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RELATIONSHIPS BETWEEN ENVIRONMENTALLY SOUND TECHNOLOGIES AND COMPETITIVENESS OF COMPANIES IN THE VALUE CHAIN OF PRINTED PAPER FROM FOREST TO MARKET

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Sanna Perkiö

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Abstract

Technologies play a well-known role in creating competitive advantages for companies as well as in controlling environmental impacts. This study deals with the relationship between environmentally sound technologies and the competitiveness of companies in the value chain of printed paper from forest to market. These connections are important to understand, because the technology is an important solution in facing environmental requirements. This study answers the following five questions: Which environmentally sound technologies are the most important for environmental impacts in the value chain of printed paper? How do they impact on the competitiveness of companies? How do these technologies differ across the value chain? Do they impact on competitiveness of companies in the other part of the value chain? The fifth research question involves studying differences between function mechanisms of pollution-prevention technology and pollution-abatement technology in facing legal requirements. This is studied as a part of the so-called 'Porter Hypothesis'. A term, *environmental value creation*, has been defined as 'performing activities by managing environmental aspects so that the value of goods and services to consumers or to customers increases.' Data was collected from the value chain of printed paper and were divided into the following parts: forest harvesting, pulp mill, paper mill and printing house. Eight experts were interviewed resulting in 69 environmentally sound technologies during the time periods 1980-1999 and 2000-2019. The data was analysed by non-parametrical statistical tests.

As a result of this study, automation, measurement and information technologies, closing-up technologies and energy technologies were found to be the most important for environmental impacts and frequently mentioned responses of environmentally sound technologies in the value chain of printed paper. The cost factors of raw material and staff and differentiation factors of company image and product image were the most indicative of increasing competitiveness of companies among environmentally sound technologies. Of the cost factors investigated, capital invested in technologies reduced the competitiveness of companies the most. The function mechanism of pollution-prevention technologies will replace pollution-abatement technologies in time period 2000-2019. Competitiveness impacts were not found to have a relationship with having or not having legal incentive among environmentally sound technologies, but significantly competitiveness-decreasing technologies have been found to be more frequently legal incentives impacted on than the other investigated technologies. The use of raw materials and natural resources of environmental aspects is intensively focused by the environmentally sound technologies along the value chain and this progress will strengthen in the technologies of the time period 2000-2019. When the differences among the parts of value chain of printed paper were studied, it was found that the environmentally sound technologies increase competitiveness of companies mostly in printing houses and decrease it mostly in pulp mills. Half of the investigated technologies have an effect on competitiveness of companies in the other part of the value chain, too.

As a result of this study, a part of Porter Hypothesis concerning the positive role of the pollution prevention in fulfilling environmental requirements is accepted only when the competitiveness of companies is measured by the factor of staff, but rejected by the factors of raw material, energy, capital, other costs, product characteristics, product image, company image and other differentiation factors. It concludes in saying that pollution-prevention technologies are not the one and only key for competitive advantage in companies; pollution-abatement technologies can also increase competitiveness of companies. For the regulative point of view this means that there is no need to tailor the environmental regulation for pollution prevention approaches. Environmental regulation should focus on controlling of environmental impacts, not on ideas of win-win situations of pollution prevention, which might not be capitalised ever.

Tiivistelmä

Tekniikat luovat yrityksille kilpailukykyä ja niillä rajoitetaan haitallisia ympäristövaikutuksia. Tässä työssä tutkittiin ympäristömyötäisten tekniikoiden ja yritysten kilpailukyvyn välisiä yhteyksiä. Näiden yhteyksien ymmärtäminen on tärkeää, koska tekniikat ovat ylivoimainen ratkaisu ympäristölainsäädännön vaatimusten täyttämisessä. Tutkimuskohteena oli painopaperin arvoketju metsästä markkinoille. Tutkimus vastaa seuraavaan viiteen kysymykseen: Mitkä ovat ympäristövaikutusten kannalta tärkeimmät ympäristömyötäiset tekniikat painopaperin arvoketjussa? Miten nämä tekniikat vaikuttavat yritysten kilpailukykyyn? Miten tekniikat eroavat toisistaan arvoketjun eri osissa? Vaikuttavatko tekniikat yritysten kilpailukykyyn muissa arvoketjun osissa? Viidennessä tutkimuskysymyksessä haettiin vastausta ns. Porterin hypoteesin siihen osaan, jonka mukaan luodakseen kilpailuetua yrityksille ympäristölainsäädännön tulisi ohjata ottamaan käyttöön ympäristön pilaantumista ennaltaehkäisevää tekniikkaa (pollution prevention technology) päästöjen puhdistustekniikan (pollution abatement technology) sijaan. Ympäristön huomioonottavan lisäarvon tuottamisen (environmental value creation) käsite määriteltiin "toimiksi, jotka lisäävät tuotteen tai palvelun arvoa kuluttajalle tai asiakkaalle ympäristönäkökohtien hallinnan avulla." Tutkimusaineisto koottiin neljästä painopaperin arvoketjun osasta, jotka olivat metsänkorjuu, sellunvalmistus, paperinvalmistus ja painotalo. Kahdeksaa asiantuntijaa haastateltiin. Sen tuloksena tutkimusaineistoksi saatiin 69 ympäristömyötäistä ja ympäristövaikutuksiltaan merkittävintä tekniikkaa. Tekniikat olivat ajanjaksoilta 1980-1999 ja 2000-2019. Niitä tutkittiin tekniikkaluokkiin jaoteltuina. Aineisto analysoitiin non-parametrisin tilastollisin menetelmin.

Automaatio-, mittaus- ja tietotekniikat, suljettujen kiertojen tekniikat ja energiatekniikat olivat kaikkein merkittävimpiä myönteisten ympäristövaikutusten kannalta ja myös kaikkein useimmin mainittuja ympäristömyötäisiä tekniikoita tutkimuksessa. Ympäristömyötäisiin tekniikoihin liittyvinä kustannustekijöinä raaka-aineet ja henkilöstö sekä erilaistamistekijöinä tuotemielikuva ja yritysmielikuva lisäsivät kaikkein eniten yritysten kilpailukykyä. Tutkituista kustannustekijöistä tekniikoihin käytetty pääoma vähensi kaikkein eniten yritysten kilpailukykyä. Ympäristön pilaantumista ennaltaehkäisevät tekniikat (pollution prevention technologies) syrjäyttävät päästöjenpuhdistustekniikat (pollution abatement technologies) ajanjaksolla 2000-2019. Koko tutkimusaineistoa tarkasteltaessa kilpailukykyvaikutuksilla ei havaittu olevan yhteyttä siihen, oliko tekniikalla lainsäädännöllisiä kannustimia vai ei. Kuitenkin merkittävästi kilpailukykyä heikentävien tekniikoiden havaittiin olevan useammin lainsäädännöllisten kannustimien vaikuttamina kuin muiden tutkittujen tekniikoiden. Raaka-aineiden ja luonnonvarojen käyttö oli kaikkein useimmin mainittu ympäristönäkökohta, jota tutkitut tekniikat hallitsivat ja tämä kehitys vahvistuu tulevaisuuden tekniikoissa ajanjaksolla 2000-2019. Kun tutkittiin ympäristömyötäisten tekniikoiden välisiä eroja painopaperin arvoketjun eri osissa, havaittiin, että tekniikat lisäsivät kilpailukykyä eniten painotaloissa ja vähensivät sitä eniten sellunvalmistuksessa. Arvoketjun osat eivät eroa toisistaan siinä, onko tutkituilla tekniikoilla lainsäädännöllisiä kannustimia vai ei. Puolella tutkituista tekniikoista oli vaikutuksia yritysten kilpailukykyyn myös muussa arvoketjun osassa.

Työssä tutkittiin ns. Porterin hypoteesin sitä osaa, jossa väitetään, että ympäristölainsäädännön tulee kannustaa yrityksiä ympäristön pilaantumista ennaltaehkäisevän tekniikan käyttöön lainsäädännöllisten vaatimusten täyttämisessä. Näin yritys saa kilpailuetua. Tutkimuksen tuloksena Porterin hypoteesi hyväksyttiin ainoastaan silloin, kun tekniikan kilpailukykyvaikutuksia yrityksissä arvioitiin henkilöstökustannuksilla. Muiden tekniikkaan liittyvien tekijöiden kilpailukykyvaikutuksia arvioitaessa Porterin hypoteesia ei voitu hyväksyä. Muut arvioidut kilpailukykytekijät olivat kustannustekijöinä raaka-aine, energia, pääoma ja muut kustannustekijät sekä erilaistamistekijöinä tuoteominaisuus, tuotemielikuva ja yritysmielikuva ja muut erilaistamistekijät. Tutkimuksen johtopäätöksenä voidaan todeta, että ympäristön pilaantumista ennaltaehkäisevät tekniikat eivät ole ainoa ratkaisu kilpailukyvyn tuottamiseen, vaan myös päästöjen vähentämisen tekniikat voivat lisätä kilpailukykyä. Lainsäätäjän kannalta tämä tarkoittaa, että yritysten kilpailukyvyn kannalta ei ole perusteltua pyrkiä laatimaan sellaisia säädöksiä, jotka nimenomaisesti kannustaisivat ympäristön pilaantumista ennaltaehkäisevän tekniikan käyttöönottoon. Ympäristölainsäädännön tulee kohdistua ympäristövaikutusten hallintaan eikä ympäristön pilaantumisen ennaltaehkäisyn mahdollisesti tuottamaan kilpailuetuun.

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The data collection of the study is based on interviews with eight professors in the industrial sectors of the value chain of printed paper. I am very grateful to the respondents for having provided their knowledge, expertise and time to my study.

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1 Introduction

The motivation of this study was to contribute to the discussion of the role of technology in solving environmental problems in companies. Society's demands on corporations related to their management of environmental issues have increased immensely during the past two or three decades. Technical solutions are one essential means to improve the environmental performance of corporations.

The importance of technology as a solution is obvious, but the motives of companies in investing in environmentally sound technology can vary from compliance to regulations and laws to gaining competitive advantage and value creation. The incentives for technology investments are either voluntary or based on environmental regulation. Any technology has an impact on the competitive advantage of companies; these impacts consist of various factors and extend over the value chain.

Very conflicting opinions have been presented of the effects on corporate competitiveness of implementing environmentally sound technologies and there is also great variation in research results related to this topic. As competitiveness issues are naturally vital to corporations and considering that there is no unanimity on the effects on competition of environmentally sound technologies, a more detailed analysis of the topic is desirable. This research topic adds to the theoretical knowledge of the effects on competitiveness of environmentally sound technology.

The value chain of printed paper was chosen as the focus of this study because, in recent years, the companies in the value chain of printed paper have faced diverse public criticism over environmental issues, such as forest biodiversity, use of elementary chlorine in bleaching, use of recycled fibre, use of energy, and the digital distribution of printed materials. With a view to solving these problems, many environmental technologies have been implemented and many are under development in this value chain.

This study provides new knowledge about what kind of environmentally sound technologies have economical benefits at the company level in the value chain of printedpaper. It focuses on environmentally sound technologies, not only on environmental technologies. This study also provides further information about those environmental aspects controlled by the technologies. It provides further understanding about environmentally sound technologies, the competitiveness of companies, and also the legal and other incentives at the company level. Incentives for investigating technologies were explored. The many previous studies have focused at the macro-economy level and do not draw a clear picture of competitiveness aspects inside companies. As well, these impacts vary according to industry sector and part of value chain. This study offers company managers further information about the competitiveness impacts of environmentally sound technologies inside the company and encourages solving environmental problems benefiting impacting factors other than the environment. The difference between the pollution prevention approach and pollution abatement approach was studied. Impacts of environmentally sound technologies on competitiveness of companies in the other part of the value chain than where the technology is positioned were studied as well.

The study assesses to some extent the validity of the so-called Porter Hypothesis at the company level. Porter (1991 a and b) argues that the right kind of legal pressure encourages competitiveness by adding benefiting environmental solutions at the company level. This study contributes to the discussion about this hypothesis by studying relationships involved in pollution-prevention technology and pollution-abatement technology, in legal incentives and in the competitiveness factors on companies. The results provide further knowledge to public regulators about the influences of environmental regulation inside companies and ideal solutions to the pressure of regulation. They also contribute to discussion of the impact of environmental regulation on the competitiveness of companies and the role of technology in meeting the pressures of regulation.

Data were collected from interviews with eight experts covering the value chain of printed paper from forest to market, which involves 69 technologies. The studied technologies cover the time periods 1980-1999 and 2000-2019. The importance of technologies for the environmental impacts was assessed, as well as their impacts on the competitiveness of companies. The relationships among various factors related to the technologies were explored using statistical tests.

2 Environmental Technology

Technology plays the role of solving problems in the context of the environment. In this chapter, environmental technology is presented as a relationship between technology and the environment; definitions are given of environmental technology and related concepts, including the pollution prevention and pollution abatement approaches. Technological development affects companies and the environment. It is a solution, but also causes harmful environmental impacts. This study focuses on existing and forthcoming technological changes.

2.1 Environment and Technology

Environment is defined as those surroundings, including air, water, land, natural resources, flora, fauna, humans and their interrelationship in which an organisation operates. The surroundings referred to in this context extend from within an organisation to the global system (Finnish Standards Association, 1996; International Organization for Standardization, 1998). Environmentalists have connected technology and environment. According to Hart (1997), nearly three decades ago, environmentalists, such as Paul Ehrlich and Barry Commoner, made this observation about sustainable development: 'The total environmental burden (EB) created by human activity is a function of three factors, namely population (P); affluence (A), which is a proxy for consumption; and technology (T), which is how wealth is created. The product of these three factors determines the total environmental burden. It can be expressed as a formula with the following equation (1).

$$EB = P \times A \times T \qquad (1)$$'

'*Technology is the application science, especially to industrial or commercial objectives, including the entire body of methods and materials used to achieve* *such objectives.' (Anonymous, 1995) 'It is important to draw a distinction between technology and technique, which means mechanical skill in art, skilful manipulation of situation, people, etc*.' (Anonymous, 1998)

'*Technological change is the driving force of development. Technological change increases the level of output resulting from automations and computerised methods of production. Apart from increasing output, technological change can affect the ratio of capital to labour used in factories*.' (Anonymous, 1998)

According to Ashford (1993), technological change is now generally regarded as essential in achieving the next major advantages in pollution reduction. Necessary technological changes must include: (1) the substitution of materials used as inputs, (2) process redesign, and (3) final-product reformulation.

2.2 Definitions of Environmental Technology and Related Concepts

The use of terminology concerning environmental technology has changed over the decades from green technology to environmental technology. At the beginning of the 90s, the term *green technology* was coined to refer to saving the environment as well as making profits (Marshall, 1993).

Environmental technology and engineering is the field of technology aiming to prevent and decrease the pollution of the environment (Tekniikan sanastokeskus, 1998). According to Shrivastava (1995), environmental technologies involve production equipment, methods and procedures, product designs, and product delivery mechanisms that conserve energy and natural resources, minimise the environmental load of human activities, and protect the natural environment. They include hardware and operating methods. They evolve both as a set of techniques (technologies, equipment, operations procedures) and as a management orientation. As techniques, they are used for pollution abatement, waste management, energy, water conservation and material conservation and for improving the technological efficiency of production.

Environmental technology involves pollution control devices and systems, waste treatment processes and storage facilities, and site remediation technologies and their components that may be used to remove pollutants or contaminants from the environment, or to prevent them from entering it (The National Safety Council, 2006) or, in brief, it involves equipment used for environmental protection (Kemira Corporation, 2006).

The elements of environmental technology can be described as in Figure 2.2.1 (Tekniikan sanastokeskus ry, 1998), where the major elements are pollution prevention, clean technology, end-of-pipe technology, source reduction, closed cycle and best available technology.

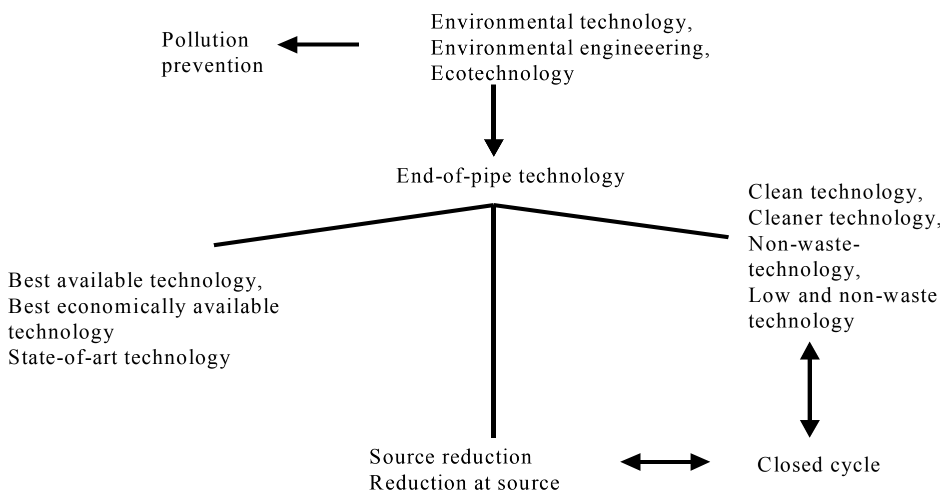

Figure 2.2.1 Elements of environmental technology (Tekniikan sanastokeskus ry, 1998)

A concept wider than environmental technology is environmentally sound technology. Environmentally sound technology is technology concerning environmental values and aspects (Tekniikan sanastokeskus, 1998).

