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Path-breaking Research in the Pulp and Paper Industry; the Roles of Science, Government and Industry [Nordic debate]

Objectives

The presentation analyzes the roles that science, government and industry have in establishing the conditions for path-breaking research in the Nordic pulp and paper industry. However, the establishment of good research conditions does not guarantee business success. Besides the creation of the right research conditions, research needs to be focused on the right topics, and the industry needs to have a system that will ensure that the results of the research will lead to the continued prosperity of the Nordic pulp and paper industry. As a special case of this presentation, the relations between science, government and industry are analysed for the Finnish pulp and paper industry.
Please note that the opinions presented here are my personal ones and do not necessarily represent the official opinions of my employer.

Role of path-breaking research in Western societies during the last quarter of the 20th century

By path-breaking research one understands the research which allows the society and/or an industry to comprehend new relationships of the type "cause and effect" in a way which will eventually allow the establishment of new business or the manufacturing of new products or already existing products with completely new properties or with revolutionary economics. Path-breaking research is the necessary preceding step before a great product innovation or before the introduction of new innovative *disruptive* technology.

During the last quarter of the 20th century path-breaking research has been recognised as an important driving force for continued economic growth in most of the developed societies. Especially the many examples of innovations in the IC and biotechnology field emphasise the catalytic role played by path-breaking research.

Many governments have developed national programmes to speed up innovations in order to enhance economic growth in the high tech areas. The European Union has also passed the Lisbon resolution, according to which the EU will become the most innovative global business idea[1] by the year 2010.

Fig. 1 presents the development of the national R&D input in various countries over the years.

[1] At the meeting of the European business directors in Helsinki, July 4, 2003, the Associate Editor and Chief Economics Commentator of the Financial Times, Mr. Martin Wolf commented this Lisbon decision saying that "the EU politicians have a good sense of humour when they set targets like this for themselves".

