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**Knowledge infrastructure
in the Norwegian pulp
and paper industry**

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Preface

This paper presents brief characterisation of the knowledge infrastructure in the Norwegian pulp and paper industry. The paper has been written in the context of the STEP group's ongoing work in the RISE project, which is a part of the EU commission's TSER programme.

Oslo, December 1999

Thor Egil Braadland

Abstract

This paper takes a closer look at how a traditional low-tech Norwegian industry responds to the ubiquitous changes in how knowledge is acquired and used across Europe. In this paper we analyse the knowledge infrastructure of the pulp and paper industry, in an attempt to illuminate which knowledge suppliers are regarded as vital to the development of the industry.

What we in short describe is an industry that in many ways is not a technologically sophisticated industry. It is constituted by a simple production line, with few knowledge bases and few sources for knowledge input. It is an industry which use little resources on research and development, and which ideas rarely lead to patents. The employees have less formal education than average in Norwegian industry, and are seemingly not evolving towards any upskilling at all. The industry has little contact with formal external knowledge suppliers. In the European CIS survey, neither universities, research laboratories nor external consultants were reported to play any significant role as source to innovation.

In spite of all this, the industry is highly innovative. It is an industry depending on sophisticated external suppliers for its innovations. Advanced suppliers of knowledge, such as customers/clients, machinery suppliers and equipment suppliers, play a crucial role in the pulp and paper industry.

Keywords: Cluster, Innovation, Networks, Pulp, Paper, Services

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Knowledge Infrastructures in the Norwegian Pulp and Paper Industry

Introduction

The Pulp and Paper (p&p) industry is often considered a low-tech sector. It consists of a relatively simple production line, where wood is separated into pulp, which again is transformed into paper and paper board. The view on p&p as a low-tech industry is underlined by the fact that investment in R&D is low, and that enterprises in the p&p industry rarely patent.

However, in spite of the 'simplicity' of the production line and the low bias on 'regular' technology indicators, the sector is undoubtedly highly innovative. The sector is one of the biggest spender on capital investments, mostly in new production machinery. It innovates in tight relationships with suppliers of machinery and equipment. The last two decades, energy-saving equipment and development of more environmental-friendly products have been rationale for a continuing process of renewal in the industry¹.

The 'low-tech', but still innovative p&p industry is increasingly exposed to a double development in Europe. On the one hand there is an ongoing increase in knowledge intensity in almost all OECD industrial sectors, referred to as the Knowledge-based Economy². For instance, the 1980s demonstrated a profound upskilling across all manufacturing industries, where high-skilled employment in all manufacturing sectors grew much more rapidly than low-skilled employment³. The second (and related to the first) emerging trend is a trend of knowledge privatisation, first and foremost characterised by the profound growth in so-called knowledge-intensive business services (KIBS). Use of external consultants is an important indicator on innovation activities, as such activities are related to problem-solving, inter-active learning and often implementation of information- and communication technologies. A Norwegian survey from 1992 demonstrated that more than 50 percent of Norwegian manufacturing industries used external consultants as source for innovation⁴.

Our question for this paper is to illuminate how the p&p industry in particular has responded to these two economic developments. Who is the most central knowledge suppliers to the industry? Has the industry managed to develop the

¹ Lastadius, Staffan: *The relevance of science and technology indicators: the case of pulp and paper*, in *Research Policy* 27 (1998)

² The Knowledge-based Economy, 1996, OECD/GD(96)102, OECD Paris

³ The evolution of Skills in the OECD countries and the role of technology; A. Colecchia and G. Papaconstantinou, 1996, OECD, Paris

⁴ Johan Hauknes, Pim den Hertog and Ian Miles: *Services in the learning Economy - Implications for technology policy*, STEP working paper 1/97.

technical skill of their employees? Where do information leading to industrial change and innovation come from? Is it possible to trace a transition in how and where knowledge is emerging, from collective (public) knowledge producers to private knowledge producers?

In order to answer these questions, it is useful to use the p&p knowledge infrastructure as an analytical starting point. By knowledge infrastructure we mean which knowledges constitute the activities in the p&p sector, and how these knowledges are a) used, b) developed and c) transferred in and between agents within the technological system (see Figure 2).

The use of knowledge suppliers can be measured in several ways. A central method illuminating which knowledge suppliers are regarded as important to the industry, is to look at how innovation take place in the industry. The CIS survey from 1995 answered several European p&p companies about their innovation activities, investments in physical capital, information sources to innovation and so on. Data from this survey can be used to identify central information suppliers to innovation activities.

Another approach to map central knowledge suppliers is to look at flow of commodities and services to the industry; to grasp which industries are the core suppliers to the p&p industry. Our figures are taken from the national account, and covers traded commodities and services between different industries in 1986.

A third approach is to use patent data as a proxy to see in which part of the knowledge infrastructure the most radical innovations are taking place.

Before we analyse the empirical material, we will look at some basic information about the Norwegian p&p enterprises.

Norwegian Pulp and Paper basics

Norwegian p&p industries commenced in the late 19th century. Localisation of the industry was based on closeness to two factors: Timber, serving as raw material input, and a river, serving as means of transportation and energy source. In the last part of the century, over 60 small mechanical pulp plants were established. The first cellulose enterprise established in Norway was Hafslunds Chem. Træmassefabrik (1874). In 1909, there were 31 cellulose factories, 44 mechanical pulp plants and 28 paper and paper board factories in Norway. The most advanced paper producer at this time was A/S Union in Skien (Telemark), with more than 12.000 persons engaged. During the early 20th century, pulp and paper was the largest exporting industry⁵.