Environmental investments are investments that protect and/or increase an economy's natural capital stock. These include investment in clean technology, although it is difficult to separate the environmental protection component from the productivity component (Markandya et al., 2001). A summary of definitions of environmental technologies is presented in Table 2.2.1.

Table 2.2.1 Summary of Definitions of Environmental Technology

Concept	**Definition**	**Author**
Environmental technology	A set of techniques and management orientation	Shrivastava, 1995
	Pollution control devices, systems, processes, facilities, remediation and their components	The National Safety Council, 2006
	Equipment used for environmental protection	Kemira Corporation, 2006
Environmentally sound technology	Technology concerning environmental values and aspects	Tekniikan sanastokeskus, 1998
Environmental investment	Protect and/or increase an economy's natural capital stock.	Markandya et al., 2001

The definition of environmental technology has many variations, and the term is internationally used. The definition of environmentally sound technology is broader and includes any technology having an impact on the environment. It is very well known in Finland, and is used in this study because the aim is to explore technologies that control environmental impacts.

2.3 Pollution-Prevention Technology

Environmental technology can also be categorised according to the type of technology as end-of-the pipe technology (cleaning and prevention) and preventive technology (prevention of pollution) (Keltanen and Salminen, 1993).

Pollution prevention is an approach of environmental technology. In this study, environmentally sound technologies were categorised as pollution prevention and pollution abatement.

The U.S. Environmental Protection Agency (EPA) developed a formal definition of pollution prevention for the *Pollution Prevention Act of 1990*. Pollution prevention means 'source reduction', as defined under the *Pollution Prevention Act*, and other practices that reduce or eliminate the creation of pollutants through '*increased efficiency in the use of raw materials, energy, water, or other resources, or protection of natural resources by conservation'* (U.S. Environmental Protection Agency, 2006).

Pollution prevention is also defined as an action aiming to prevent pollution beforehand (Tekniikan sanastokeskus, 1998). Prevention of pollution is the use of processes, practices, materials or products that avoid, reduce or control pollution, which may include recycling, treatment, process changes, control mechanisms, efficient use of resources and material substitution. The potential benefits of prevention of pollution include the reduction of adverse environmental impacts, improved efficiency and reduced costs (Finnish Standards Association, 1996, International Organization for Standardization, 1998). '*Pollution prevention or source reduction is product, process or equipment design that emits fewer pollutants to air, water and/or soil.*' (Salvendy, 2001) '*Pollution prevention can be accomplished by the methods of design, process changes, materials substitution, material reuse, resource efficiency and improved work practices'* (The Pacific North West Pollution Resource Center, 2006).

The U.S. *Pollution Prevention Act* defines '*source reduction'* as '*any practice, which reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and reduces the hazards to public health and the environment* *associated with the release of such substances, pollutants, or contaminants. The term includes equipment or technology modifications, process or procedure modifications, reformulation or redesign or products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control*' (U.S. Environmental Protection Agency, 2006).

Under the U.S. *Pollution Prevention Act*, recycling, energy recovery, treatment, and disposal are not included within the definition of pollution prevention. Some practices commonly described as 'in-process recycling' may qualify as such, however. Recycling that is conducted in an environmentally sound manner shares many of the advantages of prevention—it can reduce the need for treatment or disposal, and conserve energy and resources.

Definitions of technology related to pollution-prevention technology refer to cleaner technology and clean technology. Fry (1990) presented the pollution control hierarchy of clean technology, beginning from dirty technology, to cleaner technology, to technology with zero discharges of pollutants, as presented in Figure 2.3.1.

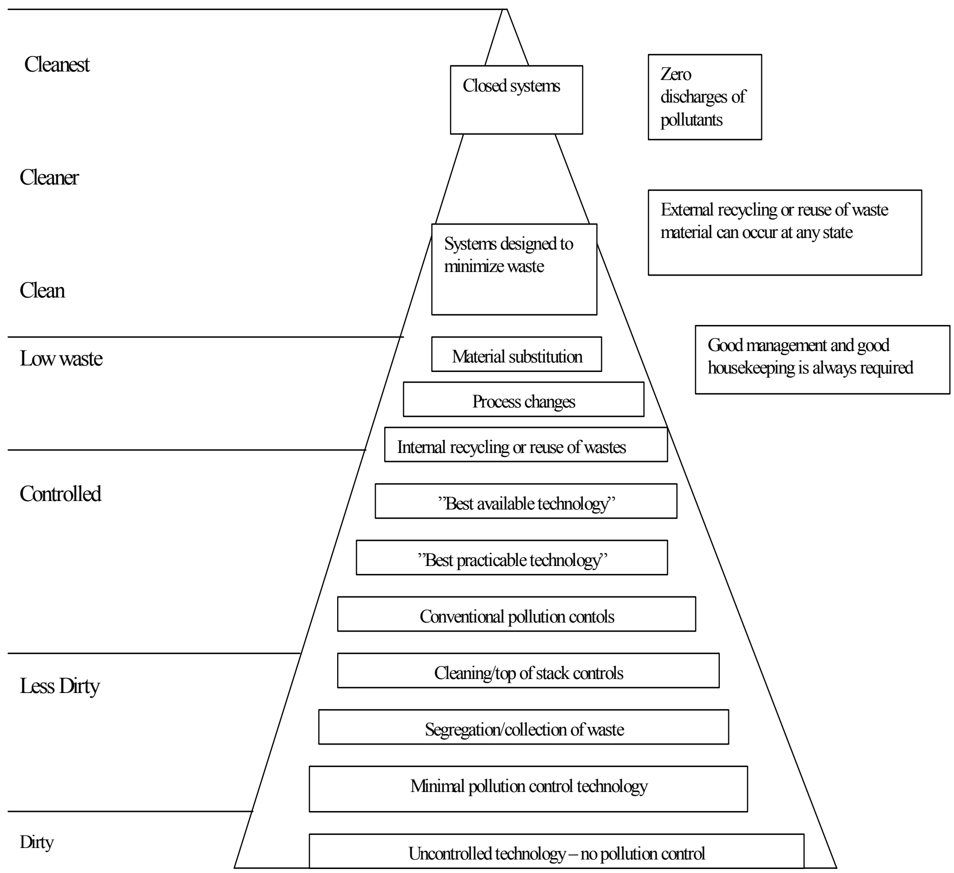

Figure 2.3.1 Hierarchy of pollution control (Fry, 1990)

According to Kemp (1993), the general term 'cleaner technologies' is preferred and is defined as '*all techniques, processes, and products that avoid or diminish environmental damage and/or the usage of raw materials, natural resources, and energy*.' Clean technology comprises input reduction or substitution, process-integrated changes that prevent pollution, recycling technology, and cleaner consumer products. Clean technology is preventive, whereas cleaning technology is curative (Kemp, 1993). Clean technology is environmental technology that aims to minimise environmental impacts, and to decrease the impacts of the use of raw materials and energy in the process (Tekniikan sanastokeskus, 1998).

Clean production is a comprehensive way to minimise the ecological damage caused by the design and consumption of products. Clean production offers a way to limit the unsustainable use of materials and energy. It is based upon the circular concepts of the product life cycle and uses a precautionary principle in approaching material selection and system and product design. It also aims to protect biological and social diversity (Markandya et al., 2001).

In addition to improving environmental quality, the benefits from the adoption of clean technology are said by the OECD to include an overall improvement in the production process, savings in raw materials and energy leading to increased profitability, a reduction in the cost of pollution abatement, the diffusion of new process-creating market opportunities and the further stimulation of innovation (Irwin and Hooper, 1992). Table 2.3.1 summarises the definitions of pollution prevention and related technologies.

Table 2.3.1 Summary of Definitions of Pollution Prevention and Related Technologies

Concept	Definition	Authors
Pollution prevention	Source reduction and other practices that reduce or eliminate the creation of pollutants. Does not include 'in-process' recycling.	The U.S. Environmental Protection Agency, 1990, www.umich.edu/nppcpub/p2defined.html, 30.1.2006
	Action aiming to prevent pollution beforehand.	Tekniikan sanastokeskus, 1998
	Use of processes, practices, materials or products that avoid, reduce or control pollution.	Finnish Standards Association, 1998
	Accomplished by the methods of design, process changes, materials substitution, material use, resource efficiency and improved work practices.	The Pacific North West Pollution Resource Center, 2006
Clean technology	Aiming to minimise environmental impacts, to decrease the effect of the use of raw materials and energy in the process	Tekniikan sanastokeskus, 1998
	Preventive comprises input reduction or substitution, process-integrated changes that prevent pollution, recycling technology, and cleaner consumer products.	Kemp, 1993
	An overall improvement in production process, savings in raw materials and energy leading to increased profitability, a reduction in the cost of pollution abatement	Irwin and Hooper, 1992
	Aiming to minimise environmental impacts, to decrease the effect of the use of raw materials and energy in the process.	Tekniikan sanastokeskus, 1998
Cleaner technology	All techniques, processes, and products that avoid or diminish environmental damage and/or the usage of raw materials, natural resources, and energy	Kemp, 1993

The definitions of clean technology and cleaner technology were in common use during the early 90s, but they were gradually replaced by definitions of pollution-prevention technology. The following definition of pollution prevention (Tekniikan sanastokeskus, 1998) was used in this study: '*pollution prevention is an action aiming to prevent pollution beforehand*'. In this study, 'in-process' recycling was included in the definition of the pollution prevention approach.

2.4 Pollution-Abatement Technology

The concept of pollution-abatement technology is used in this study. Other concepts similar to this are cleaning technology and end-of-pipe technology. Cleaning technology is environmental technology, which is conceptualised as being at the end of the process (Tekniikan sanastokeskus, 1998). Cleaning technology consists of end-of-pipe technology and treatment facilities, such as water treatment plants and waste facilities. Clean technology is preventive, whereas cleaning technology is curative (Kemp, 1993). End-of-pipe technology is a type of technology that reduces the pollution contained in waste products before they are emitted into the environment (Markandya et al., 2001).

According to Statistics Finland (2001), environmental protection investment by the industrial sector can be divided into end-of-pipe investment and process-integrated investment. End-of pipe investments consist of cleaners and other accessories or solutions that do not significantly alter the actual production process. Most end-of-pipe investments are made in clean-up equipment.

Pollution abatement takes the form of decreasing the daily load of air, water and soil pollution created by industrial and domestic man. When applied to industry, pollution abatement poses a difficult and often costly problem, because it involves either additional expenditures on control processes or abatement in the rate of production, or both (Sarnoff, 2001). As a definition, pollution-abatement technology is a technology 'designed to treat pollutants or reduce emissions of pollutants after they have been physically created' (Department of Agricultural Economics and Rural Sociology at Penn State University and International Agricultural Trade Research Consortium, 2006).

Oates et al. (1993) described the role of the abatement technology industry. The distinction between polluting industries and the abatement technology industry is, to some extent, a conceptual artefact. Clearly, various polluting industries can find themselves in the business of discovering, patenting and marketing new control techniques. The point is that it is conceptually useful to distinguish between the development and marketing of new abatement technology, and the production of goods and services that have polluting side effects. A summary of the definitions of pollution abatement and related technologies is presented in Table 2.4.1.

Table 2.4.1 Definitions of Pollution Abatement and Related Technologies

Concept	Definition	Author
Pollution-abatement technology	Designed to treat pollutants or reduce pollutants after they have been physically created	Department of Agricultural Economics and Rural Sociology at Penn State University and International Agricultural Trade Research Consortium, 2006
End-of-pipe technology	Reduces the pollution contained in waste products before they are emitted into the environment	Markandya et al., 2001
End-of-pipe investment	Consists of cleaners and other accessories or solutions that do not significantly alter the actual production process	Statistic Finland, 2001
Cleaning technology	Situated at the end of the process	Tekniikan sanastokeskus, 1998
	Consists of end-of-pipe technology and other treatment, curative technology	Kemp, 1993

The definitions of end-of-pipe technology and cleaning technology are very close to each other, but cleaning technology includes cleaning actions also. The definition of pollution-abatement technology is used in this study.

2.5 Best Available Technology and Other Related Definitions

The definition of best available technology (BAT) is very widely used to describe the level of environmental technology. It is an important concept in environmental regulation. A closely related concept is the best available technology not entailing excessive costs, abbreviated as BATNEEC.

A definition of the best available (environmental) technology (BAT) refers to the best solution in terms of the technical and economic aspects of the technology (Tekniikan sanastokeskus, 1998). ‘Best available techniques’ (Anonymous, 1996) or ‘best available technology’ (BAT) (Markandya et al., 2001) means ‘*the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing, in principle, the basis for emission-limit values designed to prevent and, where that is not practicable, generally reduce, emissions and the impact on the environment*.’

The phrase 'best available techniques or technology not entailing excessive cost' (BATNEEC) was first used in European Commission Directive 84/360 on the Combating of Air Pollution from Large Industrial Plants and the concept is included in the Integrated Pollution Prevention and Control (IPPC) regulations. BATNEEC makes explicit the economic considerations relevant to assessing 'best available techniques' (BAT). 'Not entailing excessive cost' suggests that cost should not be excessive when compared with the benefits of the environmental protection to be achieved (Markandya et al., 2001).

2.6 Other Categorisations of Environmental Technology

Environmental technologies can be categorised in many different ways, either according to the controlled environmental aspect, or the purpose of technology. The following categories are partly applied in this study in categorising data. Environmental technology is traditionally divided into four sectors: protection of air, water, soil and waste management. Also included are noise prevention, oil spill control, radiation safety, as well as health and safety at work. Since the various sectors of the environment constantly interact, there is currently a shift from the sector division to a broader-based overall approach to the environment (Keltanen and Salminen, 1993).

Environmental Business International, Inc. (1996) has developed an industry segmentation method that divides the environmental market into three broad categories: services, equipment, and resources. The category of equipment includes instrument manufacturing, water equipment and chemicals, air pollution control equipment, waste management equipment and process and prevention technology. The environmental industry may be regarded as consisting of the broad areas (Higgins, 1996a) of solid waste handling and control, air pollution technology and control, water and wastewater treatment, land management and resource conservation, environmental health and safety, green products and services and energy alternatives and energy conservation.

The types of processes (or technologies) offered or used by environmental companies vary from simple physical ones (e.g. the settling of dissolved solids in wastewater in a pond) to highly sophisticated chemical and thermal ones (e.g. high temperature gas phase reduction of toxic wastes). Environmental processes and technologies may be arbitrarily categorised as physical, chemical and thermal (Higgins, 1996b). Environmental protection equipment and infrastructure is generally classified in European statistics as the '*protection of airborne and climate, wastewater management, waste management, protection of soil and groundwater and prevention of noise*' (Tilastokeskus, 2002).

Helmut Kaiser Consultancy (1991) presented opportunities and risks for the industry in the area of environmental technology. In their environmental technology product portfolio, the following categories of environmental technology were presented: measurement, process control and analysis; solid waste and hazardous waste and recycling technologies, sanitation of contaminated sites; noise reduction technologies; operation; energy conservation; air quality control; water purification; effluents clarification plants, and consulting, engineering and services.

2.7 Summary of Environmental Technology

Environmentally sound technology is the technology concerned with environmental values and aspects (Tekniikan sanastokeskus, 1989). The pollution prevention approach aims to prevent pollution beforehand (Tekniikan sanastokeskus, 1989). The U.S. Environmental Protection Agency does not include 'in-process' recycling in the pollution prevention approach (Environmental Protection Agency, 1990). The concepts of pollution-prevention technology and clean technology are very close to each other. Pollution-abatement technology is a technology designed to treat pollutants or reduce emissions of pollutants after they have been physically created (Department of

Agricultural Economics and Rural Sociology, 2006). The meaning of end-of-pipe technology is identical.

Environmentally sound technology is not very widely used as a definition of environmental technology, but it is used as such in this study. It includes clearly both pollution prevention and pollution-abatement technologies. The environmental technology can be seen as a narrower concept than environmentally sound technology. The definition of environmentally sound technology is better for the purpose of this study because the focus of this study is on the technologies controlling environmental impacts.

Helmut Kaiser Consultancy (1991) presented a portfolio of environmental technologies including the following: air quality control, water purification, effluents clarification plants, energy conservation, consulting and engineering services, solid waste and hazardous waste and recycling technologies, operation noise reduction technologies, sanitation and contaminated sites, measurement, process control analysis. These categories guided in some extent the categorising of the environmentally sound technologies in this study.

3 Economic Success of Companies and Environmental Issues

Profit is a measurement of economic success of a company. Companies achieve higher profits through value creation, which are affected by differentiation and cost advantage. In this chapter, relationships between economic success and environmental performance are presented. Studies of a connection between profitability and environmental performance are reviewed. In this study, profitability and value creation caused by the environmentally sound technologies and measured by competitive advantage of cost and differentiation are explored. Eco-efficiency links value creation and environmental performance, but environmental performance is not measured in this study. The definitions of competitiveness and competitive advantage are studied, as well as their connections to environmental performance. The term *environmental value creation* is defined. The measurement model of this study, including cost advantage and differentiation advantage, is based on the literature.