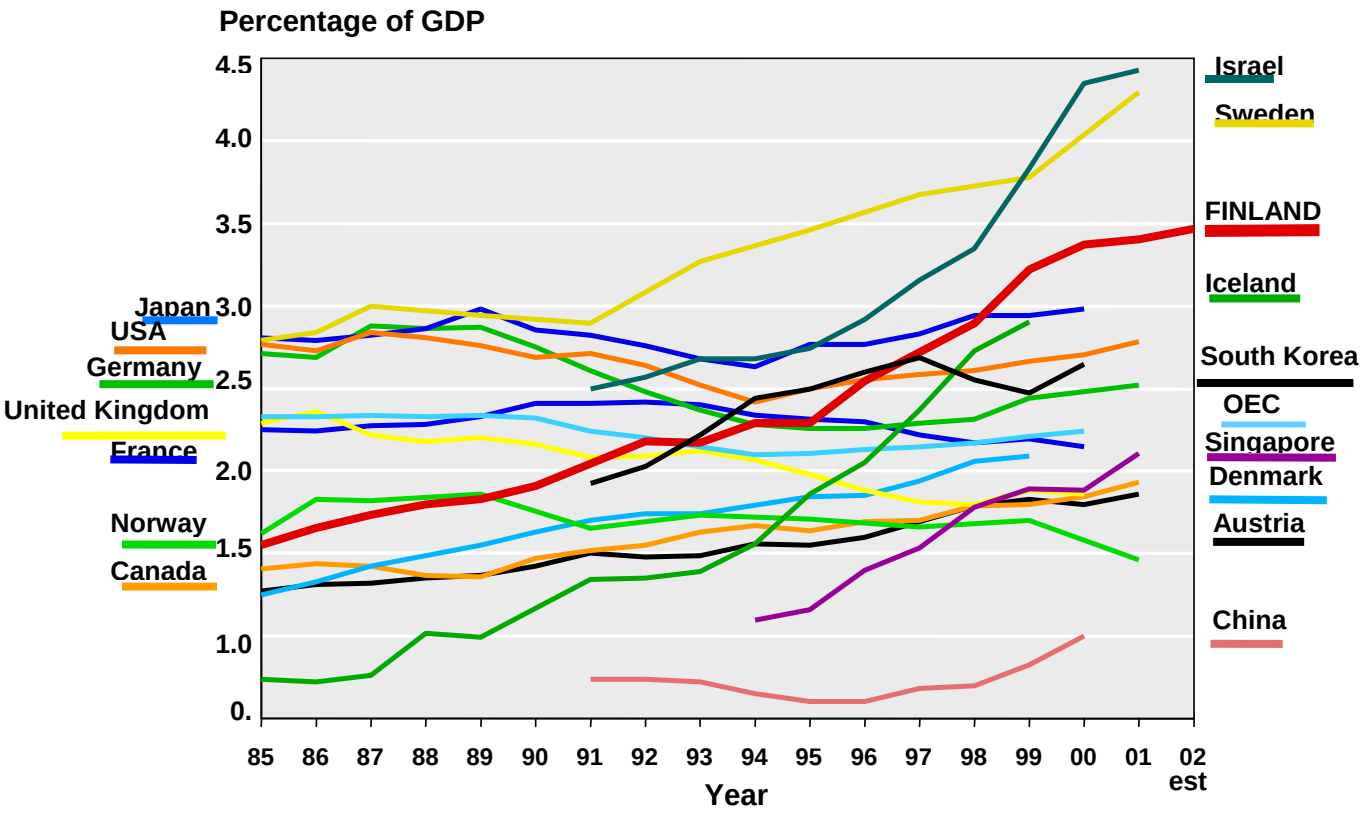

Figure 1. Development of national R&D input in some OECD countries

The R&D investments in Finland have risen rapidly over the past 30 years. From a level below 1% of the gross *domestic* product in 1970s they are now approaching 3.5% of GDP. In comparison to the OECD average, which is slightly over 2%, and the EU average, which is below 2%, Sweden and Finland are leading the way for the rest of the world. This is especially true when one keeps in mind that the role of research for military purposes is very small in both these countries.

However, the key question is not how high the national R&D investments are! Instead, one should ask: "What do you get with the national R&D input?" Are you capable of changing the economic structure of a country? Can you generate national wealth better if you have an above average R&D investment?

The traditional measurement method of research effectiveness has been based on publication and citation records, on advanced degrees in higher education and on international scientific rewards. However, unless the increased R&D input eventually delivers even better economic activity and increased national wealth, the increase of the R&D investment has not been a very successful one. Of course the research alone does not have the sole responsibility for turning the research results into national wealth. Even an innovative system with appropriate vehicles and encouragement for the commercialisation of the research results needs to be functional. Moreover, the business players, i.e. companies, need to have a culture of utilising the results of the R&D.

Role of government in path-breaking research and innovation

Traditionally the OECD divides [1] the industry branches into high tech, low tech and "in between" industries. The R&D intensity of a given industry branch (Table I) is used as the division criterion.

Table I. Division of industries into high tech, low tech and "in between" industries

Definition of Industry	R&D as % of sales
High tech industry	> 4
Low tech industry	> 1
"In between" or medium low tech or medium high tech industry	1<---> 4

All the capital-intensive process industries - such as the oil & gas, commodity chemicals, steel, other basic metals, cement, and pulp and paper industries - belong to the low tech industry group.

Some criticism has been raised about this measurement of the technology intensity of an industry branch. The measurement is based on the ratio of the R&D expenditure of a company to its annual turnover.[see Equation (1)].

$$\text{R\&D intensity} = \frac{\text{R\&D expenditure}}{\text{Annual turnover}} \qquad (1)$$

In the capital-intensive process industries the numerator is based on 7.5 hours per day, 5 days per week excluding the summer vacation and other holidays. The denominator corresponds to the production time of 24 hours per day and 360 days per year. In many other industries it is based only on 8 hours a day and about 240 days a year production time. Thus the process industries have four times more production hours in the denominator than many other industries. Eventually one should multiply the relative R&D intensities of the process industry by four in order to make them comparable with the other industries that do not work in a continuous three shift arrangement. If such a conversion is made, then the process industries cannot any more be so clearly classified to low tech industries as they are with the present evaluation method.

In recent years the governments and the politicians have called upon increased public support for the innovation process in order to accelerate the economic growth that high tech industries have been thought to bring along. However, apparently the differences that exist in the innovation process between the high tech and low tech industries are not fully understood by the politicians and the science sector decision-makers, nor even by many of the *actual science performers* [the scientists/researchers themselves]. As a matter of fact, the measures that favour innovation in the high tech area do not necessarily help innovation in the low tech areas.

Table II describes the special characteristic features of the innovation process in the high tech and the low tech industries [1].

Table II. Comparison of the low tech and high tech industries.