Today, about 6.000 persons are engaged in the Norwegian p&p sector (Table 1), representing 0,3 percent of total Norwegian employment. The sector consists of about 45 firms, with 'production of paper and paperboard' being the largest sub-

⁵ Paragraph based on Olaf Ulseth (1992)

industry with 26 firms and 4.258 employees. The largest enterprises in Norway is Norske Skog Industries⁶, Borregaard Industries Ltd, M. Peterson & Søn⁷ and Hunsfos Industrier.

Arithmetic average employment in Norwegian p&p firms is 135 persons, slightly the same as in Italy (156), but considerably lower than in the Netherlands (317) and in Germany (432)⁸. The average company size in Norway for all manufacturing industries is 49 (1994).

Table 1: Employment and number of firms in different Norwegian Pulp and Paper industries 1996 (source: SSB employment register).

Pulp and Paper industry	NACE	Employees	Firms
Production of mechanical pulp	21111	1.301	14
Production of sulphur- and sulphite cellulose	21112	539	5
Production of paper and paperboard	21120	4.258	26
<u>Total</u>		<u>6.098</u>	<u>45</u>

The recession in pulp and paper market in the late 80s/early 90s led to international decline in production and employment, so also in Norway. Total employment in Norwegian pulp and paper industry in 1986 was 10.071 persons⁹, today it is reduced with 40 percent of the 1986 situation.

The index in Figure 1 shows that yearly production has increased slightly since 1988. Production output in 1988 was 80 percent of production in 1997, representing a 25 percent increase during the last nine years, or an annual growth on 2,78 percent. The figure also shows how the market recession affected Norwegian producers. In the period between 1989 and 1992, the production output went down with almost ten percent.

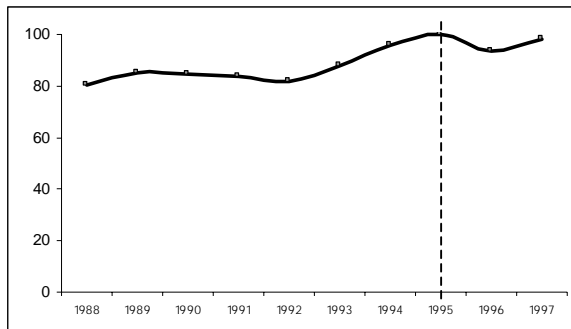
⁶ Including Follum Fabrikker A/S, Tofte Industrier A/S and A/S Union

⁷ Olof Ulseth (1992); Treforedlingsindustrien, report to the Norwegian Porter project 'A competitive Norway', SNF-report 62/92

⁸ E. Auttio, E. Dietrichs, K. Führer and K. Smith: *Innovation Activities in Pulp, Paper and Paper Products in Europe*, STEP report 4/97, Oslo.

⁹ See Footnote 22.

Figure 1: Yearly production index for Norwegian Pulp and Paper industry 1988-1997, 1995=100 (source: SSB Statistical Yearbook 1998).



The Pulp and Paper knowledge filière

The p&p knowledge infrastructure can be understood as a filière (Figure 2) consisting of two integrated systems; the p&p production line and the p&p knowledge bases. By production line we mean the whole industrial process of making paper out of trees; from cutting threes and boiling pulp to fabrication of paper and paper products¹⁰. (The production line is marked with white arrows in the figure). Pulp is the basic material for making paper, and is produced by thermal, mechanical-thermal or chemical separation of wood fibres¹¹. Paper is then again used in different paper products, as packaging products, household and hygienic paper goods, office supplies etc. The different actors in the production system are in some way linked to each other. The links may vary from pure marked contact, via informal communication, personal contacts and exchange of information about prices, quality, knowledge, employers, technologies and standards to formal co-operation agreements and ownership.

The p&p knowledge filière consist of the industry's different knowledge-based elements, what we term the p&p knowledge base. The industrial knowledge base consists of those core activities which make up the p&p industry¹² (the industries are marked in the figure with a grey circle). Typical knowledge bases in the sector are equipment manufacturers, chemical suppliers, suppliers of control and info-systems and electricity generation - and of course production of pulp and paper itself. Between all these knowledge bases technology, experience and competencies are exchanged, through communication, through purchase of machinery and other manufacturing goods, through monitoring development in related technologies, through flows of personnel and through purchase of consultancy and development services. Hence, the configuration of p&p knowledge bases constitutes an important element in the understanding of industry's innovation capacity.

The two systems mentioned above represent complementary views on how the p&p enterprises should be interpreted and understood in terms of which knowl-

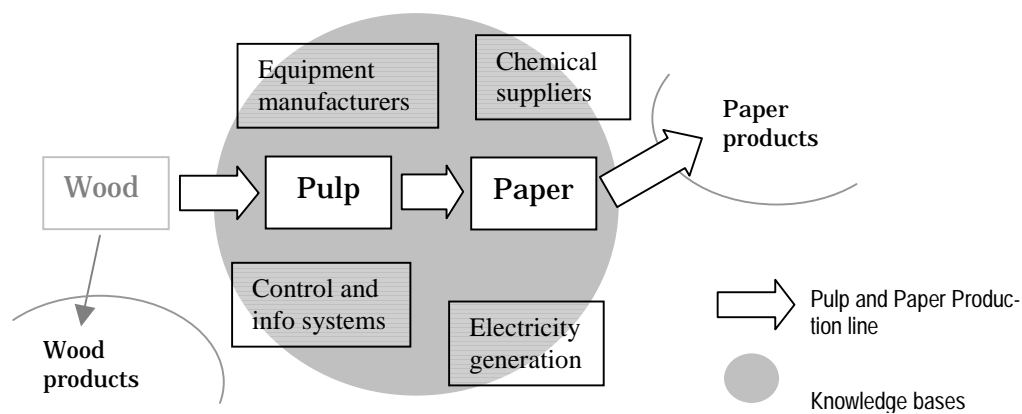
¹⁰ See Ulseth *ibid.* for such an approach to industrial studies

¹¹ Auttio et al., *ibid.*

¹² *Ibid.*

edge linkages they have with external firms and environments. The difference between the two systems is that the production line view, on the one hand, is centred around the industry's *product*, around which suppliers and producers related to each other are related in a vertical production line. The industrial knowledge base view, on the other hand, is focused on the *knowledge supplying environment* surrounding the p&p enterprises.