3.1 Profitability and Environmental Performance

The discussion of the relationship between profitability and environmental performance has been going on since the 1970s. The definition of profitability is the profit earned by a firm in relation to the size of the firm, measured in terms of total assets employed, long-term capital or number of employees (Pass et al., 2003).

Bragdon and Marlin (1972) concluded that, at least in the pulp and paper industry, there is a strong correlation between companies with a good record in pollution control and companies with a good profit record. They explained the relationship in terms of the lower costs associated with better pollution control or of differences in management ability.

Grant (1991) introduced the resource-based theory of competitive advantage. He argued that the key to a resource-based approach to strategy formulation is an understanding of the relationships between resources, capabilities, competitive advantage, and profitability. A firm's ability to earn a rate of profit in excess of its cost of capital depends upon two factors: the attractiveness of the industry in which it is located, and its establishing a competitive advantage over its rivals. Figure 3.1.1 shows a connection between rate of profit and competitive advantage divided into cost advantage and differentiation advantage. Cost advantage is impacted by process technology; the size of plants and access to low-cost inputs and differentiation advantage is impacted by brands, product technology and marketing, and distribution and service capabilities. All these factors are explored in this study, with the exception of size of plants.

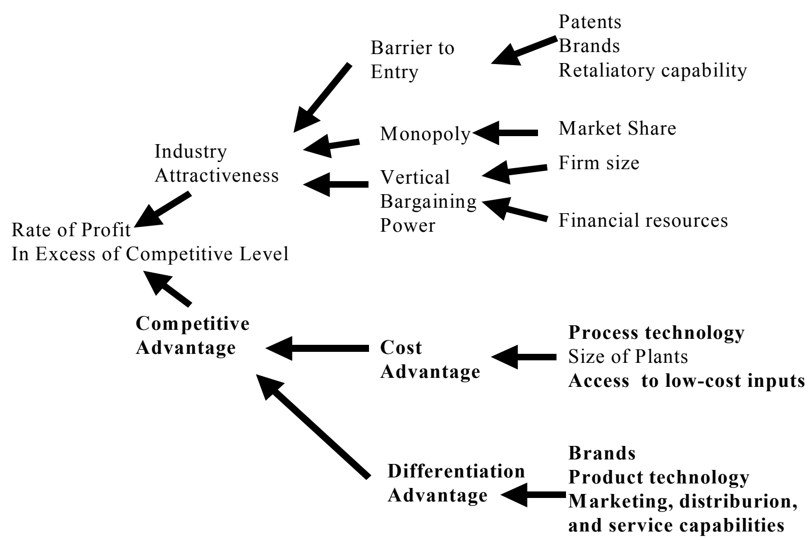

Figure 3.1.1 Resources affecting profitability (Grant, 1991)

Drawing on the resource-based view of the firm, Russo and Fouts (1997) stated that environmental performance and economic performance are positively linked and that the industry growth moderates the relationship, with returns to environmental performance higher in higher-growth industries. They tested these hypotheses with an analysis of 243 firms over two years, using independently developed environmental ratings. Results indicated that ‘it pays to be green’ and this relationship strengthens with industry growth. Their study stated that higher environmental performance is associated with higher financial performance, and that this relationship is strengthened as industry growth rises.

Jaggi and Freedman (1992 a) studied the impact of pollution performance on economic and market performance in thirteen pulp and paper firms in the U.S. The results of the study provide evidence that the markets are not rewarding good pollution performance of the firms. The results of the negative association between environmental performance and economic performance suggest that, in the short run, the firm's profitability will be negatively affected by pollution abatement activities involving heavy expenditures. The market's reaction on an overall basis to pollution performance has also been negative. This negative market reaction obviously ignores the expected better profitability in the long run resulting from positive counter-balancing effects of pollution abatement activities. Freedman and Jaggi (1992) studied the economic impact of pollution performance from the micro long-run perspective of periods of six and nine years. As a result, they reported that firms were not negatively impacted economically by abating water pollution in their pulp and paper mills.

Hart and Ahuja (1994) studied whether emission reduction and pollution prevention had a positive impact on the bottom line of *Standard and Poor's 500 Index of Corporations* in 1989-1993. They found that efforts to prevent pollution and reduce emissions appear to drop to the ‘bottom line’ within one to two years after initiation. They argued that poor environmental performance might affect a firm’s cost of capital. Their results also suggest that the marginal costs of reducing emissions do not exceed marginal benefits. The data suggest that a strategy to reduce emissions does not negatively impact the bottom line, even among those firms that have already drastically reduced emission levels.

Hart and Arbor (1996) examined empirically the relationship between emission reduction and firm performance for a sample of *Standard and Poor's 500 Index of Corporations*. Their results indicate that efforts to prevent pollution and reduce emissions drop to the 'bottom line' within one to two years of initiation, and that those firms with the highest emission levels stand to gain the most.

Klassen and McLaughlin (1996) proposed a theoretical model that links environmental management and performance to the financial performance of the firm, as measured by stock market performance. In Figure 3.1.2, the cost pathways from environmental management to improved financial performance are shown, together with the role of technology. Environmental management affects both structural and infrastructure components, as it involves choices of product and process technology and underlying management systems. Product technology includes the use of recycled raw materials or post-consumer recycling. Process technology includes more efficient product systems, such as 'end-of-pipe' control technology and preventative barriers. Management system encompasses programs, such as continuous monitoring of any process discharges, worker training and environmental audits. Environmental performance is affected by all these choices (Figure 3.1.2). Market gains and cost savings are focused on in this study.

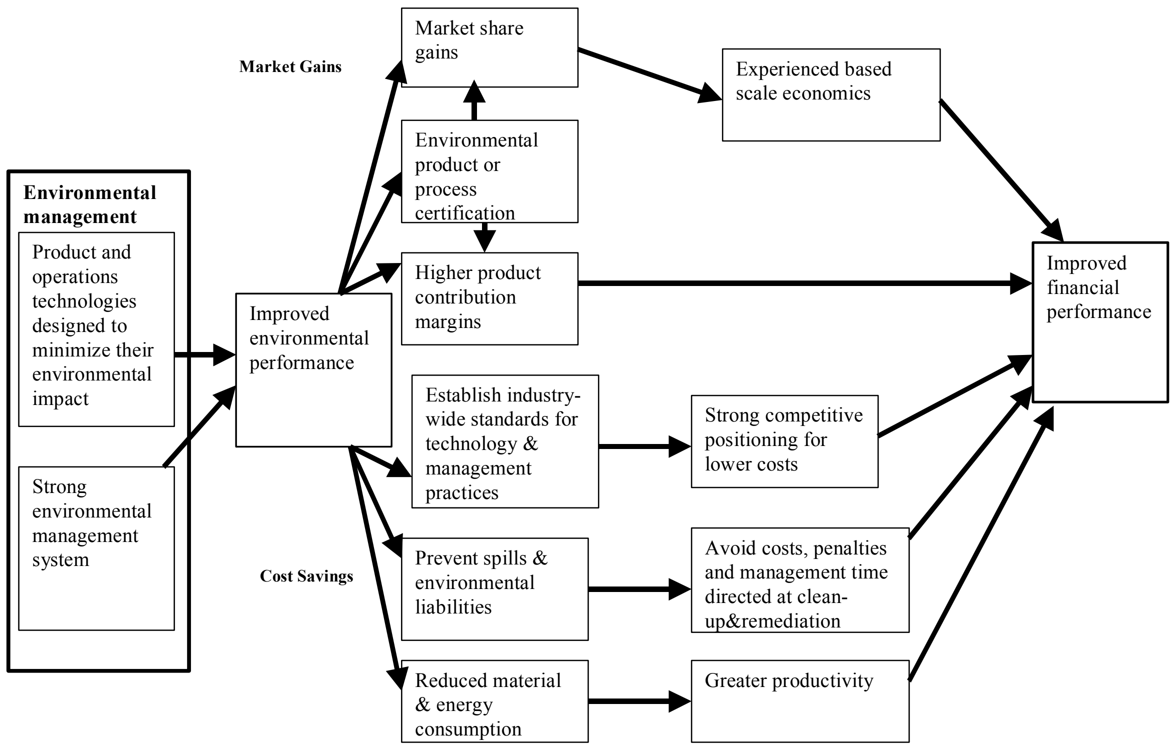

Figure 3.1.2 Cost pathways from environmental management to improved financial performance (Klassen and McLaughlin, 1996)

Cohen et al. (1997) studied the relationship between financial and environmental performance of *Standard and Poor's 500 Index* companies. They showed statistically that firms that perform well on environmental dimensions also perform well financially, but they did not ask which comes first. Aupperle et al. (1985) studied empirically the relationship between corporate social responsibility and profitability, and they did not find any relationship between them in their survey of corporate CEOs.

Norwegian managers perceive environmental initiatives as having a positive effect on economic goals, except for short-term profit, where the actions have no influence. Environmental actions are considered to have the greatest positive influence on the corporate image, the product image and on long-term profit. (Ytterhus, 1997)

Lankoski (2000) analysed the firm-level relationship between environmental performance and economic performance, and showed that the firm-level relationship between environmental and economic performance takes the form of an inverted U-shaped function of environmental performance, and varies from firm to firm based on the six main determinants of environmental profit. The determinants are technology, discount rate, regime, benchmarks, visibility and willingness to pay. Table 3.1.1 presents studies of economic performance and environmental performance: topic, author, data collection, indicator and research method, main result and connection between economic and environmental performance.

Table 3.1.1 Studies of Economic Performance and Environmental Performance: Author, Topic, Data Collection, Indicators, Research Method, Main Result and Connection Between Economic and Environmental Performance.

Author	**Topic**	**Data Collection, Indicators and Research Method**	**Main Results**	**Connection Between Economic and Environmental Performance**
Bragdon and Marlin, 1972	Is Pollution Profitable? Environmental Virtue and Reward: Must Stiffer Pollution Controls Hurt Profits?	Pulp and paper industry, 17 companies, profits and pollution records compared in the time period 1965-70, rank correlation method used	A strong correlation between companies with good records in pollution control and companies with a good profit record.	Positive
Russo and Fouts, 1997	A Resource-Based Perspective on Corporate Environmental Performance and Profitability	Data from ratings of Franklin Research and Development Corporation (243 industrial firms) of years of 1991 and 1992. Variables of return of assets, firm growth rate, advertising intensity, firm size, capital intensity, industry concentration, industry growth rate, environmental rating. Descriptive statistics and correlation used.	Environmental performance and economic performance are positively linked and that industry growth moderates the relationship with the returns to environmental performance higher in high-growth industries.	Positive
Freedman and Jaggi, 1992	An Investigation of the Long-run Relationship Between Pollution Performance and Economic Performance: The Case of Pulp and Paper Firms	Pulp and paper industry (13 firms) in the time period of 1978-1986, water pollutants as environmental indicator, economic performance of profits and cash flows, percentage changes tested by Spearman rank correlation coefficients, time perspective of six and nine years tested.	Firms were not negatively impacted economically by abating water pollution in their pulp and paper mills in six and nine years time horizon.	No negative connection
Jaggi and Freedman, 1992	An Examination of the Impact of Pollution Performance on Economic and Market Performance: Pulp and Paper firms	Pulp and paper industry (13 firms and 81 plants), pollution index including water pollutants, and economic and market indicators of net income, return equity, return of assets, cash flow/equity, cash flow/assets, Pearson Correlation test for the three different time periods 1975-77, 1978 and 1978-80	The economic performance is negatively associated with pollution performance over short period time.	Negative connection
Hart and Arbor, 1996	Does it Pay to be Green? An empirical Examination of the Relationship between Pollution Prevention and Firm Performance	Firms of *Standard and Poor's 500 Index* of manufacturing, mining or production companies (127 firms) and their data from Responsibility Research Centre's Corporate Environmental Profile and Compustat. Operation performance data, financial performance data. Multiple regression analysis used.	Efforts of pollution prevention and reduce emissions drop to the `bottom line´ within one to two years of initiation and that those firms with the highest emission levels stands the most to gain.	Positive
Cohen et al., 1997	Environmental and Financial Performance: Are They Related?	*Standard and Poor's 500 Index*, portfolios of lowest polluting firms (189) and highest polluting firms (104), environmental performance variable and financial performance variable, data from the time period of 1987-1991, statistical tests	Firms that perform well on environmental dimensions also perform well financially.	Positive
Aupperle et al., 1985	An Empirical Examination of the Relationship between Corporate Social Responsibility and Profitability	Survey of corporate CEOs	No relationship between corporate social responsibility and profitability	No connection
Ytterhus, 1997	Norwegian Business Environmental Barometer	Environmental barometer	Environmental initiatives have a positive effect on the economic goals at the greatest, for example, on long-term profit.	Positive
Lankoski, 2000	Determinants of Environmental Profit, An analysis of the firm-level relationship between environmental performance and economic performance.	Mathematical model, statistic analysis of 108 manufacturing plants, 11 case studies.	The firm-level relationship between environmental and economic performance takes the form of invert U-shaped function of environmental performance.	Positive and negative

Economic performance and environmental performance are mainly positively linked in previous studies, but also negative connections exist. Industry growth seems to impact on the relationship, with the returns to environmental performance higher in higher-growth industries. The negative connection between them is found in the short term after initial adoption of the pollution prevention approach.

3.2 Competitiveness of Companies and Environmental Performance

The economic success of a company is measured by its profitability. The factors involved in the competitiveness of the companies impact on this. The actions concerning environmental performance are linked to factors of competitive advantage. The dimensions of the competitive-advantage strategy are cost advantage and differentiation, but also focus. The competitiveness of a company and related concepts, as well as the connections of these concepts to environmental performance, are presented in this chapter.

Day (1998) presented three tiers of business benefit from business sustainability: process efficiency, product enhancement and market positioning. Process efficiency investments are generally low-risk and high-yield. However, cost savings do not 'grow' a company. Potential gains are much greater for product enhancement growth, which refers to additional returns gained with the introduction of new processes or products. The final tier of business value from sustainability is market positioning and development for a world of increasingly stringent constraints. Companies will be forced to meet higher standards of environmental and social performance in order to maintain their right to operate. Accordingly, forward-looking companies may try to anticipate these constrains and strategically position themselves beforehand, thus gaining 'first mover' advantages. This study focuses on competitive advantage created by environmentally sound technologies.

3.2.1 Definitions of Competitiveness of Companies and Related Concepts

Competitiveness usually refers to characteristics that permit a firm to compete, perhaps internationally, effectively with other firms due to low cost or superior technology (Deardorff, 2000, 2001). The term is often used to describe the overall economic performance of a nation (van der Linde, 1993; Anonymous, 1998; Bannock, Baxter and Davis, 1998). Competitiveness is a country or region's ability to maintain and raise the productivity with which it employs its scarce resources, capital and labour relative to other countries and regions (van der Linde, 1993).

Competitive advantage is any situation, price structure, or customer convenience that gives one market an advantage over another (Anonymous, 1995). Competitive advantage is a group of factors that gives a company an advantage over its rivals. For companies marketing similar products, one may achieve a competitive advantage by creative design and memorable advertising, innovative package design, or superior distribution methods (Anonymous, 1998). The generic building blocks of competitive advantage are efficiency, quality, innovation, and customer responsiveness (Hill and Jones, 1999). Reed and De Fillippe (1990) argue that there is substantial agreement within the literature on the price, cost, and differentiation definition of competitive advantage.

Efficiency, quality, customer responsiveness, and innovation are all important elements in obtaining a competitive advantage. Superior efficiency enables a company to lower its costs, while superior quality lets it both charge a higher price and lower its costs. Superior customer responsiveness allows it to charge a higher price, while superior innovation can lead to higher prices and lower unit costs. Together, these four factors help a company create more value by lowering costs or differentiating its products from those of its competitors, which enables the company to outperform them. Figure 3.2.1.1 illustrates the roots of competitive advantage (Hill and Jones, 1999).

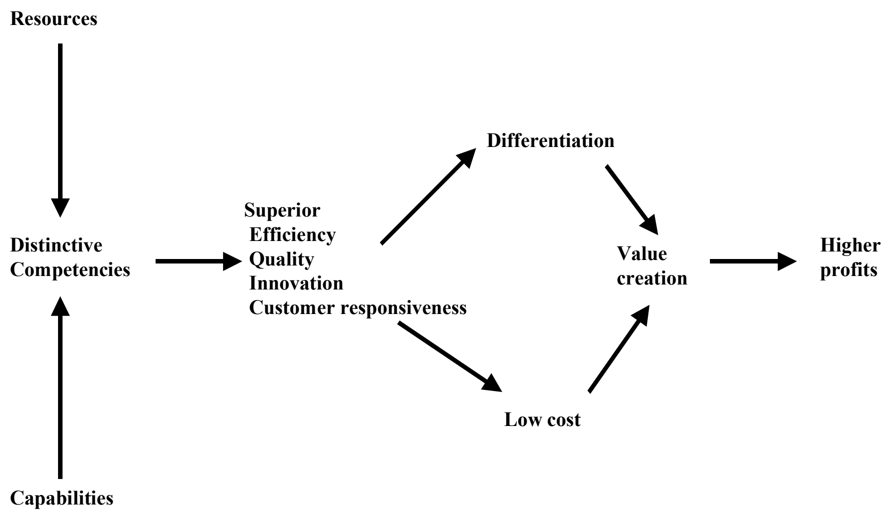

Figure 3.2.1.1 Roots of competitive advantage (Hill & Jones, 1999)

In this study, *competitiveness of company* is used as a synonym for competitive advantage. Cost advantage and differentiation are measured in this study.