Characteristic	Low tech industry	High tech industry
Competition criterion	Price / Quality	Innovation
R&D intensity	Low	High
Patenting	Low	High
Innovation focus	Process -> "Product"	Product
Scale of innovation	Incremental	Fundamental
Source of innovation	Information already available in other areas	Self (in co-operation with universities) searched new information
Type of knowledge	Tacit	Practical, codified
Type of learning	Learning by using	Searching, exploring
Co-operation	Customer, producer	University, producer
Skills & competences	Practical knowledge + skills	Theoretical knowledge + cognitive skills

As can be seen from this table, innovation in the process industry focuses more on the process than in the high tech industry. This is a clear follow-up of the capital intensity of the process industry; once the "steel" has been put into the ground, one has to live with it for decades. Innovation in the low tech industry concentrates on the process, i.e. how to introduce better or new properties into the product or how to produce the same product at a lower cost. In other words, the innovation in the low tech industry is incremental, and in many cases it is based on discoveries made in other fields of technology rather than in the dedicated technology of the industry under consideration.

On the contrary, in the high tech industry the innovation is based on path-breaking research knowledge created – in many cases - on the request of the high tech industry in the universities[2]. In other words, universities are the co-operation partner of the high tech industry company, while in the low tech industry the co-operation partner is often the customer or the supplier of process equipment or chemicals.

Another important reason that guides the innovation in the low tech industries towards incremental improvements is the fact that in most cases the products of the low tech industry are industrial intermediates, i.e. other industries use these products as raw material for their own processes. Therefore it is much more difficult to realise a revolutionary product innovation in the case of the low tech process industry, because such a revolutionary product would require new investments all through the customer industry. For instance, in the case of the paper industry, a revolutionary new paper grade might easily require a different printing process or different printing ink and therefore it would not necessarily be a very welcome innovation. For industrial intermediate products, i.e. products of the capital-intensive processing industry, *disruptive* innovations are usually not very welcome [2].

One more aspect that makes it difficult to create new revolutionary manufacturing processes for the capital-intensive process industries by the path-breaking research carried out in university laboratories, is the scale factor. In other words, the distance in time and money from a brilliant university idea for a new revolutionary manufacturing process of a typical process industry to a commercially ready and tested process is very long (Fig. 2).

[2] There has been some criticism in recent years that the co-operation of the high tech industry companies with the research carried out in the universities is restricting the free research possibilities of the universities. In some cases it is actually turning certain university laboratories into satellite laboratories of the high tech industry company.

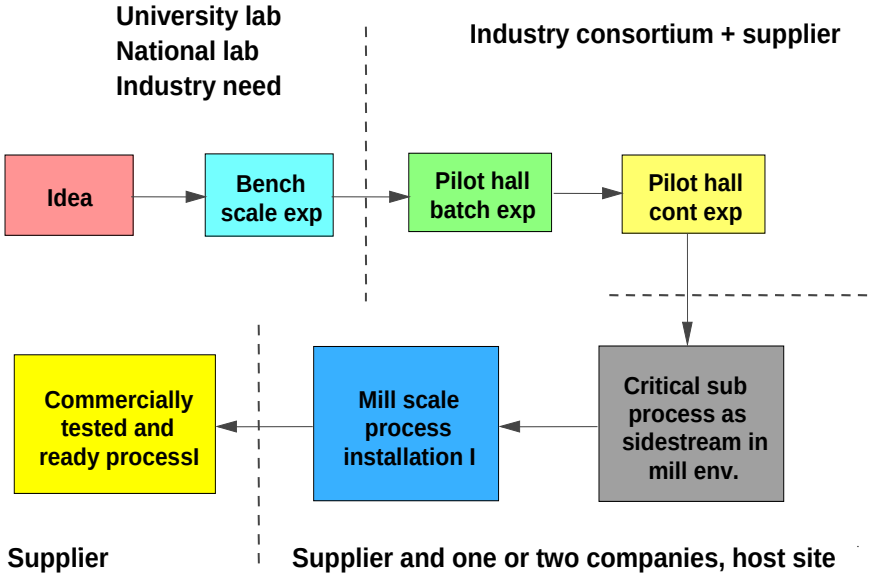

Figure 2. Actions required to move from an idea for a new revolutionary process to a commercially ready process.

The university laboratories do not have the resources to take the idea much further than to the batch scale pilot experimenting. However, this is a stage at which no company is willing to make the investment decision to scale it up to full commercial size, i.e. to the capacity of thousands of tons of product per day.

The 'quarterly capitalism' that is guiding the present process industry does not make it easy for an individual company to sponsor the whole development chain from pilot hall batch operations to continuous commercial scale process. Thus the Scandinavian pulp and paper industry does have a problem: i.e. how to organise the future path-breaking research and ensure that its results will *act as seeds for* better manufacturing processes called upon by sustainable development and by the competition from the low cost producers of South America and South-East Asia.