Figure 2: The Pulp and Paper knowledge filière (partly based on E. Auttio et al. 1997)



Which role do these different suppliers play to the industry? Table 2 brings a list of which industries serving the p&p industry with goods and services. The list gives us a good indication on where we find the most central inter-industrial interactions with the p&p industry, measured in pure economic terms. Figures are from 1986.

The table shows that the single most important supplying industry to p&p is agents *within* the pulp and paper production line. The three most important suppliers to the sector are 'Manufacture of paper and paper products', 'Wholesale trade/commission' and 'Forestry and logging', representing as much as two thirds of the industry's expenditure in 1986. If we add the expenditures in 'Manufacture of wood and wood products', 'manufacture of fibre boards' and 'printing/publishing', these sectors represent a total of 75 percent of the overall p&p expenditures.

The most expensive *external* inputs came from Electricity, gas and water suppliers (7,7 percent). Chemicals represented 3,2 percent of the p&p purchase, while machinery represented 1,6 percent of expenditure. Business services represented 1,5 percent of all industrial expenditure.

The table also shows that most p&p expenditures go to domestic suppliers. About 85 percent of p&p expenditures in 1986 went to suppliers located within Norway.

Table 2: Goods and services purchase in the pulp and paper industry (1986).

Source: SSB input/output.

	Delivering sector	Share ¹ (percent)
	Manufacture of paper and paper products	31,8
	Wholesale trade and commission broking, retail trade	18,6
	Forestry and logging	15,4
	Electricity, gas and water supply	7,7
	Manufacture of wood and wood products except furniture and prefabrication of wooden houses	6,6
	Manufacture of industrial chemicals and other chemical products	3,2
	Transport, storage and communication	2,0
	Manufacture of fibreboard	1,9
	Machinery excluding office equipment	1,6
	Business services except machinery and equipment rental and leasing	1,5
	Printing, publishing and allied industries	1,0
	Crude petroleum and natural gas production, transport and drilling	0,9
	Others	7,7
	Total (domestic)	100
	<i>Total (domestic)</i>	84,8
	<i>Imported</i>	15,2
	Total (domestic + imported)	100,0

How does the European Pulp and Paper industry innovate?

We have looked at data for which sectors p&p have spend most money. These figures do in a fairly good manner tell us something about the structure in the industry; which are the important suppliers to the industry, and where do we find the most important external knowledge links. However, these data do not necessarily illuminate which are the most important technological or knowledge sources to the industry. Data from OECD STAN/Industrial database and the 1992 CIS survey give us some stylised facts on how the European Pulp and Paper industry innovates.

Innovation expenditure

Innovation expenditures are the sum of tangible and intangible investments. Tangible investments is another word for capital expenditure, like investments in plant equipment and machinery. Intangible investments are the sum of 'soft', knowledge-related expenditure, as R&D investments, acquisition of patents and licences, product design, trial production, training and tooling up and market analysis. From the p&p CIS survey data presented in E. Auttio, E. Dietrichs, K. Führer and K. Smith: *Innovation Activities in Pulp, Paper and Paper Products in Europe*, we find the following results:

- The data reveals that total innovation costs in p&p industry are higher than manufacturing average. Investment intensity defined as gross fixed capital formation as percentage of value added in ISIC 34¹³ are 50-100 percent higher than average in manufacturing industries.
- R&D expenditures in p&p are much lower than average expenditures in manufacturing industries. Pulp, paper and paper product manufacturers (ISIC 34) spend 1/9 on R&D (measured as R&D expenditures as share of sales) of other manufacturing industries¹⁴.
- Intangible investments as share of tangible investment is lower for p&p than for other industries. The difference is particularly high for large firms. For small p&p firms, the share is 45 percent. For large firms, the share is 8 percent. For other manufacturing industries, the share is about 60 percent in both firm size classes.

Allocation of innovation expenditures

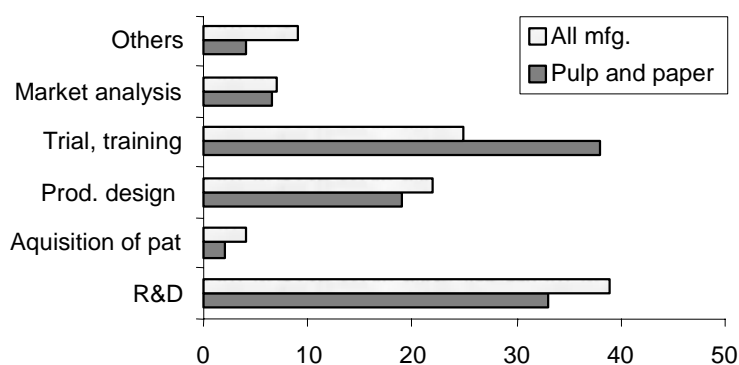
How do p&p enterprises allocate their innovation expenditures? Do they differ from other industries? Are there large differences between different firm sizes? With data from the CIS survey we shall try to illuminate these questions. This is what the data tell us:

- Allocation of innovation expenditures in p&p co-varies with innovation expenditures in large enterprises in other industries (Figure 3). In both industrial categories, 'Trial production, training and tooling up', 'R&D' and 'Product design' are reported as the most valued sources for information to innovation. The category where p&p differs most, is 'Trial production, training and tooling up', to which 40 percent of innovation expenditures goes. This is 15 percent points higher than industrial average. The biased share of this category is mirrored by slightly lower shares on other sources of information, relative to the industrial average. The negative difference is particular high for 'Other sources' and 'Acquisition of patents', both approximately 50 percent lower than industrial average.