3.2.2 Environmental Value Creation and Eco-efficiency

For this study, a term—'*environmental value creation'*—was defined. '*Value creation'* is defined as '*performing activities that increase the value of goods and services to consumers'* (www.enbv.narod.ru/text/econom/str/261.html,30.1.2006). '*Environmental aspect*' refers to an element of an organisation's activities or products or services that interact with the environment (SFS-EN ISO 14001, 2004). In this study, '*environmental value* creation' is defined as '*performing activities by managing environmental aspects so that the value of goods and services to consumers or to customers increases*.'

Emerson (2003) presented the concept of *blended value creation*. It includes economic, social and environmental value creation. Loucks and Gorman (2004) reviewed ecosystem services and the rating of investment opportunities. They presented the concept of environmental value creation through investment (EVCI), which is the research method of rating the value of ecosystem services enhanced (or put at risk) by a range of company products or production processes.

Schaltegger and Sturm (1990) presented the definition of eco-efficiency as a sum of inputs (for example materials and energy) and desirable outputs (products) divided by a sum of impacts of undesirable outputs (wastewater, emissions to air, solid waste) and transportation. According to the World Business Council (WBCD, 1996), a key feature of eco-efficiency is that it harnesses the business concept of creating value and links it with environmental concerns. The goal is to create value for society, and for the company, by doing more with less over a life cycle. By promoting change toward sustainable growth, eco-efficiency enables a company's business to grow in a qualitative way by adding value, while reducing adverse environmental impact. It also signals a significant shift in focus to concentrate on real customer needs. This emphasis on creating and adding value is clearly to society's benefit. Further, it matches the changing dynamics of the marketplace. Consumers want higher quality and increased value at lower cost. This trend is likely to develop, and companies that report annually on their environmental performance will be rewarded in the marketplace.

According to Markandya et al. (2001), eco-efficiency as a term describes patterns of production that exploit the positive correlation between economic efficiency and ecological efficiency. That is, the achievement of eco-efficiency involves continuing to produce goods and services that satisfy customer needs at competitive prices, while reducing the environmental resources used in, and the environmental damage caused by, their production. A measure of eco-efficiency would be the ratio of the value of goods and services produced to the environmental inputs used and damage associated with the production. Specific means by which eco-efficiency can be improved include reducing the materials and energy used to produce goods and service, limiting waste emissions from the production process, maximising the potential for recycling, and maximising the sustainable use of renewable resources.

Helminen (1998) developed an eco-efficiency index and tested it with a population of 31 Finnish and 37 Swedish pulp, paper and board mills in 1993–1996. Her results suggested that Swedish mills are somewhat more eco-efficient than their Finnish counterparts in all valuation methods. The Finnish mills seem to be more eco-efficient in integrated wood-free paper, solid bleached sulphate board and liquid packaging board. However, the small number of mills in these grade categories limits the possibility of generalising the results.

As a summary, the term *eco-efficiency* (World Business Council, 1996, Markandya et al., 2001) and the term *environmental value creation* in this study are close in meaning to each other. The goal of eco-efficiency is to create value for society, and for the company. The goal of environmental value creation is to create value for the company's products and services by managing environmental aspects. According to Markandya et al. (2001), a measure of eco-efficiency would be the ratio of the value of goods and services produced to the environmental inputs used and damage associated with the production. The concept of eco-efficiency is not specifically explored in this study, because the value for society was measured only by putting the environmentally sound technologies in order of importance of environmental impact. Instead of that, it measured value creation and economic performance of environmentally sound technologies.

3.2.3 Competitive Advantage and Environmental Performance

'Competitive advantage' is a widely used term. Here it is presented in the context of environmental performance. According to Turner et al. (1993), there are at least four reasons why industry can gain from adopting a strong environmental stance. These are efficiency (material, energy, labour, capital), image (causing better market share and employers), market opportunity (end-of pipe and source reduction equipment) and compliance (avoiding non-compliance costs). These factors are used as part of the measurement frame in the empirical part of the study.

Porter's (1985) generic competitive strategy model suggest three alternatives reflecting the basis of competition and the extent of the market coverage a company pursues: cost leadership, differentiation and focus. Peattie (1995) applied Porter's ideas of strategic approaches to environmental issues as follows:

- Cost leadership. Greening (referring here to the environment) is not associated with a cost-leadership strategy because of the general, but often mistaken, assumption that improved environmental performance involves a cost burden. Increasing opportunities to reduce costs by reducing resource inputs, and the increasing costs of poor environmental performance will push the issue of greening up the agenda for low-cost strategies of the future (Peattie, 1995).
- Differentiation. Mass-market products, which are differentiated from those of the competition on the basis of superior eco-performance, are becoming increasingly widespread. Switching to compete on the basis of eco-performance can have a miraculous effect on company strategy (Peattie, 1995).
- Focus. A focus strategy involves targeting a product, which is differentiated or low in cost in a particular segment of the market. In the early days of environmental marketing, the lack of mass consumer interest in green issues limited most green companies to a focus strategy. Many green products have moved on to gain mass-market acceptance. Others, such as green investment products, are still targeted at specific segments of the market (Peattie, 1995). Figure 3.2.3.1 presents generic strategies for green competitive advantage.

Competitive Advantage

Market Scope	Low cost	Differentiation
Broad	Green cost leadership	Eco-excellence
Narrow	Green cost focus	Green nichemanship

Figure 3.2.3.1 Generic strategies for green competitive advantage (Peattie, 1995)

Hart (1995) developed a theory of competitive advantage based upon the firm's relationship to the natural environment. It included three interconnected strategies: pollution prevention, product stewardship and sustainable development. Propositions are advanced for each of these strategies regarding key resource requirements and their contributions to sustain competitive advantage. Hart (1995) argues that one of the most important drivers of new resource and capability development for firms will be the constraints and challenges posed by the natural (biophysical) environment.

Bansal and Roth (2000) studied why firms are ecologically responsive by identifying their motivations and their context. In the competitive profile, the interaction between individual concern and low field cohesion promotes a mixed motive of ecological responsibility and competitiveness, and this mixed motive results in potentially high responsiveness. As individual concerns are translated into initiatives motivated by ecological responsibility, a firm is additionally motivated by competitive advantage. When field cohesion is low, competitors do not recognise the firm's ecological responsiveness as a competitive threat. Competitors do not respond to the initiatives, nor are they inclined to mimic the firm, given the institutional context. The firm can then develop a strategic niche in which it distinguishes itself as a green alternative. This combined interest in competitiveness and ecological responsibility often leads to innovations that would not otherwise be realised. Innovations result in more ecologically benign products or processes for which there are gains in efficiency or marketing, or products or processes that are superior in other ways.

According to Bansal and Roth (2000), competitiveness is the potential of ecological responsiveness to improve long-term profitability; according to respondents in their study, ecological responses that improved competitiveness included energy and waste management, source reductions resulting in a higher output for the same inputs (process intensification), ecolabelling and green marketing, and the development of 'ecoproducts'.

Cost Advantage and Environmental Performance

'*There are two major ways that a firm can gain a cost advantage: control cost drivers and reconfigure the value chain. Once a firm has identified its value chain and diagnosed the cost drivers of significant value activities, cost advantage grows out of controlling those drivers better than competitors*.' (Porter, 1985)

Sorsa (1994) investigated trade flows in environmental-sensitive goods (incl. pulp and paper, paperboard) and environmental expenditures in seven industrial countries, all claiming to adhere to high environmental standards—Austria, Finland, Norway, Sweden, Germany, Japan, and the United States—during the period 1970-1990. The results note that i) environmental expenditures are a small share of total expenditures and therefore unlikely to cause shifts in comparative advantages in most industries on their own; ii) differences in environmental expenditures among industrial countries seem to be minor; iii) environmental expenditures are concentrated in a few basic industries, which are under strong pressure for structural change from the international division of labour; iv) energy use and environmental expenditures are closely linked; and v) positive adjustment what revealed comparative advantage in environmental-sensitive goods were more pronounced in countries where environmental policies encourage investment rather than current expenditures.

In this study, the competitiveness impacts of environmentally sound technologies were measured through the operating costs of raw material, energy, staff, and miscellaneous other costs.

Operating Costs

There are four major ways that a company's pollution control investment can reduce operating costs, and two other ways that profits might be increased (Bragdon and Marlin, 1972):

1) lower costs of raw material inputs per unit of production
2) lower labour costs, resulting from improvements in morale, performance, health, lower turnover, and reduced health insurance premiums;
3) lower taxes and legal costs
4) lower costs for plant and equipment purchase and maintenance;
5) lower financial costs
6) higher revenues from the sale of by-products that had formerly been discharged as waste, from the sale of regular products to new customers who had switched from companies that pollute, and from the sale of recycled products

The concept of resource productivity opens up a new way of looking at both the full systems costs and value associated with any product. Resource inefficiencies are most obvious within a company in the form of incomplete material usage and poor process controls, which result in unnecessary waste, defects, and stored materials. But there are also many other hidden costs buried in the life cycle of the product; for example, packaging discarded by distributors or customer's wastes resources and adds to costs. Customers bear additional costs when they use products that pollute or waste energy. Resources are lost when products that contain usable materials are discarded and when customers pay—directly or indirectly—for product disposal. The level of resource productivity, environmental improvement and competitiveness come together (Porter and van der Linde, 1995).

According to Day (1998), process efficiency has clear short-term benefits on the firm, primary in the form of waste reduction. By reducing costs, process efficiency gains in that firms can lower their immediate impact on the environment and establish a cost advantage. According to Turner et al. (1993), there are efficiency factors relating to material, energy, labour and capital that help explain why industry can gain from adopting a strong environmental stance.

Capital Costs

Florida's (1996) survey collected data on the share of capital expenditures that firms earmark specifically to pollution prevention. He studied 450 manufacturing firms from *Standard and Poor's (S&P) Index* including 250 larger firms, 100 mid-sized firms and 100 small firms. The survey results indicate that pollution prevention expenditures are a significant component of overall capital expenditures. The overwhelming majority of respondents allocate between one and 10% of their total capital expenditures to pollution prevention, with more than eight in ten (84.6%) of respondents reporting pollution prevention expenditures in this range. A significant proportion of respondents, however, provide a greater share of their capital expenditures to pollution prevention. According to the survey data, one in six respondents earmarks more than 10% of total capital expenditure to pollution prevention. Furthermore, only a small fraction of respondents (0.6%) reported that they do not allocate any capital expenditures to pollution prevention.

Boyd and McClelland (1999) measured how environmental constraints account for differences between plant-level efficiency and whether simultaneous improvements in environmental performance and productivity are feasible in integrated paper mills. They found that abatement-capital spending lowers productivity by squeezing out other investments, while overall environmental constrains lower potential productivity. In this study, the competitiveness impacts of capital cost were assessed. Table 3.2.3.1 presents the summary of cost-advantage factors of raw material, energy, staff, capital and other costs, and author and findings concerning them.

Table 3.2.3.1 Summary of Cost-Advantage Factors of Raw Material, Energy, Staff, Capital and Other Costs, Authors and Findings Concerning Them

Measured Variable in This Study	**Author**	**Findings**
Raw material	Bragdon and Marlin, 1972	Lower costs of raw material inputs per unit of production.
	Turner, 1993	Efficiency factor of material can be gained from adopting a strong environmental stance.
	Porter and van der Linde, 1995	Material usage as resource inefficiency, stored materials, defects, wastes.
	Day, 1998	Process efficiency in the form of waste reduction.
Energy	Turner, 1993	Efficiency factor of energy can be gained from adopting a strong environmental stance.
	Sorsa, 1994	Energy use and environmental expenditures are closely linked.
	Porter and van der Linde, 1995	Waste energy.
Staff	Bragdon and Marlin, 1972	Lower labour costs, resulting from improvements in morale, performance, health, lower turnover, and reduced health insurance premiums.
	Turner, 1993	Efficiency factor of labour can be gained from adopting a strong environmental stance.
	Sorsa, 1994	Environmental expenditures are concentrated in a few industries that are under strong pressures for structural change from the international division of labour.
Capital	Bragdon and Marlin, 1972	Lower costs for plant and equipment purchase.
	Turner, 1993	Efficiency factor of capital can be gained from adopting a strong environmental stance.
	Florida, 1996	Pollution prevention expenditures are a significant component of overall capital expenditure.
	Boyd and McClelland, 1999	Abatement capital spending lowers productivity by squeezing out other investments and overall environmental constrains lower potential productivity.
Other costs	Bragdon and Marlin, 1972	Lower taxes and legal costs, plant and equipment maintenance, lower financial costs.

Differentiation Advantage and Environmental Performance

Differentiation advantages impacted by environmentally sound technologies were studied in the empirical part of this study. According Porter (1985), a firm differentiates itself from its competitors when it provides something unique that is valuable to buyers beyond simply offering a low price. Differentiation leads to superior performance if the price premium achieved exceeds any added costs of being unique. A firm's differentiation may appeal to a broad group of buyers in an industry or only to a subset of buyers with particular needs. Differentiation stems from the specific activities a firm performs and how they affect the buyer. It grows out of the firm's value chain. Virtually any value activity is a potential source of uniqueness. For example, sources of differentiation can take the form of procurement of raw materials, technology development, operation activities or the breadth of its activities. Raising the performance of industrial, commercial or institutional buyers can also be based on helping them meet their non-economic goals, such as status, image, or prestige. For products sold to consumers, raising buyer performance will be a function of better satisfying needs (Porter, 1985).

Product differentiation is a change in the appearance or presentation of a product to make consumers believe that it is different from similar products. This differentiation is undertaken to give the producer to some extent the power of a monopolist with a unique product. The concept is at the heart of the theory of monopolistic competition, but, in practice, it occurs most frequently in oligopolistic industries (Rutherford, 1992).

The significance of product differentiation in economic theory is that, by relaxing the assumption of product homogeneity under perfect competition, each supplier may create an opportunity to depart from the market price, charge a premium for his product and make greater profits. Under conditions of perfect competition, this supplier would sell nothing if he raised the price above market levels; with differentiation, he may be able to build up some loyalty from his customers. The means by which suppliers differentiate their products may involve improved product performance and innovation, advertising and packaging. In business economics, differentiation is seen as one of two important strategic directions, the other being leadership through volume sales and low cost (Bannock, Baxter and Davis, 1998).

Lahti-Nuuttila (2000) studied the features on the environmental competitiveness of the Finnish paper industry. Competitiveness was divided into resource leadership and environmental differentiation. In his study, the strategy of environmental differentiation meant affirming stakeholders or minimising environmental costs by means other than those related to resource leadership. These means can be found from the physical, communicational, operational or cultural sections of the company's activities. As examples of environmental differentiation in the paper industry, he mentioned non-chlorine bleaching in chemical pulping or use of recycled paper, both of which are included in this study. As a conclusion, it was suggested that the corporate culture of the Finnish paper industry includes features that complicate the opportunities for winning competitive advantage through environmental differentiation.

In this study, the differentiation advantage factors of environmentally sound technologies were measured, too. The factors were product characteristics, product image and company image.

Product Characteristics and Product Image

As early as 1972, Bragdon and Marlin (1972) argued that it is possible to earnhigher revenues from the sale of by-products, which have formerly been discharged as waste, from the sale of regular products to new customers who have switched from companies that pollute, and from the sale of recycled products.

Klassen and McLaughlin (1996) present how the financial performance of the firm is affected by strong environmental performance through both market (revenue) and cost pathways, which is presented in Figure 3.1.2. On the revenue side, customers show preferences for environmentally oriented companies.

Manufacturers who demonstrate efforts to minimise the negative environmental impacts of their products and processes, recycle post-consumer waste, and establish environmental management systems are poised to expanded their markets or displace competitors that fail to promote strong environmental performance. Norwegian managers' environmental actions are considered to have the greatest positive influence on product image (Ytterhus, 1997).

In the study of Bansal and Roth (2000), several respondents indicated that, if environmental science was more definitive in assessing the ecological impacts of alternative activities, and if consumers were more demanding, then they would more likely show greater ecological responsiveness. Shrum et al. (1995) constructed a psychographic profile of the green consumer. The result shows that the green consumer is rather sceptical of advertising. The implication is that green consumers may be receptive to green marketing and advertising, but marketers should take care not to alienate them by using ambiguous or misleading messages. Vandermerwe and Oliff (1990) discuss the impacts of the 'green' movement on business, as it becomes an integral element of consumer demand. Shrivastava (1995 b) assumed that there was a large and growing segment of consumers who want ecologically friendly products, packaging and management practices. These 'green' consumers are drawn to companies that genuinely use sustainable practices. Scerbinski (1991) mentions recycled non-toxic paper products as an example of products for environment-conscious consumers.