The national and EU-wide support schemes for R&D do not seem to discern the different type of innovation support and encouragement that is needed by the capital-intensive process industry, including the pulp and paper industry. On the contrary, most of the public innovation support is focused on the innovation support of the high tech companies. For instance in the 6th Framework Programme of the European Union, much of the support has been directed to the high tech industries, and although the traditional process industries cover more than 30% of the added value generated by the whole manufacturing sector of the EU, its share of the 6th Framework support money for European industry is very small. This example supports the inference drawn in the previous paragraph that the whole European capital-intensive process industry seems to have a problem in getting basic public funding for path-breaking long-term research. In other words, my view is that the governments of the EU countries and the Union itself are not paying enough attention to the conditions of path-breaking research in the European process industry. One may therefore state that the governmental role in the path-breaking research of various capital-intensive process industries is just now quite meagre in Europe.

Examples of path-breaking R&D in the P&P industry

Looking at the 20 Marcus Wallenberg Prizes that have been awarded, they could perhaps be divided into the classes given in Table III[3].

Table III. Division of the Marcus Wallenberg Prizes according to their roles, i.e. deeper understanding *vs.* practical discovery type roles.

Type of recognition	**Forests & Forestry**	**Mechanical Forest Industry**	**Chemical Forest Industry**
New theoretical understanding	**5**	**3**	**3.5**
New (revolutionary) practical discovery	**2**	**1**	**5.5**

It can be seen in Table III that about 60% of the prizes have been awarded to providing a better understanding of the fundamentals on which the forest industry is based, and about 40% of the awarded prizes focus on readily applicable practical technologies[4]. The role of prizes for increased theoretical understanding has been the highest in the Forests & Forestry sector and in the Mechanical Forest Industry sector. In the Pulp and Paper Industry the share of practical discoveries in the prizes awarded has been the highest, i.e. about 60%.

Case Finland; the role of science

Next I will analyse the role of science in the pulp and paper industry of Finland and Sweden. Table IV compares the development of matters related to the pulp and paper industry in Finland and Sweden over the past 30 years.

[3] It needs to be emphasised that the division of the Marcus Wallenberg Prizes to the various classes in Table III has been made purely according to my personal judgement.

[4] Here I have divided this year's prize, i.e. the discovery of the role of hexauronic acids in bleaching to 50% deepening of theoretical understanding and 50% to practical discovery.

Table IV. Development of key characteristics in the Finnish and Swedish pulp and paper industry during the past 30 years.

	Finland		Sweden	
Category	**1970**	**2001**	**1970**	**2001**
Pulp production, Mt/a	**6.2**	**11.2**	**8.2**	**11.0**
Paper production,Mt/a	**4.3**	**12.5**	**4.4**	**10.5**
Consulting activity	Pöyry, Ekono	Pöyry, PI, CTS	ÅF. IVL, Pöyry NLK (Celpap)	Pöyry, ÅF-IVL
Machinery suppliers	**Valmet, Tampella Ahlström, Wärtsilä (P&P firms had own mach. comp.)**	**Metso, Kvaerner Andritz,Vaahto**	**KMW, Sunds Defibrator, Udde-valla verkst.** BTG	**Metso**
Chemical suppliers	**Kemira, Oulu, Raisio, others**	**Raisio, Kemira**	**KemaNord, EKA, AGA, Dow, others**	**EKA-Chem. (Akzo-Nobel), BIM**
Harvester mfrs	**Lokomo, Valmet, Farm.tractor modif.**	**Timberjack, Ponse Valmet (Kone)**	**Volvo BM, Ösa, Kockum, Farming .tractor modficat.**	**~~Timberjack,Deere~~ Valmet (Kone), Rotne**
Joint central research	KCL, VTT	**KCL,VTT, Län-nen laboratorio**	STFI, YKI,IVL Packforsk	STFI, YKI
Joint marketing	yes	no	no	no
Prod. cap. (P&P) M.+D.Sc./a	35 / 4-5	110 / 25	15/0	60/12
Globalisation in P&P	**Nordland, Star, Kitimat, Tivoli**	**3 firms are among the 12 big ones**	**Stora, SCA**	SCA

It can be seen from the table that in the year 1970 pulp production in Sweden was about 30% higher than in Finland. Paper and board production was the same in both countries. In 2001 the Finnish pulp mills had increased their capacity by 80% and exceeded the corresponding Swedish capacity that had grown only by about 33%. In the 30-year period the Finnish paper and board production had grown threefold and was about 20% higher than the corresponding production in Sweden, which had grown by a factor of 2.5.