¹³ ISIC 34 includes printing, publishing and allied products in addition to Pulp and Paper and articles of these.

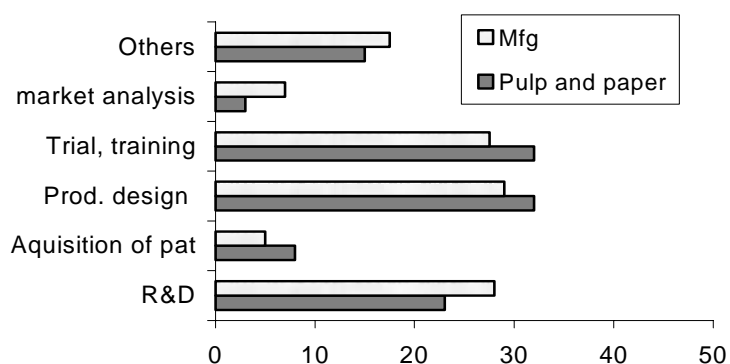
¹⁴ Ibid p 31

Figure 3: Large firms' allocation of innovation expenditure by category, percentages. All mfg. industries and NACE 21.1 (Pulp and Paper). Source: CIS Eurostat.



➤ For SMEs, 'Trial production, training and tooling up' and 'product design' are the two areas where most of the innovation expenditures are aimed (Figure 4). These areas are also two areas where the SME in the industry exceeds most the manufacturing industries. In addition, SMEs show a larger priority to acquisition of patents than other firms with same size and larger firms in the same industry.

Figure 4: SMEs' allocation of innovation expenditure by category, percentages. All mfg. and NACE 21.1 (Pulp and Paper). Source: CIS Eurostat.



Information sources for innovation

What are the main information sources for innovation in p&p enterprises? In the CIS survey from 1992, p&p firms were asked to rank different sources for information leading to innovation¹⁵. Following are the main results from this survey:

➤ The three sources for innovation most often ranked as important by large enterprises were (Figure 5):

¹⁵ The sources they should rank were: Within the enterprise, within group of enterprises, suppliers of materials, suppliers of equipment, customers/clients, competitors, consultancy firms, universities/higher education, government research institutes, industrial association institutes, patent disclosures, conferences/literature or fairs/exhibitions.

- a) Within enterprise
- b) Customers/clients
- c) Equipment suppliers

➤ The three sources for innovation most often ranked as important by small and medium-sized enterprises were (Figure 6):

- a) Within enterprise
- b) Customers/clients
- c) Materials suppliers

➤ Universities, consultancies and governmental research institutes are those sources most rarely ranked as important sources for innovation.

➤ Large p&p firms regard external partners as much more important for innovation than other industries do. Large firms (Figure 5) in p&p show a higher ranking of a) conferences/literature, b) equipment suppliers, c) materials suppliers, d) customers/clients and e) consultancy as more important sources for innovation than other industries.

➤ Small and medium-sized enterprises (Figure 3) are also ranking external sources as much more important sources for innovation than other industries tend to do. The exception is customers, which play a significant lesser role as source for innovation for small firms than they do for large ones.

Figure 5: Share of large firms ranking sources to innovation as 'important', all mfg industries and Pulp and Paper (NACE 21.1), percentages. Source: CIS Eurostat.

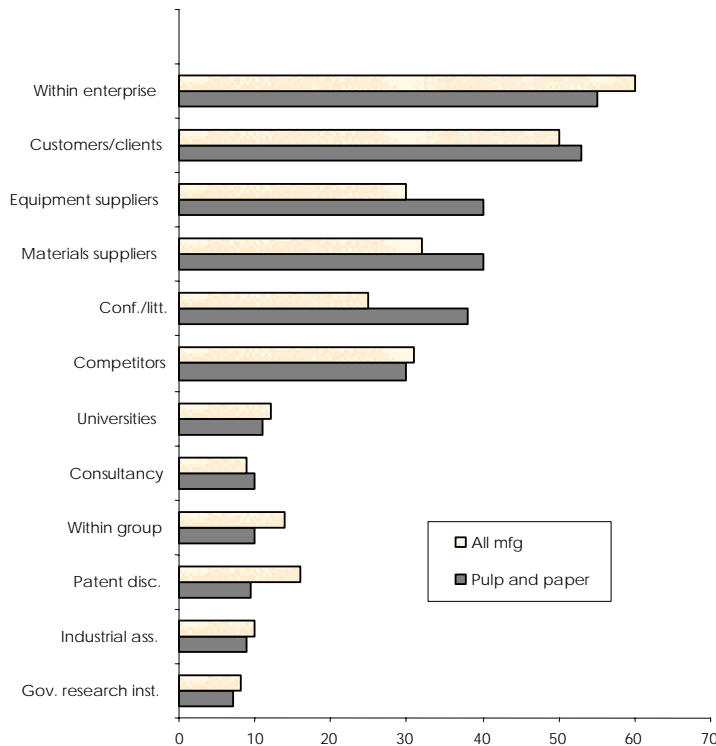
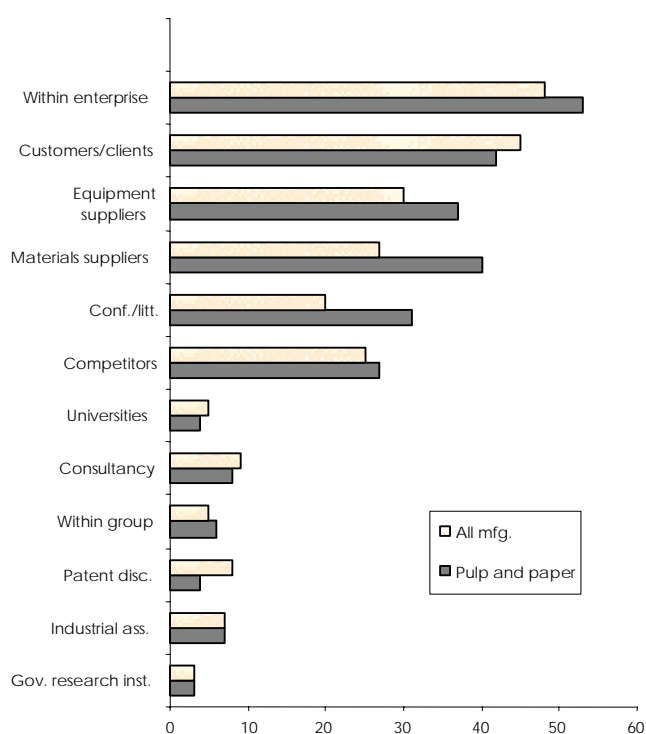