Company Image

The regulated industries are not only affected by new regulatory requirements; pressure on firms to improve their environmental performance may also come from various groups within society. These might include the following: competitors, environmental sector, labour, financial sector, media, green pressure groups, customers and consumers (Spengler, 1998). Henriques and Sadorsky (1996) found that a firm's formulation of an environmental plan is positively influenced by customer pressure, shareholder pressure, government regulatory pressure and neighbourhood and community group pressure, but negatively influenced by other lobby-group pressure sources and a firm's sales-to-asset ratio. Polonsky (1995) has discussed how environmental marketing strategy can be improved by the four-step stakeholder management process. Kemp (1993) argued that a bad environmental reputation may have a negative effect on the company's sales and may lead to personnel problems. However, such stimuli are still rather weak.

Miles and Covin (2000) found that there is strong support for being a good environmental steward, and that this helps create a reputation advantage that leads to enhanced marketing and financing. The forest-products industry was presented as an example. Klassen and McLaughlin (1996) studied the role of environmental management in the financial performance of a firm from the reputation point of view. They found that the first-time environmental award announcements—a sign of a good reputation—were associated with greater increases in market valuation, although smaller increases were observed for firms in environmentally dirty industries, possibly due to market scepticism.

Ganzi (1997) illustrated thoughts of the financial sector about environmental performance and financial performance. However, a company that minimises its use of natural resources, institutes good housekeeping measures, minimises fugitive emissions, and reduces exposure of workers and consumers to toxic materials is keeping both its costs and potential liabilities down, which should eventually show up in its bottom line or net income. Conversely, a company that invests a lot in pollution prevention or potential investors may see control equipment as cash-poor and unprofitable. Konar and Cohen (2000) reported a study that relates the market value of firms in the *Standard and Poor's 500 Index* (omitting non-polluting industries) to objective measures of their environmental performance. The primary objective of the study is to explore the relationship between firm-level environmental performance and intangible assets. After controlling for the effect of a number of variables on firm-level financial performance, it was found that poor environmental performance has a significant negative effect on the intangible asset value of publicly traded firms that belong to the S&P 500. However, firms that have better environmental reputations have higher intangible assets. The effect of environmental litigation on intangible asset value tends to be economically insignificant in most industries. The effect of toxic emission levels tends to be both statistically and economically significant (Konar and Cohen, 2000). According to Papmehl (2000), linking corporative image with good corporate citizenship through effective communication of sustainable development initiatives enhances a company's competitive edge.

Graves and Waddock, (1994) hypothesised that institutions invest more heavily in companies with strong corporate social performance (CSP). Their analysis indicated a significant positive relationship between social performance and the number of institutions holding the shares of a company and a positive, but insignificant, relationship between social performance and the percentage of shares held by institutions. Later, the same study (Waddock and Graves, 1997) reported the results of a rigorous study of the empirical linkages between financial and social performance. Corporate social performance is found to be positively associated with prior financial performance, supporting the theory that slack resource availability and CSP are positively related. CPS is also found to be positively associated with future financial performance, supporting the theory that good management and CSP are positively related. .

Cormier and Magnan (1997) investigate how investors assess the financial implications of a firm's environmental performance, as measured by its pollution record relative to existing regulations and found that a firm's poor environmental performance reduces its stock-market valuation, thus implying the existence of implicit environmental liabilities.

Bansal and Roth (2000) developed testable propositions for a model of corporate ecological responsiveness. In terms of salient characteristics, interviewees in Bansal and Roth's study (2000) were motivated by competitiveness and perceived that their ecological responsiveness led to sustained advantage and hence improved their long-term profitability. Reputation, process efficiencies and product reliability were developed through green marketing, source reductions and process intensification, and new capital equipment. Some respondents also indicated that it was easier to hire quality employees if a firm had a better reputation. Competitively motivated firms engaged in activities that are more visible to improve their corporate environmental reputations. These activities served to enhance the firm's competitive advantage (Bansal and Roth, 2000). Mendleson and Polonsky (1995) present aspects of strategic alliances to develop credible green marketing. Table 3.2.3.2 presents a summary of the differentiation—advantage factors of product characteristic, product image and company image, author and the findings concerning them.

Table 3.2.3.2 Summary of Differentiation Advantage Factors, Authors and Findings Concerning Them

Measured Variable in This Study	**Author**	**Findings**
Product characteristic	Bragdon and Marlin, 1972	Higher revenues from the sale of by-products, which have formerly been discharged as waste, from the sale of regular products to new customers who have switched from companies that pollute, and from the sale of recycled products.
	Vandermerwe and Oliff, 1990	Green movement on business becomes an integral element of consumer demand.
	Shrivastava, 1995 b	Growing segment of consumers who want ecologically friendly products.
	Klassen and McLaughlin, 1996	Financial performance of the firm is affected by strong environmental performance through market (revenue).
	Bannock et al., 1998	Product performance, packaging.
Product image	Ytterhus, 1997	Environmental actions are considered to have the great positive influence on the product image.
	Bansal and Roth, 2000	If consumers were more demanding, producers would more likely to show greater ecological responsiveness.
	Shrum et al., 1995	A psychographic profile of the green consumer shows that green consumer is rather sceptical of advertising.
Company image	Kemp, 1993	A bad environmental reputation may have a negative effect on the company's sales.
	Klassen and McLaughlin, 1996	First-time award announcements were associated with greater increases in market valuation, although smaller increases were observed for firms in environmental dirty industries, possibly indicative of market scepticism.
	Henriques and Sadorsky, 1996	A formulation of environmental plan is positively influenced by stakeholders.
	Graves and Waddock, 1994; Waddock and Graves, 1997	A significant positive relationship between social performance and number of institutions holding the shares of a company. Pollution control equipment included.
	Ganzi, 1997	Financial sector sees environmental actions of companies cash-poor and unprofitable, but also net income producing.
	Bansal and Roth, 2000	Ecological responsiveness lead to sustained advantage and improved long-term profitability.
	Miles and Covin, 2000	Good environmental steward helps to create a reputation advantage that leads to enhance marketing and financing.
	Konar and Cohen, 2000	Poor environmental performance has a significant negative effect on the intangible asset value of publicity traded firms.
	Papmehl, 2000	Linking corporative image with good corporate citizenship through effective communication of sustainable development initiatives enhances a company's competitive edge.

3.3 Summary of Economic Success and Environmental Performance

Profitability is a result of value creation, which is to be formed of cost advantage and differentiation. Competitive advantage is a group of factors that gives a company an advantage over its rivals. Competitive advantage can be achieved through cost leadership, differentiation advantage or focus (Porter, 1985).

Environmental performance of a company and good records of profitability have a positive association according to many studies (Bragdon and Marlin, 1972; Russo and Fouts, 1997; Cohen et al., 1997; Ytterhus, 1997). There are also studies in which has been found a negative association between them (Jaggi and Freedman, 1992) or no negative association (Freedman and Jaggi, 1992) or positive and negative association (Lankoski, 2000).

In this study, environmental value creation is defined as performing activities by managing environmental aspects so that the value of goods and services to consumers or to customers increase Eco-efficiency means joint value creation for society and company. It links the goals of business excellence and environmental excellence (World Business Council for Sustainable Development, 1996). Helminen (1998) developed the eco-efficiency index for testing the Scandinavian pulp and paper industry.

Cost advantage is affected by process technology, size of plants and access to low-cost inputs. There are two major ways that a firm can gain a cost advantage: control cost drivers and configure the value chain (Porter, 1985). Pollution control investment can reduce operating costs through lower costs of raw material, labour, taxes and legal costs, or costs for plant and equipment purchase and maintenance. Profits might be increased by the sale of by-products (Bragdon and Marlin, 1972). Pollution prevention expenditures are a component of overall capital expenditures (Florida, 1996). In this study, the competitiveness impacts of environmentally sound technologies through factors of raw material, energy, staff, capital and other costs were measured. The category of 'other costs' consists of taxes, legal costs, plant and equipment maintenance and financial cost. As a summary, it may be said that environmental performance concerning the raw material factor consists of efficiency in the use of material, production of waste and costs relating to materials (Turner, 1993; Porter and van der Linde, 1995; Day, 1998). The energy factor consists of energy efficiency, waste energy and the connection between energy use and environmental expenditure (Turner, 1993; Porter and van der Linde, 1995; Sorsa, 1994). Environmental performance concerning labour lowers costs resulting from performance in morale, performance, health, lowers turnover and reduced health insurance premiums (Bragdon and Marlin, 1972). Environmental expenditures are concentrated in a few industries, which are under strong pressures for structural change from the international division of labour (Sorsa, 1994). Pollution prevention expenditures are a significant component of overall capital expenditure (Florida, 1996). Abatement allocates capital to lower productivity investments, but also lowers costs for plant and equipment purchase (Boyd and McClelland, 1999).

Differentiation advantage is affected by brands, product technology, marketing, and distribution and service capabilities. A growing segment of consumers wants ecologically friendly products, packaging and management practices (Shrivastava, 1995 b, Bansal and Roth, 2000). Environmental actions are considered to have the great positive influence on the product image (Ytterhus, 1997). Reputation advantage is enhanced by environmental performance (Kemp, 1993). A bad environmental reputation may have a negative effect on the company's sales and may lead to personnel problems (Bansal and Roth, 2000). Linking corporative image with good corporate citizenship through effective communication of sustainable development initiatives enhances a company's competitive edge (Papmehl, 2000).

4 Environmental Technology and Company Competitiveness

A role of environmental technology in the economic success of a company is the focus of this study. This chapter includes the review of studies concerning environmental technology and competitiveness of company.

What technological change can impact on the competitiveness of companies? According to Porter (1985), technological change by a firm will lead to a sustainable competitive advantage when the technological change itself lowers cost or enhances differentiation, when the firm's technological lead is sustainable, and when the technological change shifts cost or uniqueness drivers in favour of a firm. These statements concerning environmental technology are explored in this study by measuring cost and differentiation impacts. Porter (1985) continues that, when the technological change improves overall industry structure, sustainable competitive advantage can be achieved through technological change.

The technology employed in a value activity is not itself a cost driver, but rather an outcome of the interplay of cost drivers. Scale, timing, location, and other drivers shape the technology employed in combination with the policy decisions a firm makes. The relationship between technology and the cost drivers is important in determining the feasibility of technological changes (Porter, 1985). The latest relationship is examined in this study.

New technology often supports cost advantage. Technology can also allow a firm to make its competitor's advantages vis-à-vis cost drivers obsolete. Some of the important ways in which technology investment lowers costs include developing low cost processes, facilitating automation and low-cost product designs (Porter, 1985).

Ulph (1994) examined the argument that if, instead of spending resources on abatement, firms had to allocate resources to research and development in order to discover some new 'environmentally friendly' technology with lower levels of emissions, then the strategic incentives of governments to engage in environmental policy might be reversed, and that they might now be overeager to impose environmental policy, because, by doing so, they would force firms in their country to innovative ahead of rivals, and this could give them a competitive advantage.

4.1 Environmental Technology and Competitive Advantage

Environmental Technology and Cost Advantage

Freedman and Jaggi (1992 b) found that the pulp and paper firms were not negatively impacted economically by abating water pollution in their mills. These results do not support the expectation that there would be a negative impact on the economic performance from pollution abatement activities of the firms.

Florida's (1996) survey results indicated that manufacturing firms are adopting new technologies and manufacturing systems to achieve joint improvements in environmental and industrial performance. He studied 450 manufacturing firms from *Standard and Poor's (S&P) Index*, including 250 larger firms, 100 mid-sized firms and 100 small firms. The firms strongly favour source reduction, recycling, and production process improvement over treatment and end-of-pipe control technology. Large fractions of 212 respondents indicated that they use source reduction (89.6%), recycling (85.8%), and production process improvements (77.7%) as main elements of their pollution prevention strategies. Significantly smaller percentages report the use of control technology as a main element of their pollution prevention efforts, with 36% reporting treatment and 25% reporting end-of-pipe technology as main elements of their pollution prevention strategy. Overall, the survey responses indicated that, instead of simply treating wastes with end-of-pipe technology, firms are investing in new manufacturing process technology, which simultaneously prevents pollution and increases productivity (Florida, 1996).

Kemp (1993) carries out theoretically and through evidence an economic analysis of cleaner technology. He explored the factors that promote and obstruct use of cleaner technologies and developed a theory of environment-saving technological change. In case studies, he identifies factors that also influence the decision to adopt cleaner technology beyond government regulation. The cases are chlorofluorocarbons (CFC) substitutes, low-solvent paints and coatings and membrane technology in the metal-plating industry. These influencing factors are price and quality of the innovation, transfer of knowledge about environmental problems and the alternative technologies and information and risk and uncertainty surrounding the adoption of the technology.

According to Kemp (1993), price and quality, meaning the technical characteristics of the innovation, determine to a large extent costs and benefits of adoption of cleaner technology and its attractiveness to a potential user. The cost elements may involve the cost of purchasing the technology, implementation costs, financing costs, and operating costs. Benefits may involve improvement of the firm's public image and consumer satisfaction.

It appears (Kemp, 1993) that the purchase price of a cleaner technology is often not the most important factor. A switch to another technology implies a simultaneous change in the number of financial and non-financial systems and measures of costs and benefits. As a result of the decision-making surrounding, a switch to a cleaner technology is often complex. However, this does not mean that price ratios will not play a role at some point in the decision-making process.

Kemp (1993) assumed that environment-saving technological change should be viewed in a manner similar to that of normal technological change.

Environment-saving technological change is an endogenous process, driven by economic demand and supply factors that are embedded in environmental and technical opportunities and socio-institutional relations. Just like other innovations, cleaner technologies have to compete with existing production modes and products, either directly or indirectly. There is one important difference, however: actors in the economic process do not receive appropriate signals from the market.

Klassen and Whybark (1999 a) explored the impact of environmental technologies on manufacturing performance. Their sample was seven furniture plants from the U.S. Environmental Protection Agency database. Data was collected from personal interviews with managers. Environmental technologies were classified as either pollution-prevention technologies, comprising product and process adaptation, management systems, or pollution control technologies comprising remediation and end-of-pipe technologies. Of greatest importance, significantly better manufacturing performance was found in those plants where management investment in the environment portfolio was increasingly allocated toward pollution-prevention technologies. In contrast, performance worsened as the proportion of pollution control technologies increased. Similar results were found for cost, speed, and flexibility performance. The major exception was quality performance, where no relationship was found, possibly because a relatively short two-year period was studied. Finally, environmental performance, measured in terms of the release and transfer of toxic chemicals, also improvements as a higher proportion of portfolio investment was allocated toward pollution-prevention technologies. In this study, competitiveness impacts of pollution prevention and pollution abatement are explored.

Klassen and Whybark (1999 b) studied environmental management in operations and the selection of environmental technologies. They developed a basic conceptual model of environmental management within operations. The model proposes that the general orientation of operations managers on environmental issues ranges from proactive to reactive, and this is intrinsically related to the investment pattern in environmental technologies. Results from empirical validation of this model are presented for a sample plants from the furniture industry. Three distinct groups were identified on the basis of the linkage between environmental management orientation and investment in environmental technologies. These groups are system analysis and planning, organisational responsibility, and management controls. Contrary to the prescriptive environmental literature, which recommends that proactive orientation should emphasise pollution prevention (i.e., fundamental product and process changes), proactive managers implemented a balanced portfolio that also included a sizable proportion of pollution control technologies (i.e., traditional end-of-pipe technologies and remediation).

Shrivastava (1995) explains the concept of 'environmental technologies' as a competitive force and a tool for competitive advantage. Integrating environmental technology into strategic management offers a lot of competitive advantage, but also faces many barriers. The advantages are cost reduction, revenue enhancement by a growing market for environmental products and technologies, supplier ties, competitive edge, reduction of liabilities, social and health benefits, public image, and keeping ahead of the regulatory curve. Despite the barriers in individual companies, environmental technologies are being adopted widely and are collectively affecting the competitive landscape.

Chung et al. (1997) introduced a performance measure that credits the reduction of undesirable outputs, such as pollution, while simultaneously crediting increases in desirable outputs. The new index, called Malmquist-Luenberger index, which also accounts for reduction of pollutants, can be decomposed into two parts: efficiency change and technological change. The productivity in the Swedish pulp and paper mills in 1986-1990 was measured by the new index. This result shows that the productivity in that industry has improved on average over the entire time period. The main source of the productivity improvements is technological advance rather than efficiency improvement. In fact, technical efficiency fell throughout the period, except 1987/1988 (Chung et al., 1997).

Table 4.1.1 presents a summary of cost-competitiveness factors, author, topic, type of technology and findings.