When comparing the other listed categories one may observe that the Finnish consulting activity for the pulp and paper industry has taken over world leadership with Jaakko Pöyry Company, while the Swedish consulting activity for the industry has remained fairly stable. The same has happened for the Swedish machinery supply industry, as the Finnish company Metso has taken over the Swedish companies KMW and Sunds. The joint dedicated research activities have decreased somewhat in Sweden and remained about the same in Finland. The Finnish output of dedicated M.Sc. and Ph.D. graduates in pulp and paper technology has increased considerably. In recent years Sweden has also increased this output, although the strategic position of basic pulping and papermaking technology may have diminished a little at the same time. Moreover, the globalisation of international pulp and paper industry has favoured those companies which have their headquarters in Finland more than the corresponding Swedish companies.

What has been the reason for the seemingly higher growth rate of the Finnish industry and for the formation of a more active forest industry cluster in Finland (Fig. 3)?

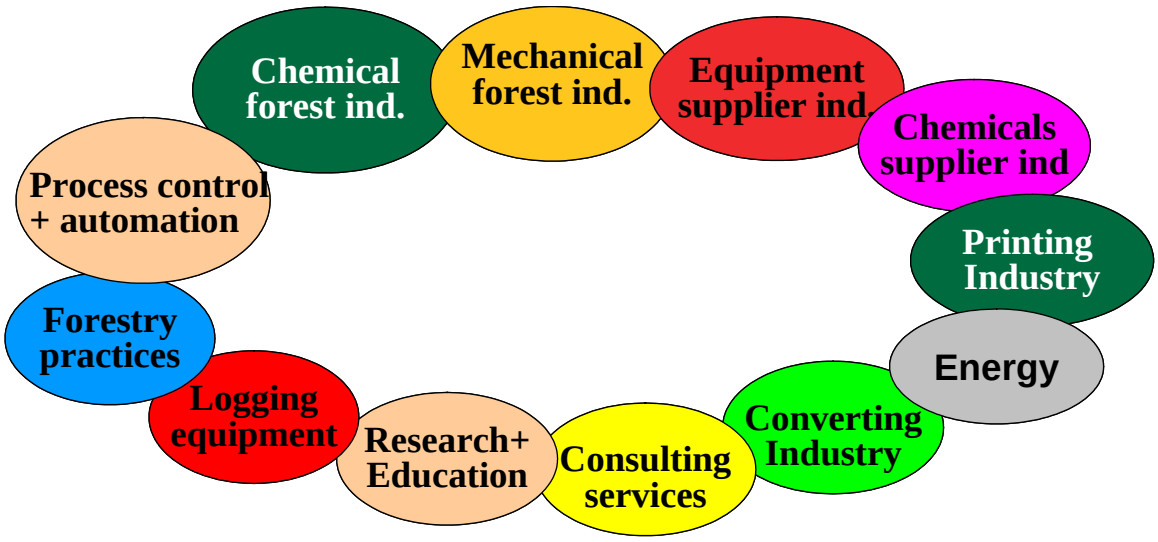

Figure 3. Structure of the Finnish forest industry cluster

My personal opinion is that many factors have affected this development. The most important are perhaps:

1. Education and technology resulting from it
2. Co-operation practices in marketing, research, financing arrangements and with the suppliers. In other words, the efficient utilisation of home ground advantages within the forest industry cluster especially in the 1970s and 1980s.
3. Understanding of the role of forest industry in the national economy by the government and the respective authorities.
4. Sweden has had more important industries than the forest industry to look after.

In this connection I particularly want to emphasise the important role of Professor Niilo Ryti in the development of paper technology from an art into a quantitative processing technology. Especially the concepts "product analysis" and "process analysis" were revolutionary when they were first introduced in the middle of the 1970s. As a matter of fact, the pulp and paper industry is perhaps a typical example where success is based more on the efficient use of technology than on pure science.

In the case of the Finnish Pulp and Paper Research Institute, KCL, one should also remember to emphasise that it has had a superior pilot equipment park that has enabled, among others, the testing of various fibrous raw materials and web structures for coating and printing at high speeds before proceeding to the mill-scale verification runs.

TEKES (The National Technology Agency of Finland) has organised and financed large national pulp and paper technology programmes more frequently than the corresponding joint Swedish financing organisations (see Table V).

Table V describes the most important national technology programmes dedicated to the pulp and paper technology during the past 15 years in Finland and Sweden. It can be seen from this table that the number of programmes has been higher in Finland. The total amount of money involved has also been higher. It is important to note that in all its technology programmes TEKES has used an industry team to set the targets for the programme, and the individual projects have also had a project coordination

team where the industry experts have provided assistance and support for the research. Normally the share of the industrial companies of the total costs[5] has been around 30%.