Figure 6: Share of small and medium-sized firms ranking sources to innovation as 'important', all mfg. industries and Pulp and Paper (NACE 21.1), percentages.

Source: CIS Eurostat.



Innovation patterns in Norwegian Pulp and Paper industries

The above presented statistics and research results are based on answers from European p&p firms. It is plausible to imagine that these statistics in some extent also describe the Norwegian situation. Norwegian manufacturers represent fairly 10 percent of the CIS enterprise sample¹⁶. On the other hand, the statistics also demonstrate that the p&p industry varies strongly between nations with respect to distribution of innovation costs (Ibid. p. 51-53). For example, there is a remarkable difference between Italy and Netherlands in product design expenditure, where Italian firms tend to spend 15-20 percent points more of its innovation expenditure on product design than Dutch firms do. In the following section we ask which types of qualitative evidence there exist on innovation in Norwegian p&p enterprises.

¹⁶ E. Auttuo, *ibid*, Table 3.1, p. 62

The Pulp and Paper knowledge filière - some qualitative aspects

As Figure 2 shows, managing p&p industry involves the savoir-faire of several different knowledge bases. Suppliers of wood and buyers of p&p found the respective extremities of the production line. In the process of producing p&p, mechanical equipment, chemical suppliers, control and info systems and electricity generation are important knowledges feeding into the industry. The agents in this knowledge filière is relatively segregated, as few enterprises control all knowledge bases; i.e. enterprises supplying wood, machinery, chemicals, paper producing plants and so on. This does not mean that there do not exist any technologically co-operation between the different firms. An investigation from Sweden (1996) reports that 'technological collaboration seems to be the rule rather than the exception in this field'¹⁷, pointing at very tight relations between - in particular - machinery producers and machinery users. In a case study, the author refers to development and implementation of an 33 million SEK energy-saving process in production of p&p. In the development, four knowledge suppliers were involved: R&D staff, people from the production line, engineers from Sunds (major supplier of p&p machinery) and engineers from Ortviken Paper Mill. Although the interviewees had different opinions on which ideas occurred where and from who, "they all agreed that the development process was the result of the joint work of (individuals in) these four units"¹⁸.

Machine tools sector

In Norway, there are two kinds of knowledge suppliers to the Norwegian p&p industry. Firstly, the industrial machine-tools suppliers, as Kværner Eureka, Kamyr AB and Simrad A/S. Kværner Eureka is the single largest Norwegian supplier of mass producing equipment to the p&p industry, with a turnover in the early 90s on 250 million NOKs¹⁹. Five percent of the turnover is from domestic purchasers, the rest stems from the export market. Parts of Myrens Verksted is today integrated in Kværner Eureka. Kamyr is the largest supplier of equipment for cellulose production in the Nordic area, with a turnover in 1990 on three billion SEK. Kamyr is owned by Kværner, and is a result of a venture between the remaining parts of Myrens verksted and Karlstad Mekaniske verksted. Simrad A/S is a IT-based enterprise specialising in monitoring with basis in Kongsberg (Buskerud). The enterprise has not been traditionally focused on pulp and paper, but Simrad was one of the largest Norwegian suppliers when Norske Skog established their sulph.-cellulose plant in Halden. Simrad won a contract on 150 million NOKs for supplying an electronic process surveillance system.

¹⁷ Lastadius, Staffan: *The relevance of science and technology indicators: the case of pulp and paper*, in *Research Policy* 27 (1998)

¹⁸ Laestadius, p 389

¹⁹ Olaf Ulseth 1992, p 26

Technical-industrial research institutes

The second branch of knowledge suppliers for the p&p industry are the technical-industrial research institutes. The most central institute is Papirindustriens Forskningsinstitutt (PFI), the oldest and largest industrial research institute in Norway. It was established in 1923, concurrently jointly owned by Norwegian pulp and paper enterprises. PFI is today involved in most of the research council supported research project on pulp and paper technology. Their core activity areas are paper as print carrier, fibre treatment, non-chloric sulphite mass bleaching, kalandrering, picture analysis and environmental research projects²⁰. PFI has recently moved from Oslo to Trondheim (June 1998), in order to co-operate and co-ordinate research efforts with the pulp and paper chemistry knowledge located at the Institute for chemical techniques (Institutt for Kjemiteknikk) in NTNU (University of Trondheim) and SINTEF.