Table 4.1.1 Summary of Cost-Competitiveness Factors, Authors, Topics, Types of Technology and Findings

Measured Variable in This Study/ Author	Topic	Type of Technology	Findings
Cost factors			
Porter, 1985	Competitive Advantage Creating and Sustaining Superior Performance	Technological change in general	Technological change by a firm will lead to sustainable competitive advantage under the circumstances of the technological change itself lowers cost
Kemp, 1993	An economic analysis of cleaner technology: theory and evidence	Cleaner technology	The influencing factors of decision-making of environment-saving technological change for clean technology are prize and quality of innovation. The cost elements may involve the cost of purchasing the technology, implementation costs, financing costs, operating costs.
Florida, 1996	Lean and Green. The Move to Environmental Conscious Manufacturing.	Environmental technology	Instead of treating wastes with end-of-pipe technology, firms are investing in new manufacturing process technology, which simultaneously prevents pollution and increases productivity.
Anonymous, 1998		Technical change in general	Technical change can affect ratio of capital to labour.
Shrivastava, 1995	An economic analysis of cleaner technology: theory and evidence	Cleaner technology	The cost elements of cleaner technology may involve the cost of purchasing the technology, implementation costs, financing costs, operating costs.
Klassen and Whybark, 1999 a	Impact of environmental technologies on manufacturing performance	Pollution prevention	Better manufacturing performance has been found in those plants where management investment in the environmental portfolio was increasingly allocated toward pollution-prevention technologies
Klassen and Whybark, 1999 a	Impact of environmental technologies on manufacturing performance	Pollution abatement	Manufacturing performance worsened as the proportion of pollution control technologies increased in portfolio of environmental technology
Klassen and Whybark, 1999 b	Environmental Management in Operations: the Selection of Environmental Technologies	Pollution prevention and pollution-abatement technology	Proactive managers implemented a balanced portfolio that also included a sizable proportion of pollution control technologies.
Freedman and Jaggi, 1992 b	An Investigation of the Long-run Relationship Between Pollution Performance and Economic Performance	Abatement activities	The results do not support the expectation that there would be a negative impact on the economic performance from pollution abatement activities of the firms.
Chung et al., 1997	Productivity and Undesirable Outputs: A Directional Distance Function Approach	Technological change	Pollution reducing technological advantage was source of productivity improvements rather than efficiency improvement in the Swedish pulp and paper mills 1986-1990.
Capital			
Kemp, 1993	An economic analysis of cleaner technology: theory and evidence	Cleaner technology	The purchase price is often not the most important factor in decision-making in cleaner technology.

Environmental Technology and Differentiation Advantage

Kemp (1993) studied cases of cleaner technologies. He argues that market demand seems to be the crucial factor for the successful exploitation of technological opportunities. Market demand depends strongly on government policy. Although there are other stimuli, such as pressure from local communities, the work force, investors, insurance companies, special environmental interest groups, and the larger public, these stimuli are still not very strong.

Shrivastava (1995) presents revenue improvements at the competitive edge as an implication of strategic management and argues that environmental technologies also offer companies the potential for creating unique and inimitable strategies. They can also allow entry into a growing market of environmental products and technologies. He presents implications for strategic management and argues that environmental technologies are also good for public relations and corporate image. They help companies to establish a social presence in their markets, and gain social legitimacy.

Nehrt (1996) found the case among pulp manufacturers that some customers may prefer products made from less pollution-intensive manufacturing processes, or products that are themselves less pollute when consumed or disposed of. Firms that can offer such products may find sales higher as a result. For instance, in the chemical bleached paper pulp industry, Europe (particularly Germany) has recently been willing to pay more for chemical paper pulp that has been bleached with reduced chlorine or with none at all.

According to Hart et al. (2000), companies can anticipate and invest in tomorrow's technologies. Clean technology requires fundamental changes that dramatically reduce the use of harmful materials or processes. In pursuing clean technology programs, firms allocate resources to incorporate environmental factors as parts of their R&D and technology developed processes. This strategy requires new ways of designing or manufacturing products and can help firms to leapfrog the competition, especially in emerging markets that require large, new capital investments. Table 4.1.2 presents a summary of differentiation-competitiveness factors, authors, topics, types of technology and findings.

Table 4.1.2 Summary of Differentiation-Competitiveness Factors, Authors, Topics, Types of Technology and Findings

Measured Variable in This Study/ Author	Topic	Type of Technology	Findings
Differentiation impacts, general			
Porter, 1985	Competitive Advantage Creating and Sustaining Superior Performance	Technological change	Technological change by a firm will lead to sustainable competitive advantage when the technological change itself enhances differentiation.
Kemp, 1993	An economic analysis of cleaner technology: theory and evidence	Cleaner technology	Benefits may involve improvement of firm's public image and consumer satisfaction.
Shrivastava, 1995	Environmental technology and competitive advantage	Environmental technology	Revenue improvements of competitive edge seen as an implication of strategic management; argument that environmental technologies also offer companies the potential for creating unique and inimitable strategies and advantages of supplier ties.
Hart et al., 2000	The business sustainable forestry: Meshing operations with strategic purpose	Clean technology	Clean technology programmes require new ways of designing or manufacturing products and can help in emerging markets that require large, new capital investment.
Product characteristic and product image			
Kemp, 1993	An economic analysis of cleaner technology: theory and evidence	Cleaner technology	Benefits of cleaner technology may involve improvement of consumer satisfaction.
Nehrt, 1996	Timing and intensity effect of environmental investments	Cleaner technology	The case among pulp manufacturers that some customers may prefer products made from less polluting-intensive manufacturing processes, or products that are themselves less pollute, when consumed or disposed of. Firms that can offer such products may find sales higher as a result.
Shrivastava, 1995	Environmental technology and competitive advantage	Environmental technology	Advantage of revenue enhancement of environmental products and technologies, the potential for creating unique and imitable strategies. They can also allow entry into growing market of environmental products and technologies
Company image			
Kemp, 1993	An economic analysis of cleaner technology: theory and evidence	Cleaner technology	Benefit of clean technology may involve public image.
Shrivastava, 1995	Environmental technology and competitive advantage	Environmental technology	Advantage of public relations and corporate image

4.2 Barriers to Adopting Environmental Technology and First-Movers

Most non-regulatory barriers to technological change can be categorised as follows: technological, financial, labour-force related, regulatory, consumer related, supplier related and/or managerial (Ashford, 1993). Pittman (1981) studied the relative efficiencies of different institutional arrangements for pollution control and the implications of control requirements for economies of scale and barriers to entry by modelling inputs and outputs of 30 paper mills in Wisconsin and Michigan, USA. He found that any pollution control regime has some negative effects in this industry. Treatment requirements increase the minimum size of plant, thus increasing barriers to entry and exacerbating any lack of competition on the industry. There are several barriers to the adoption of environmental technology (Shrivastava, 1995): cost of developing solutions, lack of know-how and environmental information; organisational inertia is another barrier to implementing environmental technologies, and multiple, sometimes contradictory, regulation of environmental issues sometimes acts as a barrier to action.

Many firms do not adopt cleaner techniques because of uncertainty and associated technical and economic risks. The adoption of a particular technique may require change in production routines and the organisation of work. Firms differ in their risk attitudes and in their perceptions of technical and economic (Kemp, 1993). The many barriers to introducing cleaner production to small- and medium-sized enterprises can be broadly classified into two categories: internal barriers and external barriers. The internal barriers are those limitations inherent in the SME itself and include the management barrier and the organisational barriers. External barriers include the technology barrier and the enforcement barrier. These external barriers must be removed by external agencies (Lin, 1997).

Nehrt (1996) examined the investment timing and intensity conditions under which advantage may exist for first movers in environmental investments of 50 chemical bleached paper-pulp manufactures in eight countries. He found an indication for a positive relationship between timing of investments and profit growth; for example, earlier investments in extended delignification equipment are positively and significantly associated with net income growth.

4.3 Summary of Environmental Technology and Competitiveness of Companies

Any of the technologies involved in a firm can have a significant impact on competition. A technology is important for competition if it significantly affects a firm's competitive advantage or industry structure. Technology affects competitive advantage if it has a significant role in determining relative cost position or differentiation (Porter, 1985). The competitive advantages of integrating environmental technology into strategic management will result in, for example, cost reduction and quality improvement, competitive edge and public image (Shrivastava, 1995).

Environmental-saving technological change should be viewed in a similar manner as a normal technological change. It is an endogenous process, driven by economic demand and supply factors that are embedded in an environment of technical opportunities and socio-institutional relations. An important difference compared with other technologies is that environmental technological change depends to a large extent on government regulation (Kemp, 1993). In the short term, the transition to cleaner technologies can lead to high costs and serious adjustment problems for adopters (Kemp, 1993).

Pollution-abatement technology decreases manufacturing performance, while pollution prevention investments lead to better manufacturing performance (Klassen and Whybark, 1999). About technical change, we know that it can have an affect on the ratio of labour to capital (Anonymous, 1998). The price of investment in cleaner technology has not as important a role as it has on decision-making (Kemp, 1993). There is no specific knowledge about cost advantage impacts of raw material, energy and staff factors controlled by the environmental technologies that are explored in this study.

Technological change can lead to sustainable competitive advantage when it itself enhances differentiation. Cleaner technology is supposed to improve the public image of the company because it can create unique and inimitable strategies, but also consumer satisfaction. It can result in an advantage for public relations and corporate image (Shrivastava, 1995). For instance, the customers of paper pulp manufacturers have respected chlorine-free paper production (Nehrt, 1996). There is no specific knowledge about how pollution prevention and pollution-abatement technologies differ in terms of differentiation factors. The connections among environmentally sound technologies and competitive advantages in terms of costs and differentiation are not very well understood. This study focuses on these factors.

5 Value Chain of Printed Paper

Technologies impact on value activities and on the value chain. This chapter includes definitions of *value chain*, a description of the major parts of the value and production chain of printed paperprinted-paper from forest to market, and impacts of technology and environmental performance on the value chain.

The term 'value chain' refers to the idea that a company is a chain of activities for transforming inputs into outputs that customer's value. The process of transforming inputs into outputs comprises a number of primary and support activities. Each activity adds value to the product (Hill and Jones, 1999). The value-added chain (Pass et al., 1995) is a chain of vertically linked activities that each adds value in producing and distributing a product. Strategically, where a firm 'positions' itself in the value-added chain, an industry can have an important bearing on its profitability, since different activities in the chain may generate different levels of profitability.

The value chain of printed paper consists of activities in forest harvesting, pulp mill, paper mill and printing house. Figure 5.1 presents the main parts of the value chain of printed paper from forest to market.

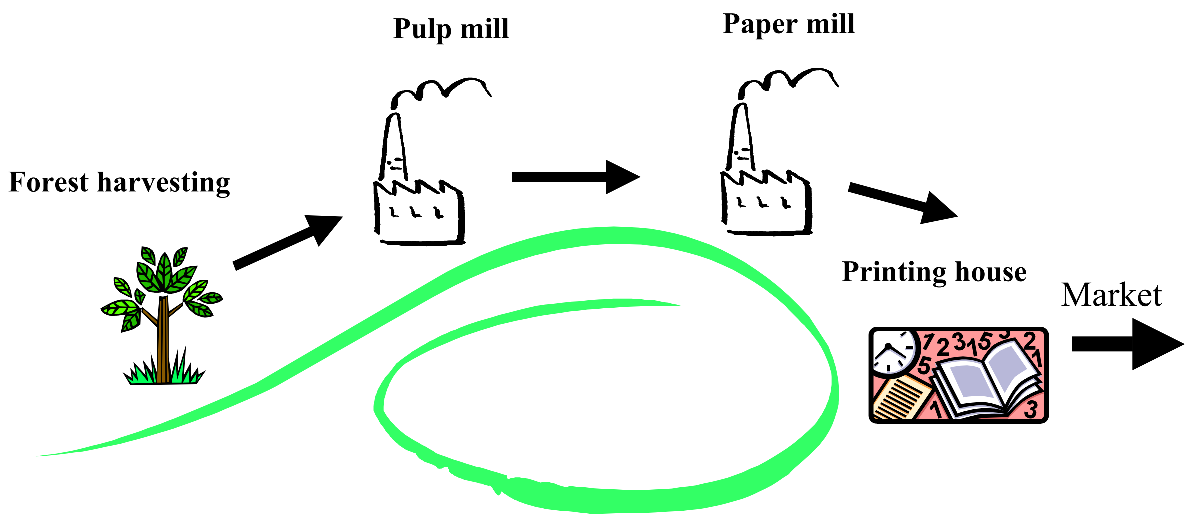

Figure 5.1 Parts of value chain of printed paper from forest to market.

Forest Harvesting

Forests are a source of timber for the mechanical and chemical forest industry and for manufacturing wood-based products and a source of energy. The main functions of forest management and harvesting are forest inventorying and planning, management of the forest ecosystem, timber procurement, timber measurement and timber transportation and storing (Kellomäki, 1998).

The important functions of forests and forest ecosystems are consumption of plants, animals, and derivatives, regulation of climate and atmospheric composition, management and conversation of biodiversity, educational and scientific services, management of ground water resources, landscape management, control of erosion, wind force, and regulated environmental benefits, protection against spread of pests and diseases, source of land and living space, outdoor recreation and other psycho-physiological influences, noise abatement, absorption of air impurities and related environmental benefits (Kellomäki, 1998).

Pulp Mills

Chemical pulping and mechanical pulping produce pulp. The pre-treatment for pulping is wood preparation. The most important activities of chemical pulping are wood handling, batch or continuous cooking, pulp washing, bleaching and pulp drying. The most important activities of mechanical pulping are refining mechanical pulps, ground wood production (grinding), screening and cleaning, reject refining, bleaching and pulp transfer (Kappel, 1999).

Furthermore, there are other functions for chemical pulping, which are chemical recovery, evaporation of black liquor, recovery boiler, white liquor preparation, combustion of bark, heat and power co-generation, closed cycle systems, and preparation and handling of bleaching chemicals (Gullichsen and Fogelholm, 2000). The most important environmental aspects of chemical pulping are the use of water, effluents to waterways, odour and energy.

Paper Manufacturing

The main activities of paper manufacturing are chemical pulp handling, pigment handling, paper machine operation, including pre-drying, coating and drying and finishing, converting and coating (Britt, 1970, Paulapuro, 2000). Furthermore, there are other functions for papermaking concerning the use of recycled fibre and deinking, slushing and pulping, deflaking, screening and fractionating, centrifugal cleaning, flotation, dewatering, washing, dispersion and kneading, refining and mixing and storing (Göttsching and Pakarinen, 2000). The most important environmental aspects of papermaking are energy production, and water supply and treatment. The environmental aspects of recycled fibre and deinking are paper cycling and the greenhouse effect, heavy-metal content of recovered paper and the content of chloro-organics in recovered paper (Göttsching and Pakarinen, 2000).

Printing Houses

The most important printing processes are gravure printing, flexography, offset lithography, screen-printing and digital printing (www.swan.ac.uk/printing/education, 16.5.2005). The most important environmental aspects of the printing sector are paper choices including issues, such as of forest management practice, recycled paper, uncoated paper, coated paper, chlorine in papers, recycled and chlorine-free papers. An important aspect is ink composition and reduction of volatile organic compounds, use of non-renewable resources and heavy metals. The use of chemicals in coatings and varnishes and lamination is an environmental aspect of printing. (Minnesota Environmental Initiative, 2006, 28.3.2006)

5.1 Technology over the Value Chain

Porter (1985) has widely presented the ideas of the value chain and the role of technology in creating competitive advantage over the value chain. This study aims to give more evidence of this role and the mechanisms of environmental technology creating competitive advantage over the value chain of printed paper.

All the technologies embodied in a firm's value chain have potential competitive impacts (Porter, 1985). Technology is embodied in every value activity in a firm, and technological change can affect competition through its impact on virtually any activity. Technology is embodied not only in primary activities, but in support activities as well. Every value activity uses some technology to combine purchased inputs and human resources to produce some output. The technologies in different value activities can be related, and this underlies a major source of linkages within the value chain. A firm's technologies are also clearly interdependent with its buyer's technologies. The points of contact between a firm's value chain and its buyer's value chain define the areas of potential interdependency of technology. Technology is pervasive in a firm and depends in part on both the buyers' channels and suppliers' technology (Porter, 1985).

Technology is also an important determinant of overall industry structure if the technology employed in a value activity becomes widespread. Technological change that is diffused can potentially affect each of the five competitive forces, and improve or erode industry attractiveness. Thus, even if technology does not yield a competitive advantage to any one firm, it may affect the profit potential of all firms. Conversely, technological change that improves a firm's competitive advantage may worsen structure as it is imitated. The potential effect of technological change on industry structure means that a firm cannot set technology strategy without considering the structural impacts (Porter, 1985). Technological change affects competition in the value chain by a mechanism of entry barriers, buyer power, supplier power, substitution, rivalry, industry boundaries and industry attractiveness (Porter, 1985).

5.2 Value Chain and Environmental Performance

Florida (1996) studied the hypothesis that the adoption of environmentally conscious manufacturing is related to the adoption of advanced manufacturing systems generally, and also to the supply chain approach. He found that close relationships across the production chain, and between end-users and suppliers in particular, facilitate the adoption of advanced manufacturing practices, creating new opportunities for joint improvements in productivity and environmental outcomes. Data were collected from twelve manufacturing firms in a variety of industrial sectors. The survey of environmental manufacturing practices asked firms to identify the key players in their pollution prevention strategies. Nearly half of the respondents identified suppliers as a key player. In addition, more than one-third of respondents identified customers as a key player in pollution prevention efforts (Florida, 1996).