Table V. Listing of large joint P&P technology programmes in Finland and Sweden over the last 15 years.

FINLAND	Total budget, M€	SWEDEN	Total budget, M€
Functional paper	13	NSP	3
Pulping "package"	10	KAM 1, pulp mill for sustain. dvl	11
Sytyke, environmental protection	3	FRAM, pulp mill for sustain. dvl	5.5
Carbohydrates in process industry	3	WURC	1/a
Fibre, energy savings	7	BiMaC (2002 – 2007)	8
Web, energy savings	10	Black Liquor Gasification.	>5
Sustainable paper, energy saving	20	Faxen hydrodynamics lab	
Electronic printing	12	Start up of Karlstadt & Mid-Högsk	
Cactus, low water consumption	16	SSVL	1.5/a
Wood wisdom	33		
Pigments in papermaking	4		
TOTAL	**141**	**TOTAL**	**<50**

One can perhaps state that Sweden has had fewer extensive co-operative technology programmes of the type "university – research institute – industry" than Finland.

Results of the Finnish pulp and paper industry technology programmes

Has this large amount of research money helped the Finnish pulp and paper industry to achieve more path-breaking research results than have been achieved by the Swedish pulp and paper industry during the same time period? If one uses the Marcus Wallenberg Prizes as a yardstick, one can see that out of the 20 prizes awarded, five have been awarded to Swedish scientists/teams and four to Finnish scientists and/or teams. Excluding the prizes awarded within the Forests and Forestry and Mechanical Forest Industry fields, Swedish scientists/teams have won four of the Prizes awarded in the Pulp and Paper technology fields and the Finnish scientists/teams have won three prizes. Thus one could draw the conclusion that the quality of path-breaking research has perhaps been better in Sweden.

Has the bigger volume of path-breaking research results provided better momentum for the Swedish pulp and paper industry than that provided for the Finnish pulp and paper industry? It is not easy to answer this question. However, judging from the size, age and efficiency of the printing and writing paper machines running in Finland, one may conclude that the investments in technology in Finland have resulted in faster and more modern machinery (Fig. 4). Further, as was seen in connection of Table IV, the Finnish paper industry has become more globalized on the basis of its technological advantage.

[5] In the Wood Wisdom Program there were also topics related to forestry, mechanical forest industry, marketing and by-products. Besides TEKES financing, also the Ministry of Agriculture and Forestry, Trade and Industry, and the Environment participated together with the Academy of Finland in the financing of the programme. The share of the industry in the financing was very small.

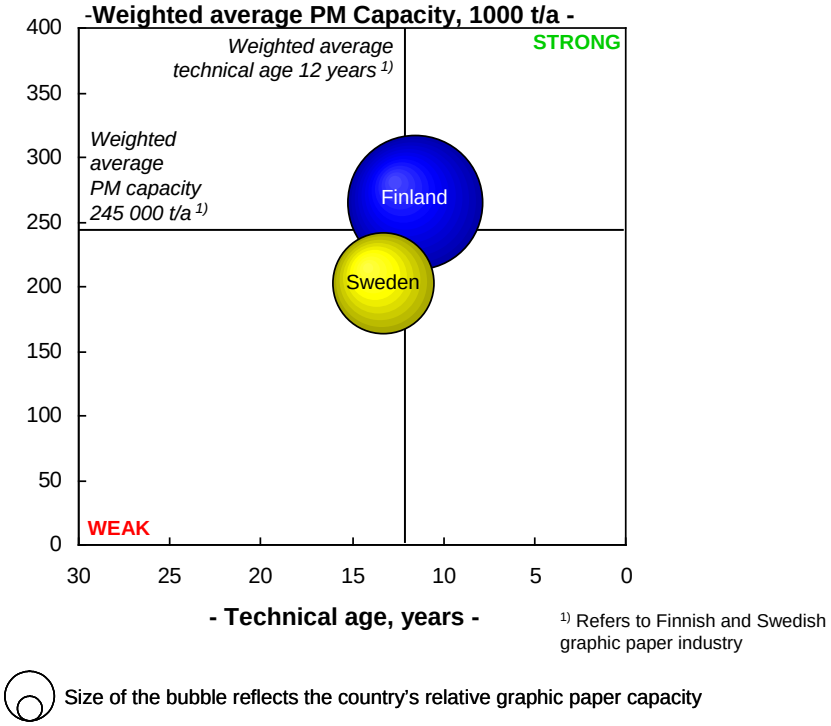

Figure 4. Technical comparison of the graphic paper machines operating in Sweden and Finland (Data provided by Jaakko Pöyry Consulting).