The Norwegian Research Council are concurrently running a programme for called EXPOMAT, aimed at exporting materials from the national process industry (p&p, petrochemicals, petroleum, non-ferrous metals²¹). 15 million NOKs a year is spent on supporting research in pulp and paper industries. The programme is a prolonging of the 2,5 billion NOKs PROSMAT programme.

Internal knowledge

One central aspect with industrial knowledge access is in which extent the industry has access to skills within its own organisational structure. One factor which illustrates such a phenomenon is the knowledge embedded in those persons working within the industry. By personal knowledge we understand both informal (e.g. working experience) and formal competencies (education). Since we only have dataset for education/formal competencies, our basic hypothesis will be that high shares of formal competencies within an industry indicates that the industry is capable of establish and perform innovation activities in a much higher degree than those industries with less access to internal competencies.

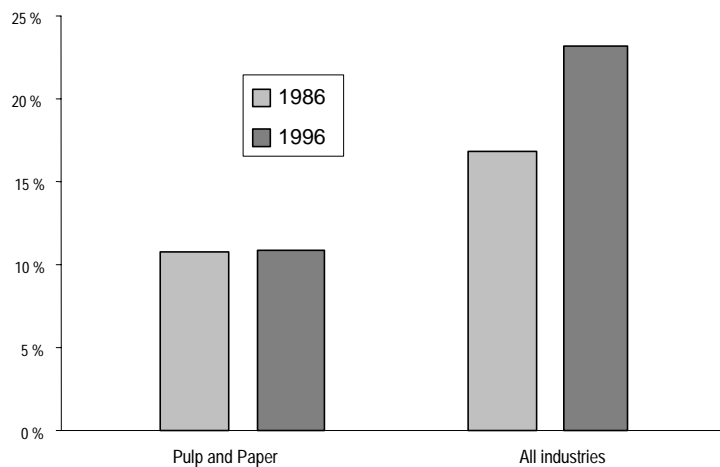
Figure 7 shows the development in formal competencies within the Norwegian p&p industry in 1986 and 1996, compared to average for all industries²². Formal competencies are here regarded as persons with higher education (university or college graduates). The figure shows that the share of persons with higher education in the p&p industry in 1996 is about 11 percent, as it was in 1986. At the same time, the national average has increased from 17 to 23 percent. In other words, the p&p has decreased its share of formal competencies, relative to the national average.

²⁰ NIFU instituttkatalogen 1998

²¹ Lettmetaller

²² For 1986, the branch / branch codes were used: Production of pulp (ISIC 34111), production of sulphate cellulose (ISIC 34112), production of sulphite cellulose (ISIC 34113) and production of paper and paperboard (ISIC 34113). For 1996, branches and branch-codes were used as presented in as in Table 1.

Figure 7: Share of employment with higher education (university/college) in respectively Pulp and Paper and All industries in 1986 and 1996 (source: STEP/SSB employment register 1986/1998).



Process innovation in focus?

Patenting data for the p&p industry show that few patents are granted to Norwegian p&p enterprises, but to their knowledge suppliers. Table 4 shows Norwegian p&p patents between 1974 and 1996. It is a relatively short list of only 15 patents; in average are two patents granted each three year. The list shows that almost all patents are assigned to industries serving as knowledge- and technology supplier to the industry. Patents 4 and 10 are the only two patents assigned to p&p enterprises; the rest is assigned to machinery suppliers.

The patents also indicate that most of the innovation activity is process-oriented; either as developments in production methods or systems (2, 3, 4, 5, 6, 7, 8, 9, 10, 12 and 13) or as development of p&p machinery and production equipment (11 and 15). Only two patents are seemingly focused on p&p product improvement or development (1 and 14).

A similar view on how the industry innovates is underpinned by employment rates and production index (Figure 1 and Table 1). We observed that employment in Norwegian pulp and paper has decreased with around 40 percent the last 11 years, whilst the production index was positive - the industry showed a yearly average growth in output on 2,78 percent. This means that the industry has managed to perform an increase in production at the same time as number of employees has decreased. In one sense, this could be interpreted as a process innovation; producing the same products in less expensive ways than before.

That pulp and paper industry is focused on process developments rather than product developments was indirectly documented in the Norwegian Knowledge Creation Study in 1995.²³ The study looked at which role introduction of new products played for different industries²⁴. The data demonstrated that p&p was

²³ Keith Smith et al (1995)

²⁴ Measured as sales of new products percentage of sales the last three years

the industry where new products played a marginal role; new products as share of sales in p&p was lower than in all other industries. The economic impact from new products in p&p varied with respect to whether the firms had established R&D collaboration or not. For firms with no R&D collaboration there were no new products involved at all. For those firms with R&D collaboration, sales of new products was five percents. In contrast, the average industrial share was respectively 11 and 21 percent. In the one end of the spectre, the IT-industry and the wood products industry respectively had the highest share of sales from new products (IT: 50 percent without R&D collaboration; wood products: 68 percent with R&D collaboration). In the other end of the spectre, p&p represented the lowest shares in both categories.

The regional aspect of pulp and paper production

Regionally based policy approaches to economic development has increasingly gained attention the last years²⁵. The regional dimension to economic development is based on two interdependent assumptions, one geographical and one social. The first assumption is that industrialisation must be understood as a territorial process, i.e. underlining the importance of agglomeration and 'non'-economic factors for economic development. The second presumption is to regard innovation as a socially embedded process, i.e. as an institutionally and culturally contextualised learning process.²⁶

In Norway, there are clear agglomeration patterns in the p&p industry. Table 3 demonstrate this in clear terms, showing share of employment in different p&p sub-sectors over different counties. The main results are:

- 72 percent of all employment in pulp and paper is located in the three counties of Østfold, Buskerud and Nord-Trøndelag
- Looking at paper and paper board production only, 67 percent of the employment is located in the Oslofjord area (Østfold and Buskerud; 38 percent + 29 percent).
- 59 percent of all employment in mechanical pulp production is located in Nord-Trøndelag.
- 80 percent of employment in sulphate and sulphite production is located in Buskerud.