According to Florida (1996), supplier relations and supply-chain management can affect industrial and environmental performance in different ways. However, manufactures have at times used their suppliers as a vehicle for improving their own environmental records by out-sourcing toxic elements of the production processes, essentially pushing waste and toxin down the supply chain. As well, new models of supplier relationships and supply-chain management create opportunities for joint approaches to improve productivity and prevent pollution.

In particular, environmental improvements were seen to result from ongoing efforts to improve productivity and implement advanced manufacturing practices, as well as from more directed efforts to transfer pollution prevention strategies and technologies. While the majority of respondents indicated that environmental improvements are frequently unintended consequences of broader efforts to improve industrial performance, a number of respondents noted that they pursue more directed efforts with suppliers to reduce waste and prevent pollution. These firms noted that they develop supplier specifications that include environmental objectives, they work with suppliers to develop new products and specifications, and they hold regular meetings with their suppliers to relate their pollution prevention strategies. His findings indicate that end-user/supplier relations operate by opening up opportunities for adoption and implementation of innovative approaches to both environmental and productivity improvement (Florida, 1996).

Linnanen (1998) found that the value creation process within industries and their actors were altered by environmental issues. It was found that the focus on environmental value chain management should not be on product characteristic as such, but on improving the entire product system in the broader sense, and that the prices and the relative costs of production factors have a key role in the change towards sustainable development. He found also that the importance of communication and rhetoric in understanding others and making others understand is rarely overvalued and that the shift in social responsibility will mirror the transition of economic actors towards sustainable development.

Pesonen (2001) presented ideas about how network dynamics could be helpful in finding new solutions to the problems of environmental management in the value chain context. For the main contractor partnership means better control over the supplier chain. For the suppliers, a reliable, long-term relationship offers better opportunities to allocate more efficiently scarce manufacturing and development resources. She presented a network project of environmental management system, whose results for supplier small and medium-sized enterprises included positive development in number of employees, staff motivation, investments, company profitability, and new customer and partner contacts. The best results were achieved in increasing the motivation of employees.

As an example, in Hart et al. (2000), a company of Parson Pines' operations and strategy exemplify the potential for impact reduction in the manufacturing and of the forest-product's value chain. The company eases pressure on existing forests by satisfying demand for certain products through the use of waste wood and realises a cost advantage in the market. A limitation of this approach, however, is that it is easy for competitors to duplicate. So, on the manufacturing side, impact-reduction efforts may not lead to a long-term competitive advantage. Parsons Pine reportedly has encountered price pressure in its markets and in its waste-wood inputs as competitors begin to copy its methods. Impact reduction may hold more promise in the forest, where such efforts preserve the value of the land base. Hart and Day (2000) developed a new framework for defining sustainable forest management (SFM) based on the literature on environmental strategy and a field study of forest-product companies. The framework was applied to 21 forest-industry business cases and it was found that a comprehensive and effective SFM approach meshes operations with strategic purpose.

5.3 Summary of Value Chain of Printed Paper

The term *value chain* refers to the idea that a company is a chain of activities for transforming inputs into outputs that customer's value (Hill and Jones, 1999). As a summary, technology can impact many ways on competitive advantage, but is also an important determinant of overall industry structure. All the technologies acting on a firm's value chain have potential competitive impacts, not only on primary activities, but also on support activities as well. The technologies in different value activities can be related, and this underlies a major source of linkages within the value chain. A firm's technologies are also clearly interdependent with its buyer's technologies. The points of contact between a firm's value chain and its buyer's value chain define the areas of potential interdependency of technology. Technology is pervasive in a firm and depends in part on both the buyers' channels and suppliers' technology (Porter, 1985). The relevant question from the point of view of environmentally sound technology is, then, whether they impact on industry structure or drivers of competitive advantage over the value chain. These issues were explored some extent in this study.

The major parts of the value chain of printed paper are forest harvesting, pulp mill, paper mill and printing house. The value chain includes activities from raw material to customer. In this study, the major raw material is timber and final customer is consumer of printed paper.

The environmental aspects in the value chain of printed paper are biodiversity, ground water protection, use of water, effluents to waterways, landscape, control of erosion, greenhouse effect, absorption of air impurities, odour, noise abatement, energy, heavy-metal content of recovered paper, content of chloro-organics in recovered paper, paper choices, composition and reduction of volatile organic compounds, use of non-renewable resources and heavy metals and use of chemicals (Kellomäki, 1998; Gullichsen and Fogelholm, 2000;

Göttsching and Pakarinen, 2000; Minnesota Environmental Initiative, 2006, 28.3.2006).

Florida (1996) found that manufacturing firms are involving suppliers in efforts to improve environmental outcomes and increase productivity. Suppliers and customers were identified as key players among industry respondents in their pollution prevention strategies. The results suggest that supplier relations create considerable opportunities for joint environmental and productivity improvement.

Linnanen (1998) found that the value creation process within industries and their actors were altered by environmental issues. It was found that the focus on environmental value chain management should not be on product characteristic as such, but on improving the entire product system in the broader sense, and that the prices and the relative costs of production factors have a key role in the change towards sustainable development. Pesonen (2001) presented a network project of environmental management system, whose results for supplier SMEs (small and medium-sized enterprises) included positive development in number of employees, staff motivation, investments, company profitability, and new customer and partner contacts. The best results were achieved in increasing the motivation of employees.

6 Environmental Regulation, Environmental Technology and Competitiveness of Companies

Environmental regulation controls the harmful environmental impacts of companies and impacts on the competitiveness of companies. Environmental technology can be seen as a solution when facing legal requirements. At the beginning of this chapter, environmental regulatory approaches are presented and environmental regulation, competitiveness of companies and environmental technology are discussed. Porter (1991 a,b) has presented statements about a win-win situation when a company faces regulatory demands and benefits economically from that at the same time. This so-called 'Porter Hypothesis' and related studies are presented. In this study, this hypothesis is explored at the company level.

6.1 Environmental Regulation Approaches

According to van der Linde (1993), environmental regulation affects two broad categories of industries. It directly affects those industries that have to comply with the regulation. It also indirectly affects pollution control industries, which supply their goods and services to the directly affected industries.

Hopfenbeck (1992) divided regulation approaches into three categories: command and control approach, market-based approach and partnership approach. According to Turner et al. (1993), environmental protection policy can be operationalised through an economic (market-based) incentives approach (using economic instruments, such as taxes/charges), or through a direct regulatory (CAC, command-and-control) approach; by precautionary principle; or through a property (resource) rights system between polluters and sufferers (Turner et al., 1993).

Nehrt (1998) examined the maintainability of first-mover advantages when environmental regulations differ between countries. He categorised environmental regulation as four basic types. In increasing order of their ability to assist in maintaining a competitive advantage, they are (1) a command-and-control regime with a required end-of-pipe technology; (2) no environmental regulations; (3) a command-and-control regime with a required environmental technology (cost-reducing, pollution-reducing) technology; and (4) incentive-based regulations.

Command-and-control regulation tends to force all businesses to adopt the same measures and practices for pollution control, and thus shoulder identical shares of the pollution-control burden, regardless of their relative impacts (Stavins and Whitehead, 1992). According to Turner et al. (1993), there are two broad sources of inefficiency in the command-and-control approach: the regulator is required to use up resources to acquire information that the polluter already possesses, and the polluters vary in the ease with which they can abate pollution. Schmidt (2000) also criticised the traditional approach to environmental regulation in the U.S., saying that it is out-dated and in need of massive reform (Schmidt, 2000).

Unlike command-and-control policies, which seek to regulate the individual polluter, market-based policies train their sights on the overall pollution in a given area. Thus, under a market-based approach, the government establishes financial incentives so that the costs imposed on businesses drive an entire industry or region to reduce its aggregate level of pollution to a desired level (Stavins and Whitehead, 1992).

Heterogeneous regulation and varying degrees of enforcement from country to country represent a considerable risk (Helmut Kaiser Consultancy, 1991; Kemp, 1993). Vickery and Iarrera (1997) have also found that important barriers to the development of the environmental industry have been uncertainty regarding environmental regulations, and related uncertainties in the supply and demand of new technologies.

6.2 Environmental Regulation and Companies

6.2.1 Environmental Compliance

Environmental compliance means fulfilling requirements of environmental regulation that gives a company right to operate. Environmental compliance is a minimum level of environmental performance.

Bansal and Roth (2000) studied conditions that are likely to lead to high corporate ecological responsiveness. Data were collected from 53 firms in the United Kingdom and Japan representing the industry sectors of food retailers, auto manufacturing and oil companies. Data analysis suggested three basic motivations for ecological responsiveness: competitiveness, legitimation and ecological responsibility. Examples of legitimation data included complying with legislation, and also other issues. Threats to a firm's legitimacy were expected to undermine a firm's licence to operate or its long-term survival. The motive of legitimation relates to the desire of a firm to improve the appropriateness of its actions within an established set of regulations, norms, values and beliefs. The decision analysis of these managers aimed to reduce the costs and risks of non-compliance. Discussions focused not on what would occur if the firm met the condition of stakeholders, but, rather, on what would happen if they did not. Hence, many respondents identified concerns about 'sanctions', 'bad publicity', 'punitive damages', 'avoiding clean-ups', 'discontented employees and work force', and 'risks'. These concerns were also reflected in firms' initiatives in that they reduced risks rather than publicised their ecological responsiveness (Bansal and Roth, 2000).

Roediger-Schluga (2003) studied the impacts of Austrian Volatile Organic Compound emission standards at company-level. They found that the standards gave rise to considerable changes in firms' product ranges and appear to have accelerated the rate of product innovation in the regulated industry. Research and development (R&D) spending to develop compliant products is found to be very unevenly distributed, mainly due to technological and, to a lesser extent, organisational factors. There is evidence that compliance efforts displace or postpone existing R&D projects. However, there is also evidence that the search for compliant products yields unexpected and beneficial ideas, knowledge, and competencies.

Shrivastava (1995) presented the implications of environmental technologies in the reduction of liabilities for strategic management and argues that they are sensitive to long-term risks of resource depletion, fluctuating energy costs, product liabilities, and pollution and waste. By introducing environmental technologies that systemically address these long-term issues early, companies can become aware of and manage these environmental risks.

Gabel and Sinclair-Desgagné (1991) explore managerial incentives and environmental compliance using a principal-agent model. They examined how incentive compensation systems can and should be devised to deal with the trade-off that managers often face between improving current profits and reducing the risk of environmental accidents. The main result was that monetary incentives should become stronger, as the principal becomes more eager to promote environmental risk-reducing activities relative to activities that enhance profit and as the monitoring technology concerning environmental risk reduction becomes relatively more accurate.

6.2.2 Environmental Regulation and Competitiveness of a Company

Environmental regulation is expected to impact on profits, productivity, the need for capital and labour, energy, operating cost, quality, development of new products, the need for information and product differentiation factors as well. The competitiveness impact of environmental regulation varies by sector and also depends of type of regulation.

By their nature, environmental regulations require investments to reduce residual flows. To the extent that these investments compete with standard plant and equipment investments, the ratio of labour to conventional capital will be increased. Moreover, because these regulations are typically based on engineering standards, the activities that they generate tend to be excessively capital intensive, and because they fall especially heavily on new pollution sources, incentive is given for uneconomic retention of existing—and lower productivity—plant and equipment. These regulations have also tended to be more heavily imposed on sectors with high post-war rates of productivity growth, and in low-pollution regions attractive for plant location. Furthermore, because pollution control equipment requires manpower to operate it, employment levels rise with no addition to marketable output. Finally, complying with these regulations requires information-gathering, administrative, and legal activities, which require inputs yielding no sellable output. Meeting these requirements may also require time—causing delay in expansion and modernisation plans and the stretching-out of construction periods (Christainsen and Haveman, 1981).

Van der Linde (1993) argues that properly designed environmental regulation may trigger a number of different advantages. It may induce firms to develop products with lower production costs, improved attributes, lower operating costs, or, in a more general form, to develop products with an early mover advantage over competing foreign products. The advantages of properly designed regulation are more–resource-efficient ways to produce goods, environmental friendly products, products with higher or more consistent quality, products that are less costly to operate or to discharge, reducing the costs of discharging the product for the user, and early-mover advantage.

With respect to the regulated sectors (Spengler, 1998), competitiveness effects will differ by industry according to a number of factors including for example significance of environmental costs, type of industry, firm size and overall competitive situation. Spengler (1998) presented the main competitiveness effects of environmental policies on regulated industries. Competitiveness effects of the significance of environmental costs will differ by sector, according to the type and scope of environmental externalities, which arise in production (for example, level of pollution, amount of wastes, extent of resource degradation) and the share of environmental compliance costs in overall costs. The negative effects of environmental costs on competitiveness may be offset by the positive contributions of environmental investments. Reduced input costs, technological innovation, greater efficiency in production reduced clean-up costs, and marketing of environmental goods and services may counterbalance environmental costs at the micro-, meso- and macro-economic level. Competitiveness effects of non-environmental factors will differ by sector, according to its competitive strengths and weaknesses in non-environmental areas, such as labour, capital and technology, which can be obtained from environmental improvements. Competitiveness effects of the type of sector will differ by sector, according to the location of the sector in the flow of materials from resource extraction to consumption and the technological advantages, which can be obtained from environmental improvements; more technically advantaged sectors may reap benefits from environmental compliance through innovations. Spengler (1998) argued that competitiveness effects of product differentiation, which will differ by sector according to whether the sector competes on the basis of price or product differentiation and the degree to which it can derive advantages from marketing environment-friendly or green products to green consumers.

Barbera and McConnell (1990) developed an approach to measuring the impact of environmental regulations on productivity growth directly and indirectly. They presented a model of production with abatement capital. Data from five manufacturing industries are used. They argued that environmental regulation has a direct impact on productivity growth due to the diversion of resources toward required abatement capital. They found that the indirect effect can be either positive or negative, and investigated energy use in the five industries.

The net impact of environmental regulation on the total factor of productivity was found to be fairly small.

Gray and Shadbegian (1993) analysed the connection between productivity, pollution abatement expenditures, and other measures of environmental regulation for plants in the three industries of paper, oil, and steel during the period 1979-1985. They found a strong connection between regulation and productivity when regulation is measured by compliance costs. More regulated plants have significantly lower productivity levels and slower productivity growth rates than less regulated plants.

Brännlund and Grosskopf (1995) have analysed the impact of the environmental regulation on profits in the Swedish pulp and paper industry. The approach taken is a non-parametric model of the technology. They calculated regulated and unregulated profits, and found that some firms do encounter a cost, or loss in profit, due to the environmental regulations imposed on them. It was found that large firms suffered more from the regulations than small firms.

Recently, the impact of EU environmental regulation on selected indicators of the competitiveness of the chemical industry in the European Union has been studied (European Commission, 1998). The research did not produce any substantial evidence of a significant impact of the strictness of environmental regulation on the competitiveness of the chemical sector in terms of the performance of this sector in world exports/imports, share of world production, productivity or employment. The overall conclusion is that fears over the strictness of environmental regulation in the EU might be jeopardising its industrial competitiveness in world markets do not appear warranted from the empirical evidence available. Table 6.2.2.1 presents a summary of studies of environmental regulation and competitiveness of companies: author, topic, research method and data collection, measurement indicator and main result.

Table 6.2.2.1 Studies of Environmental Regulation and Competitiveness of Company: Authors, Topics, Research Methods and Data Collection, Measurement Indicators and Main Results.

Author	**Topic**	**Research Method and Data Collection**	**Measurement Indicator**	**Main Result**
Barbera and McConnell, 1990	The impact of environmental Regulation on Industry Productivity: Direct and Indirect Effects	Model of production with abatement capital. Industries of paper, chemicals, stone, clay and glass, iron and steel and non-ferrous metals. Data of abatement capital series, wage bill and price of labour, productive capital stock and the user cost of capital from five polluting industry sector	Total factor productivity growth	The indirect effect of environmental regulation on industry productivity can be either positive or negative, and in all explored industries is energy using. The net impact on total factor productivity growth is fairly small.
Gray and Shadbegian, 1993	Environmental Regulation and Manufacturing Productivity at the Plant Level	Paper, oil and steel industry in 1979-1985	Productivity and pollution abatement expenditures	More regulated plants have significantly lower productivity levels than less regulated plants.
Brännlund and Grosskopf, 1995	Environmental Regulation and Profitability: An Application to Swedish Pulp and Paper Mills	A non-parametric programming model of technology, Swedish pulp and paper industry (41 pulp mills) in 1989 and 1990	Cost of regulation in terms of the ratio the regulated and unregulated profits.	Some firms do encounter a cost, or loss in profit, due to the environmental regulations imposed on them. The large firms suffered more from the regulation than small firms. Impact on the mills varies substantially in individually regulated Swedish mills.
European Commission, 1998	Study on the Impact of EU Environmental Regulation on Selected Indicators of the Competitiveness of the European Chemical Industry	Chemical industry	World exports, imports, share of world production, productivity, employment	No evidence of significant impact of the strictness of environmental regulation on the competitiveness of chemical sector

The impacts of environmental regulation on incumbent firms, early-investors and location of plants have also been studied. The primary implication of Deans and Brown's (1995) study for incumbent firms is that, contrary to the often-expressed view, environmental regulations may do more than just add to the costs of operations. Environmental regulations that place a heavier burden on new entrants confer an advantage on existing firms by increasing the barriers to entry in industries in which pollution abatement is important. Nehrt (1996) found that earlier investors in pollution-reducing processing equipment have higher profit growth than later investors. Ulph (1994) set out a model of a single industry with several producers who have to decide where to locate plants to serve several markets (countries), and the governments of these countries can take policies to restrict emissions of a pollutant. Xing and Kolstad (2000) evaluated the effect of the stringency of environmental policy on the location of polluting industries. They found that there exists a significant negative linear relationship between foreign direct investment of the US chemical and metal industries and the stringency of environmental regulation in a foreign host country.

