicates that it indeed was a prioritized question for the pulp and paper industry, to participate in the development of such tools. The SSVL-projects also explicitly addressed the licence-trial process associated to the environmental protection act, e.g., by submitting proposals for general-purpose constructions.[81] The most prominent focus areas of SSVL in

[79] *Skogsindustrins miljövårdsprojekt*, 1974.
[80] *Skogsindustrins miljövårdsprojekt*, 1974; *Klorid i återvinningssystem*, 1977; *Nordmiljö 80*, 1979; *Miljövänlig tillverkning av blekt massa*, 1982; *SSVL 85*, 1984; *Miljö 90*, 1991; *Miljö 93*, 1994.
[81] *SSVL 85*, 1984.

the 1980s, though, were the discharges of chlorinated organic substances and the discharges of acidified substances.[82]

The attention paid to the bleaching process is significant in the SSVL-project of the late 1980s; it takes up as much as 200 pages in the final report of Miljö 90 (1986-90), whereas the remaining three sub-projects only take up 10 to 40 pages each.[83] This mirrors the parallel growth in society, caused by the dioxin-discovery, of both an opinion against chlorinated discharges and of an emerging market for unbleached paper. This market was in turn driven by successful collective R&D investments transferring into an even more successful environmental adaptation that has been reported in previous literature.[84] With extensive investments in a number of different process changes, such as in prolonged cooking and oxygen delignification, the Swedish pulp industry managed to eliminate or considerably reduce discharges of problem substances like dioxin and chlorate.[85] In the first SSVL-project of the 1990s it was in turn established that the industry had come far in the environmental protection work and that it now was time for consolidation of the new technology and for the evaluation of the results. The importance to consider new questions within the area of environmental protection was also highlighted, such as the demands of the market and other opinion-related questions.[86] The public opinion and the increased demand for chlorine free bleached paper, effectively driven by Green Peace in the late 1980s, really stroked the Swedish pulp and paper industry. The pace of the final steps of the Swedish pulp and paper industry in the adaptation to chlorine free bleached paper, were essentially a response to market changes; especially in the German and Swedish markets.[87] But on the whole it was an outcome of a more long-term process of incremental innovations based on continuous improvements related to the cooking process that started in the collective STFI and SSVL projects already in the 1970s.

Discussion

In this paper, we have dealt with inter-firm and state-firm collaboration in R&D for environmental adaptation in the Swedish pulp and paper industry during the first nine decades

[82] *Miljö 90*, 1991, 39.
[83] *Miljö 90*, 1991.
[84] See, e.g. Reinstaller, Andreas, "The technological transition to chlorine free pulp bleaching technologies: lessons for transition policies", *Journal of Cleaner Production* , Vol. 16, 2009:1, 133-147 .
[85] *Miljö 90*, 1991.
[86] *Miljö 93*, 1995.
[87] Interview with Björn Lundberg 11.05.2009.

of the 20th century. Environmental adaptation has indeed constituted a long-term major challenge for this industry, involving comprehensive inter-firm and state-firm collaboration in the environmental field as well as extensive structural changes of the industry. The tradition of business cooperation became established within the Swedish pulp and paper industry already at the end of the 19th century, where the "Sulphate pulp committee" concluded on the advantages of pooling resources for joint R&D activities. Such activities were also current for other issues, besides purely environmental, such as in projects aiming for rational and efficient use of resource utilization. Therefore, when the need for radically improved environmental standards increased during the 1960s, the tradition of inter-firm, but also state-firm cooperation became of effective use. Concerning the strategies used, we find similarities to the study by Cortat who find that R&D collaboration within Swiss cable cartels was typically based on joint test laboratories and joint research laboratories. In addition we also find that the experimental activity, as Rosenberg argues to be the most costly part of R&D, was decentralized to the floor of the individual firms, however, with outcomes open for other firms to learn from. This type of organizing R&D was first practiced in the Central laboratory of the pulp industry and in the Pollution committee of the 1940s, but was later introduced in environmental R&D projects of SSVL in the 1970s. We therefore suggest that the inter-firm collaboration not only reduced costs and risks related to R&D but also likely speeded up the diffusion process of new technologies and learning about new techniques among the Swedish pulp and paper producers.

By jointly developing expertise in collaborative R&D organizations, also time consuming information gathering activities was concentrated to a common pool of human resources. Information was initially mainly transferred through the colloquiums held once a year, with start in the 1940s, and through the letters frequently handed out to individual mills. Information was however also transferred through the meetings held by the Association of pulp and paper engineers (SPCI) and through the technical assistance offered by the single service engineer of the Water protection committee in the late 1940s, a service which expanded within the Water laboratory of the wood industry (SIV) in the 1950s. Later, in the 1960s, the channels for information transfer between the collective R&D activities and individual mills increased as did the scope of information. The establishment of the industry-state joint financed Institute of Water and Air Protection (IVL) in 1966 were both an expression of the cooperative nature of the Swedish environmental protection system and the tradition of inter-firm collaboration in the Swedish forest industry. The Swedish pulp and paper industry held a big interest-share in IVL and its service company (IVL AB) until the

mid 1980s. By financing and creating a common pool of competence in IVL, individual companies got access to research and "know how" that were impossible for single mills to acquire. IVL AB, the service company connected to IVL, functioned in practice like an intermediary of "know how" between the research institute (IVL) and industry and between the mills. Furthermore, IVL, and especially the annual conferences held by IVL, was also a natural channel to governmental information on environmental policy issues that in many cases could be of crucial importance for investment plans, especially in capital intensive industries like the pulp and paper industry. Such information, especially informal information, would also have been time consuming and therefore costly for individual firms to access. Correspondingly, IVL constituted a natural channel for industrial information on environmental issues of crucial importance also to governmental institutions.

However, also the Forest Industry's Air and Water Pollution Research Foundation (SSVL) functioned as an important collective resource for the environmental adaptation of the Swedish pulp and paper industry from the 1970s and onwards. For internal process changes, it is not wrong to say that SSVL where more important than the state-industry funded IVL. The project organization was, as mentioned above, divided into the research activities of research organizations included in SSVL, and development work at the floor of individual firms. The incentives for cooperation were strong, since all firms were in the same critical situation in finding eligible measurements that enabled cost effective pollution reductions. In respect to the SSVL and IVL projects it is also important to stress the significance of involvement of consultants and suppliers of machineries. Consulting and construction firms, not the least Jaakko Pöyry and ÅF, as well as suppliers, often was directly involved in the development work of SSVL and IVL/IVL AB or was otherwise engaged by individual mills to carry out the changes proposed by the same. By being engaged by mills also in e.g., North America, Norway and Finland, those consultants and suppliers functioned as important intermediaries of the Swedish-produced environmental technologies for pulp and paper industry also internationally.

Finally, we find that there was an early agreement in the Swedish pulp and paper industry that process changes, i.e. integrated pollution preventive technology, was necessary in order to combine production expansion with pollution reduction. Reducing costs by savings of energy, heat and resources (fibre and chemicals) worked to a high degree in line with environmental adaptation. Between the 1950s and the 1990s, the Swedish pulp and paper industry was practically renewed, based on gradually developed technologies and process alterations that became embedded in new capital. Important know-how and techniques for this

renewing of industry was in some central parts advanced in the collective inter-firm projects, which also were supported by government funding. Our findings therefore suggest that environmental policies that support collaborative R&D activities might facilitate innovation processes of clean technologies. This might include funding for R&D projects that are associated with high risks and costs but with a high potential to increase efficiency and pollution reduction.

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