However, one should also keep in mind the comments made by Mr. Casimir Ehrnrooth, then Chairman of the Board of Kymmene Corporation. In an enterprise seminar arranged at the Helsinki University of Technology in 1994, after listening to Mr. Bo Berggren's, then chairman of Storas Board, praise of the research effort made by the Finnish pulp and paper industry, Mr. Ehrnrooth stated (Fig. 5):

"With the present R&D input of the Finnish forest industry we should be the best! Why are we not"? Chairman of Kymmene's Board, Mr. Casimir Ehrnrooth in Otaniemi

Figure 5. Comment by Mr. Casimir Ehrnrooth in an enterprise seminar at the HUT.

One may thus conclude that the role of science and path-breaking research is not as important for the operational and business efficiency of the international pulp and paper industry as it is for the ICT and biotechnology. Part of the reason for this sub conclusion is that due to the huge capital-intensiveness of the pulp and paper industry one needs to live with the existing processes for decades. Therefore there is not very much interest into revolutionary innovations. Instead the incremental innovations are considered sufficient.

Role of the P&P Industry

Let us next take a closer look at the financing of R&D in the Finnish forest industry cluster. Table VI outlines the estimated annual R&D input in the Finnish forest industry cluster.

Table VI. Overall R&D effort in the Finnish forest industry cluster

	R&D budget, M€	TEKES support, M€	No. of projects
Pulp and paper industry companies	**100**	**4**	11
Wood products companies	**15**	**3**	37
Equipment suppliers	**100**	**11**	35
Automation, instrumentation + process control companies	**10**	**1.4**	10
Chemicals suppliers	**10**	**2**	8
Forest industry dedicated research labs and others	**already included**	**2.0**	4
VTT and other public labs + universities	**17**	**13.4**	21
TOTAL	**252**	**38.7**	116

It can be seen from this table that the contribution of the process equipment suppliers and of the other suppliers (automation, chemicals) is slightly bigger than the actual direct R&D input by the forest industry companies. The overall public support for the forest industry cluster research is about 15%. Universities and other public research laboratories provide about 7% of the total R&D input of the cluster. However, they receive about 1/3 of the TEKES support money to the forest industry cluster. Because of this large public support, university research represents a lower-cost research activity than the research carried out by the companies themselves or by the joint research laboratories of the companies.

What is alarming in Table VI is the fact that the number of research projects supporting the pulp and paper industry is just 11. The reason for this is – at least partially – the divergent ideas about what is new and innovative in the capital-intensive pulp and paper industry. TEKES would be willing to support totally new and revolutionary project ideas like intelligent paper but is not interested in supporting the R&D that the industry itself feels to be of importance to it (see Table II; low tech *vs.* high tech innovation). As a result the public support to the forest industry cluster has been diminishing in the last five years as shown in Fig. 6.

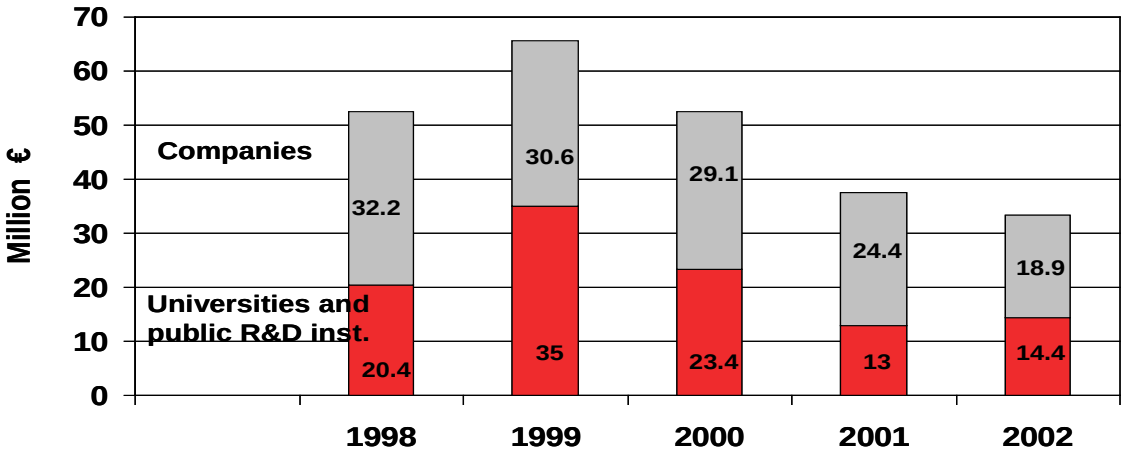

Figure 6. Development of the TEKES support to the Finnish forest industry cluster.