²⁵ Storper (1995)

²⁶ Based on Asheim (1998)

Table 3: Agglomeration in the Norwegian pulp and paper industry: Share of p&p employment in three Norwegian counties, percentages (N = 6.098). Source: SSBs employment register.

	Østfold	Buskerud	N-Trøndelag	Rest of country	Total
Production of mechanical pulp	8 %	7 %	59 %	26 %	1.301
Production of Paper and paper board	38 %	29 %	2 %	31 %	4.258
Production of sulphate and sulphite cellulose	14 %	80 %	-	6 %	539
Total (N)	1.788	1.758	841	1.711	6.098

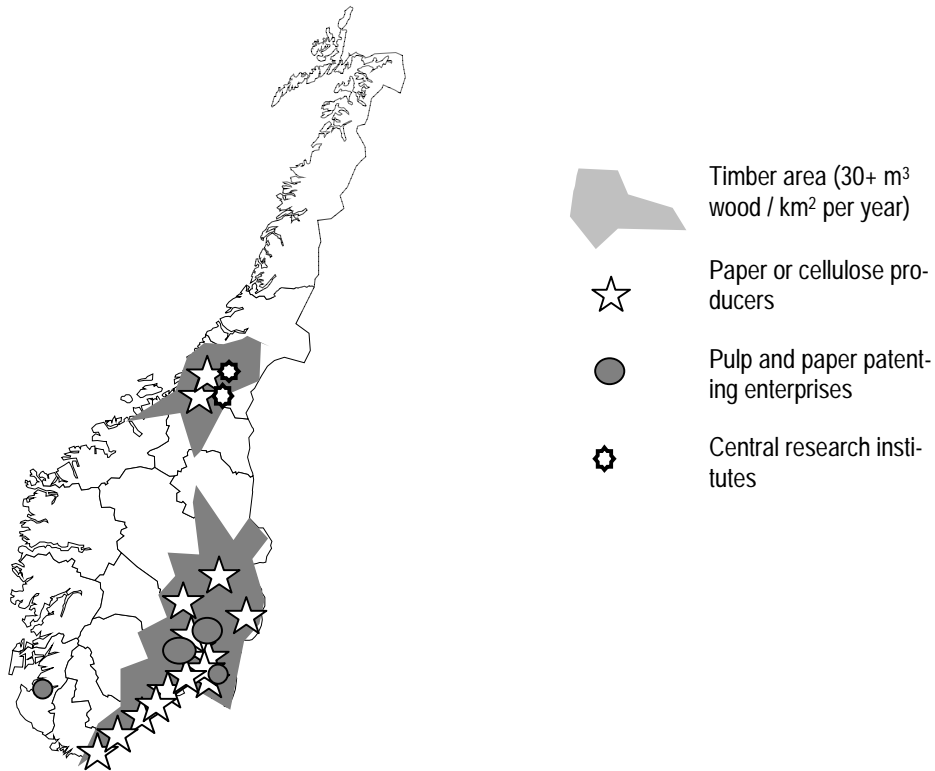
In other words, what we have found is a sharp distinction in localisation of the different stages in the pulp and paper production line. The first stage of production - production of mechanical pulp - is located in Nord-Trøndelag. Production of cellulose and paper/paper board is located in the industrial Oslofjord area.²⁷ As we shall see later, localisation of the industry goes well together with location of timbering in Norway.

Having established a localised production system in the pulp and paper industry, there is one central question raising: Who are central suppliers of technology to the pulp and paper industry, and where are they located? The core statistical database for making such an overview is again patent data. By again turning to patents, we get a good indication on which Norwegian agents are serving the pulp and paper industry with machinery and equipment, and where they are located (Table 4).

We see that all patents with one exception are developed by firms located in the central Oslofjord area, in particular Buskerud (Tranby/Drammen) and Oslo. Two of the patents are developed by large (in Norwegian comparison) paper and paper board enterprises; Peterson and Søn in Moss (Østfold) and Borregaard in Sarpsborg (Østfold), the rest is developed by machine tools suppliers or mechanical workshops like Myrens Verksted / Kværner Eureka (see Figure 8).

²⁷ See f.ex Wicken (1997)

Figure 8: Geographical location of wood (shaded area), paper and cellulose production (stars) and p&p patenting mechanical enterprises (dots) (Source: STEP Group and Norsk Treteknisk Institutt 1998²⁸).



²⁸ Sources: NIJOS, SKOG-DATA AS, Agder Skogdata, Statskog, Skogeierforeningene, Statistisk Sentralbyrå, Statens Kartverk, Treindustriens Landsforening