One can see from Figure 6 that over the last five years the overall TEKES support to the Finnish forest industry cluster has decreased in the category (direct support to the) companies, and in the category (support to) public laboratories and universities . Overall support to the cluster has decreased by about 50% from the maximum year of 1999, and the support to the universities by about 60%. These are very large changes in such a short time period.

We have already talked about the so-called 'quarterly capitalism'. This has made it difficult for the top management of companies to focus on such long-term strategic research that would - if successful - provide a true competitive edge for the company. Based on these examinations it can be stated that long-term strategic research in the pulp and paper industry, i.e. the path-breaking research for future innovations and responses required by the sustainable development objectives, is in some kind of a crisis. The Nordic pulp and paper industry cannot continue very long without good dedicated strategic research, i.e. properly applied basic research!

Based on the above reasoning my conclusion is that the role of the industry in path-breaking research is not what one would expect of the Nordic pulp and paper industry in view of its past accomplishments and global market position.

Conclusions

It can be concluded that out of the three discussed factors contributing to path-breaking research in the pulp and paper technology, i.e. science, the government and the industry, none is right now in its best possible state.

The role of the government suffers from the admiration by the science authorities of innovation in high tech industries without proper understanding that innovation in the capital-intensive process industries – including the pulp and paper industry – is different in nature. Because of this, path-breaking research for high tech industries receives much more public support in the 6th Framework Programme of the EU in comparison with the support to the European process industries, which nevertheless provide over 50% of the added value created by the European industries. The same reasoning also seems to apply to the support given by the national technology agency TEKES, i.e. conventional incremental research in the low tech industries is out of style. TEKES wants to support flashier revolutionary innovations or the creation of *disruptive* technologies for these industries.

The role of science, i.e. university research, in providing path-breaking research results for the Nordic pulp and paper industry could also be better. The basic research unit in today's technical universities is the professor and his graduate student. It is impossible to require such a unit to assume responsibility for long-term basic and applied basic research for the pulp and paper industry. One also needs to remember that the step from a laboratory-scale pilot system to commercial-scale tested production requires much large-scale piloting and experimenting. This is not possible in the university environment. In order for the universities to carry better their share of the basic and applied basic research for the pulp and paper technologies, the university laboratories need to get some permanent or semi-permanent high calibre research personnel. This is the job for the government and the Ministry of Education. In addition, the universities also need to carry out a proper amount of well focused fundamental research in order to generate path-breaking research results, based on which the future innovative products and innovative (*disruptive*) technologies will eventually be developed. In the long run probably nanotechnologies and biotechnologies will form new *disruptive* technology vehicles for the forest industry. Social sciences will probably also become more important for the forest industry in future , but one should always keep in mind that the discovery of electricity did much more good to the world than all the social studies carried out after the discovery of electricity. I would like to take this opportunity to emphasise that the research requirements for the technical universities should not jeopardise the educational role of the universities.

The pulp and paper industry companies need to accept their responsibilities in participating in the creation of the strategic options[6] of new products and/or new processes for the future of the company. Sometimes this type of research could perhaps be called visionary research. It will require clever pooling together of resources and efforts with other companies, with equipment and chemicals suppliers and with universities. The technology strategy and the business strategy of the company need to be strongly linked together. The long-term strategic research of the pulp and paper industry companies cannot be driven only by scientists for too long a period. The long-term strategic research must also support the possible new ventures activities that the company may have. I do want to emphasise here that it is not necessary that the company *per se* carry out a great deal of strategic long-term research. This can be outsourced to a large extent. Long-term strategic research is something that the management cannot delegate down to the organisation; top management does have a responsibility to integrate it into the other strategic activities.

Proposal

I like to take this opportunity to propose to the Marcus Wallenberg Foundation that the Foundation should start another Prize tradition in addition to the Marcus Wallenberg Prize which is already well established and successful. The new Prize could perhaps be called the Marcus Wallenberg Research Recognition Award. It would be granted to a CEO, COO or Senior Executive Vice President that has most successfully fostered, supported and utilized the results of long-term research during the past three-to-five-year period. It is my sincere hope that such public recognition would bring about the needed change in the appreciation of strategic long-term research in the pulp and paper industry companies.

[6] Industrial research can be defined as creation of good information for decision-making

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