Table 4: Norwegian Pulp and Paper patents granted in US 1974 to 1996²⁹

	TITLE	ASSIGNEE(S)	FILED IN US	IPC CLASS(ES)
1	Apparatus for manufacturing sleeves from fibre pulp	Engell; Renee (Oslo, NO).	May 10, 1974	D21F 100
2	Method and an apparatus for processing finely divided fibrous pulp with gas without overpressure	Myrens Verksted A/S (Oslo, NO).	Oct. 29, 1976	D21C 324, D21C 700, D21C 910
3	System for forming and treating a narrow multi-layer web	Myrens Verksted A/S (Oslo, NO).	Mar. 29, 1977	D21F 1108
4	Method for the production of unbleached sulphite cellulose or bleached cellulose from a defibrated knot pulp	Borregaard A/S (Sarpsborg, NO).	Jun. 28, 1979	D21C 302, D21C 306
5	Method for treating refined mechanical pulp and thermo mechanical pulp with ozone	Myrens Verksted A/S (NO).	Dec. 7, 1979	D21B 114, D21C 910
6	Apparatus for treating fibrous material with a gas	Myrens Verksted A/S (Oslo, NO).	Mar. 9, 1982	D21C 706, D21C 708, D21C 910
7	Method for bleaching oxygen delignified cellulose-containing pulp with ozone and peroxide	Myrens Verksted A/S (Oslo, NO).	Jul. 19, 1982	D21C 916
8	Assembly for treatment of an endless wire or felt	Thune-Eureka A/S (Tranby, NO).	Aug. 19, 1982	D21F 132
9	Method of gas treatment of fluffed pulp	Myrens Verksted A/S (Oslo, NO).	Oct. 13, 1983	D21C 910
10	Process for delignification of chemical wood pulp using sodium sulphite or bisulphite prior to oxygen-alkali treatment	M. Peterson & Son A/S (Moss, NO).	Jun. 22, 1984	D21C 304, D21C 312, D21C 320, D21C 326
11	Apparatus for thickening and refining fibre-pulp suspensions	Thune-Eureka A/S (Lier, NO).	Oct. 9, 1985	D21D 130, B02C 7/00
12	Process for bleaching cellulose pulp, a plant for performing said process, and a screw press for use with said process and plant	Thune-Eureka A/S (Tranby, NO).	Jan. 28, 1987	D21C 900
13	Assembly for heat treating of an endless wire or felt	Kvaerner Eureka A/S (Tranby, NO).	Apr. 10, 1992	D21F 132
14	Means for collecting unwanted material in an oil or gas well	Den Norske Stats Oljeselskap A.S. (Stavanger, NO).	Nov. 22, 1995	D21B 3116
15	Heatable shield for heat treatment of paper-making machine textiles	Kvaerner Eureka a.s (Tranby, NO).	Feb. 22, 1996	D21F 100, D06C 300, F26B 13/10

Summing up

In this paper, we have described the Norwegian p&p knowledge infrastructure. We have described how different elements in the industry's knowledge infrastructure interact and how these interaction promote innovation in the industry. We have used several indicators to 'map' the p&p innovation patterns. We have looked at:

²⁹ Search for Norwegian patent assignees was performed by Eric Iversen, STEP-group, in the following IPC classifications: D21B (fibrous raw materials or their mechanical treatment), D21C production of cellulose by removing non-cellulose substances from cellulose-containing materials; regeneration of pulping liquors; apparatus therefor, D21D (treatment of the materials before passing to the paper-making machine), D21H (pulp compositions (misc.)), B31D(making other paper articles), B31F (mechanical working or deformation of paper or cardboard), D21F (Paper-making machines), D21G (accessories for paper-making machines etc.), C13C (cutting mills, shredding knives, pulp presses), B 65 H 3/00 (separating sheets from piles) and D21J (fibreboard; manufacture of articles from cellulosic fibrous suspensions).

- which are the supplying sectors to the industry
- how the industry invests in intangible and tangible assets
- which technology and knowledge sources the industry uses to promote innovation
- the formal education level in the industry
- location of industry and core suppliers

What we in short have described, is an industry which in many ways is not a technologically sophisticated industry. It is constituted by a simple production line, with few knowledge bases and few sources for knowledge input. It is an industry which use little resources on research and development, and which ideas rarely lead to patents. The employment are less educated than the Norwegian industrial average, and seemingly not evolving towards any upskilling at all. The industry have little contact with formal external knowledge suppliers. In the European CIS survey, neither universities, research laboratories nor external consultants was reported to play any significant role as source to innovation.

However, the industry is a sophisticated consumer of high technology machinery and equipment. In addition, the industry is highly innovative - on its own terms. It is an industry dependant upon external sources in order to perform innovations, and suppliers of knowledge, like customers/clients, machinery suppliers and equipment suppliers play a crucial role in the p&p industry.

Statistics demonstrate that there are agglomeration tendencies both with respect to p&p production and core technology suppliers. Both the CIS survey, patent statistics and results from Swedish cases of technology implementation demonstrate that innovation in p&p industry have some major signs of recognition:

- *Mode of innovation:* Innovations in p&p in a large degree manifest as developments in process or production technology, and in lesser extent product development. Most of p&p investments are used to renewal of production equipment, and a relatively little share of investment is registered as 'research and development'.
- *Mode of innovation radicality:* P&p industry uses higher innovation expenditure on training and test production than other industries. It is also an industry with a relatively low share of educated employment. This indicates that innovation taking place inside the p&p industry most likely is incremental, and related to developments in tacit skills.
- *Mode of technological co-operation:* Innovation is often based on integrated modes of work between technology producers and users. External consultants are rarely involved in development projects, and p&p enterprises rarely uses formal knowledge suppliers, as universities or research institutes. Innovation is most commonly based on a combination of use of internal, tacit industry-specific skills and external specialised skills in knowledge supplying industries; mainly machinery, but also in chemicals, monitoring etc.

► *Mode of knowledge input:* The core technical developments are mainly taking place outside p&p industries, in industries serving as knowledge base for the p&p industry. For example, patent data show that most pulp and paper innovations is taking place in machinery supplying industries.

► What seems a plausible description is that the Norwegian p&p knowledge filière is a system of producers working with external technology suppliers in a *highly territorially and functionally integrated* production system. By territorially integrated we mean that the core knowledge users and knowledge producers are located within the same region. By functionally integrated we mean that during innovation activities there are tight relations between different actors in the production system. Such territorially and functionally integrated production systems often have informal channels facilitating communication, based on common cultural and historical similarities. Apparently, the territorial integrated system of p&p has facilitated communication, technical co-operation and development between different actors in the production system.

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STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitik og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.