6.3 Environmental Regulation and Environmental Technologies

The most important driving factors of the environmental technology market are legislation and cost (fees). In the future, these factors will motivate businesses to make considerable investments for environmental protection. To be sure, greater expenditures for environmental protection mean also a significant short-term financial burden, but result in a long-term competitive edge due to an improved corporative image, ecological products, tax breaks, etc. (Helmut Kaiser Consultancy, 1991).

OECD countries generally have well-developed systems for regulating sources of pollution and managing wastes. However, these systems have tended to encourage end-of-pipe pollution control and waste management rather than pollution prevention. One of the considerations is that regulatory systems must become 'innovation-friendly', i.e., there must be flexibility for regulated sources as industry and service providers to assess and choose specific technical measures to meet environmental targets. Enforcement must not stifle risk-taking in finding better technology approaches (Hanmer, 1997).

With respect to the choice of environmental policy instruments, Kemp's (1993) analysis suggests that no single instrument is optimal. Instead, the stimulation of depending on the specific technologies calls for a mixture of instruments, depending on the specific factors and circumstances (Kemp, 1993). Emission standards that are based on available, end-of-pipe technologies provide little incentive for the development of new, more effective technologies. To counteract this problem, technology-forcing standards and waivers for companies developing or adopting innovations can be considered. They may create a more certain and predictable market for new technologies. However, these instruments, particularly technology-forcing standards, are likely to lead to high costs for firms, unless the regulator is willing to soften and delay standards. However, this would have a negative effect on the willingness to develop innovations. As well, in the case of standards, the risk of being locked into a certain technology or trajectory, which may be suboptimal, is high (Kemp, 1993).

Market demand seems to be the crucial factor in the successful exploitations of technological opportunities (Kemp, 1993). As indicated, in the Kemp (1993) study of clean technologies, market demand depends strongly on government policy. Although there are other stimuli, such as pressure from local communities, the work force, investors, insurance companies, special environmental interest groups, and the larger public, these stimuli are still not very strong.

Bonifant and Long (1995) presented two models of competition resulting from traditional technology based regulation and environmental initiative based regulation. One model represented competition resulting from traditional methods of regulation, the competition among suppliers based on the cost of production, and competition among regulated firms based on purchasing and ability to implement low-cost technology. The other represented competition resulting from environmental initiatives, the competition among suppliers based on ability to provide means of emission reduction and the new area of competition among regulated firms based on ability to cost-effectively remain in compliance.

Firms that move ahead of regulation to minimise the impact of their products or operations on the environment are better positioned to meet tighter standards in the future. Since environmental requirements are often based on the best available technology, an industry could gain competitive advantage by establishing the industry standard and creating a potential barrier to entry (Klassen and McLaughlin, 1996).

According to Rondinelli and Berry (2000), environmental policies have brought dramatic improvements in air and water quality during the past 25 years, but further expansion of command-and-control regulations is likely to result in diminishing marginal returns. Corporations are taking new initiatives in managing their environmental impacts in ways that reduce their costs, increase their efficiency, lower their liabilities, and enhance their competitiveness, while reducing pollution, conserving resources, and eliminating waste. In the future, significant gains in environmental quality are more likely to come from widespread adoption of pollution prevention practices than from more stringent regulation of end-of-pipe emissions (Rondinelli and Berry, 2000).

Xapapadeas and de Zeeuw (1999) used a model in which firms can invest in machines with different characteristics, where newer machines are more productive and 'cleaner', but also more expensive, than older machines. They isolated two effects resulting from the introduction of a stricter environmental policy in the form of a tax on emission: A productivity effect and a profit-emission effect. Their results indicate that, although a stricter environmental policy cannot be expected to provide a win-win situation in the sense of both reducing emissions and increasing profitability in an industry, they may expect increased productivity of the capital stock, along with a relatively less severe impact on profit and more emission reductions when the stricter policy induces modernisation of capital stock. The trade-off between environmental conditions and profits of the home industry remains, but is less sharp because of downsizing and modernisation of the industry. (Xapapadeas and de Zeeuw, 1999)

Jaffe et al. (2002) provide a guide to research into technological change and the analytical tools that can be used to explore further the interaction between technology and the environment and to introduce theoretical analysis of the effects of environmental policy on technological change. They conclude that there are two principal ways in which environmental policy instruments can be compared with regard to their effects on technological change: by asking what effects alternative instruments have on the rate and direction of relevant technological change and by asking whether environmental policies encourage an efficient rate and direction of technological change, or more broadly, whether such policies result in overall economic efficiency. They explored empirically innovation and the diffusion of environmental technology.

Gray and Shadbegian (2003) used data on productivity and pollution abatement costs at individual pulp and paper mills to test whether the impact of environmental regulation on productivity differs by plant vintage and technology. Plants with higher pollution abatement costs have significantly lower productivity levels. This relationship differs greatly based on a plant’s technology, with productivity at integrated mills being greatly affected by abatement costs, while the impact at non-integrated mill is negligible. Plant vintage does not seem to matter, with older and newer plants showing similar impacts. Recorded abatement costs appear to substantially understate the true costs of abatement. Accounting for the impact of technology differences makes some difference in the estimated overall impact of environmental regulation. Van der Ploeg and de Zeeuw (1994) introduced the transboundary pollution control model in which the governments stimulate investment in the stock of clean technology in order to reduce the emission-output ratio.

6.4 Relationships Among Environmental Regulation, the Pollution Prevention Approach and Competitiveness of Companies

The pressure on environmental regulation forces companies to solve the demand for reduction of pollutants in one way or another. The approaches of pollution prevention or pollution abatement are the alternatives. It is asked in this study whether the selection of one of these approaches rather than the other impacts on the competitiveness of the company in question.

Porter (1991a, 1991b) argued that:

Turning environmental concern into competitive advantage requires that the right kind of regulations is established.

These regulations must:

1) stress pollution prevention rather than merely abatement or clean-up;

2) *not constrain the technology used to achieve them, or else innovation will be stifled;*

3) *be sensitive to the costs involved and;*

4) *use market incentives to contain them* (Porter, 1991 a, 1991 b).

This is the so-called 'Porter Hypothesis'. With regard to technology Porter (1991 a, 1991 b) argued that environmental standards, which aim to at outcomes and not methods, will encourage companies to re-engineer their technology, and, as a result, lessen pollution and lower cost and improve quality. Porter and van der Linde (1995 b) argued that properly designed environmental standards can trigger innovation that pays partially for, or more than fully offset the costs of, complying with them. Firms can actually benefit from properly crafted environmental regulations that are more stringent than those faced by their competitors in other countries. By stimulating innovation, strict environmental regulation can actually enhance competitiveness.

Porter and van der Linde (1995 b) compared the Scandinavian and U.S. pulp and paper industries, bearing in mind that there are differences between the two. Strict early U.S. regulations in the 1970s were imposed without adequate transitional periods, forcing companies to adopt the best available technologies quickly. At that time, the requirements invariably meant installing proven but costly end-of-pipe treatment systems. In Scandinavia, however, regulation permits more flexible approaches, enabling companies to focus on the production process itself, not just on the secondary treatment of wastes. Scandinavian companies developed innovative pulping and bleaching technologies that not only met emission requirements, but also lowered operating costs. Even though the United States was the first to regulate, U.S. companies were unable to realise any first-mover advantages because U.S. regulations ignored a critical principle of good environmental regulation: Create maximum opportunity for innovation by letting industries discover how to solve their own problems (Porter and van der Linde, 1995).

The Scandinavian pulp-and-paper industry was able to reap innovation offsets that went beyond those directly stemming from regulatory pressures. By the early 1990s, producers realised that growing public awareness of the environmental problems associated with pulp-mill effluents was creating a niche market. At the time, Scandinavian companies with totally chlorine-free paper were able to command significant price premiums and serve a rapidly growing market segment of environmentally informed customers (Porter and van der Linde, 1995). Since the data of this study was collected from Scandinavian experts of the pulp and paper industry, explored environmentally sound technologies are abovementioned innovations.

6.5 Studies Concerning the 'Porter Hypothesis'

The 'Porter Hypothesis' has been studied at the company level and nation economy level and in different ways. In this study was focused on a role of technology approach and affects at the company level.

'Porter Hypothesis' at the Company Level

Oates et al. (1993) and, later, Palmer et al. (1995) explored the Porter Hypothesis from a variety of perspectives, both theoretical and empirical, to see whether regulation can enhance, rather than reduce, competitiveness. They presented a simple economic model in which the hypothesis was shown to be false. The model essentially formalises the basic point that the addition (or tightening) of constrains on a firm's set of choices cannot be expected to result in a higher level of profits. The idea of marginal abatement cost (MAC) function is presented. It indicates the marginal cost incurred by the curve implies that the marginal cost incurred by the firm to reduce pollution increases by an additional unit. They found that the case for the hypothesis rests largely on the existence of some 'slack'—that is, on some pre-existing opportunities for cost-savings or profitable product enhancement that have, for some reason, gone unrealised. They found that most of the existing evidence runs counter to Porter's claim. They also argue that Porter himself offers little direct empirical evidence in support of his contention.

Boyd and McClelland (1999) employed a methodology that measures how environmental constraints account for differences between plant-level efficiency and whether simultaneous improvements in environmental performance and productivity is feasible. Viewing their method as a test of the Porter Hypothesis, they supported aspects of both sides of the debate. In their sample of plants in the paper industry, there is evidence of 'win-win'—meaning economic benefits brought about by fulfilling the requirements of environmental regulation – potential to increase production and reduce pollution, as well as evidence of losses to potential output due to environmental constrains.

Marklund (1999) tested the Porter Hypothesis in the sense that he investigated the impact of governed environmental regulations on plant efficiency in the Swedish pulp and paper industry. The study explicitly focuses on testing the hypothesis that regulation has positive effects on plant efficiency. In general, the empirical findings of the study do not support the Porter Hypothesis as it is formulated in the study. A major conclusion of the study is that there seems to be no obvious and clear relationship between environmental regulation and efficiency in that particular industry.

Xepapadeas and de Zeeuw (1999) developed a model that confirms a win-win situation, but that also draws attention to some general mechanism that reduces the trade-off considerably. Their results indicate that, although a stricter environmental policy cannot be expected to provide a win-win situation in the sense of both reducing emissions and increasing profitability in an industry, they may expect increased productivity of the capital stock, along with a relatively less severe impact on profits and more emission reductions, when the stricter policy induces modernisation of the capital stock. The trade-off between environmental conditions and profits of the home industry remains, but is less sharp with respect to the downsizing and modernisation of the industry.

Mohr (2000) shows that environmental regulations can simultaneously alleviate pollution and increase productivity and derives results consistent with Porter's hypothesis by employing a general equilibrium framework with a large number of agents, external economics of scale in production, and discrete changes in technology. The model shows that environmental regulations can simultaneously alleviate pollution and increase productivity and endogenous technical change; this makes Porter's hypothesis feasible. However, a policy that produces results consistent with Porter's hypothesis is not necessarily optimal.

Roediger-Schluga (2003) presented some micro-evidence for the techno-economic consequences of Austrian volatile organic compounds (VOC) emission standards for Austrian paint, coating, printing ink, and adhesive manufactures that is relevant to the discussion of the Porter Hypothesis. An analysis of the evolution of Austria's revealed a comparative advantage in the respective product groups shows that the strictest standards of their kind had no clear impact—that is, they had neither unequivocally negative nor positive impact—on the competitiveness of manufacturers of paints, coatings, printing inks, and adhesives, in the areas of which the overwhelming majority of firms declared that its competitiveness has not been affected by the standards. However, firm size seems to matter, as the share of firms stating to have suffered declines with firm size, while the opposite is true of firms who were able to benefit.

According to Roediger-Schluga (2003), the absence of a negative impact on the competitiveness of regulated firms may also be due to 'innovation offsets' as predicted by the Porter Hypothesis. The survey shows considerable changes in the firms' product range, which also caused the technological environment in the industry to become more dynamic after the implementation of the standards. In other words, the Austrian volatile organic compounds (VOC) emission standards appear to have accelerated the rate of product innovation in a previously rather tranquil industry.

Murty and Kumar (2003) studied the effect of environmental regulation on the productivity efficiency of water-polluting industries in India. They focused on sugar industry in India during 1996-1999. The main empirical result is that the technical efficiency of firms increases with the degree of compliance of firms to the environmental regulation and the water conservation efforts, thereby supporting the Porter Hypothesis.

Hillard (2004) compares neoclassical, Porterian, and evolutionary approaches to analyse the impacts of environmental regulation and argues that the failure of both neoclassical environmental economics and Porter's theory to provide a convincing analysis of that regulation can promote competitiveness-enhancing technical change is because of their failure to look inside the black box. She stated that, according to the neoclassical approach, profit-maximising cleaner technology will be adopted by profit-maximising firms without requiring a regulatory stimulus: regulation can only act as a constraint on firms, and that regulation, according to the approach of Porter and van der Linde (1995), can promote competitiveness-enhancing technical change. She criticises the lack of theory in the Porterian approach, and states that the evolutionary theory of the firm, with its emphasis on organisational capabilities as the driver of technical change in firms, provides a framework for the development of a coherent model of the relationship between environmental regulation and technical change by firms. Table 6.6.1 presents a summary of the studies concerning the Porter Hypothesis at the company level: author, topic, research method and data collection, measurement indicator, findings and conclusion.

Table 6.6.1 Summary of Studies Concerning the Porter Hypothesis at the Company Level: Authors, Topics, Research Methods and Data Collection, Measurement Indicators, Findings and Conclusions.

Author	**Topic**	**Data Collection, Research Methods**	**Measurement Indicators**	**Findings**	**Conclusion about Porter Hypothesis**
Oates, 1993 and Palmer et al., 1995	Environmental Regulation and International Competitiveness: Thinking About the Porter Hypothesis, Resources for the Future	Theoretical and empirical, economic model of innovation in abatement technology	Marginal abatement cost, abatement level	An increase in the stringency of environmental regulations unambiguously makes the polluting firm worse off despite the adaptation of a new, more efficient, abatement technology.	Rejected
Boyd and McClelland, 1999	The Impact of Environmental Constraints on Productivity Improvement in Integrated Paper Plant.	Hyperbolic Efficiency Analysis, primal production function and pollution treated as an output. Data of integrated paper mills.	The loss of potential productive output due to environmental constrains, the potential for improvements	Evidence of 'win-win' potential to increase production and reduce pollution as well as evidence of losses to potential output due to environmental constrains.	Accepted and rejected
Marklund, 1999	Environmental Regulation and Firm Efficiency	Swedish pulp and paper industry.	Plant efficiency	No obvious and clear relationship between environmental regulation and efficiency	No obvious accept ion
Xepapadeas and de Zeeuw, 1999	Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital	Model in which firms can invest in machines with different characteristics	Productivity effect, profit-emission effect	Downsizing and modernisation of firms subject to environmental policy will increase average productivity and will have positive effect on marginal decrease of profits and environmental damage.	Accepted
Mohr, 2000	Technical Change, External Economies, and the Porter Hypothesis	Equilibrium framework model about a closed economy including an agent of technology	Old technology, new technology	Environmental regulations can simultaneously alleviate pollution and increase productivity. Endogenous technical change makes hypothesis feasible.	Feasible
Roedeger-Schluga, 2003	Some Micro-evidence on the 'Porter Hypothesis' from Austrian VOC Emission Standards	Firm level survey data of Austrian paint, coating, printing ink and adhesive manufactures and foreign data from UN commodity trade database	The revealed comparative advantage (RCA) index and survey assessment of competitiveness impacts	The strictest standards had no clear—negative or positive—impact on competitiveness of manufacturers of regulated products, but firm size matter	No clear effect
Murty and Kumar, 2003	Win-win Opportunities and Environmental Regulation: Testing of Porter Hypothesis for Indian Manufacturing Industries	Output distance function jointly with the equation explaining the relationship between technical inefficiency and indices of environmental regulation and water conservation efforts. Indian sugar industry in 1996-1999, panel data	Productive efficiency and factors affecting it.	The technical efficiency of firms increases with the degree of compliance of firms to the environmental regulation and the water conservation efforts there by supporting hypothesis.	Accepted
Hillard, 2004	Conflicting Views: Neoclassical, Porterian, and Evolutionary Approaches to the Analysis of Environmental Regulation of Industrial Activity	Literature review		Failure of Porter's theory to provide convincing analysis about regulation inducing competitiveness is rooted in failure to look inside the companies.	Rejected

Other aspects of the Porter Hypothesis at the company level have been studied. Heyes and Liston-Heyes (1999) studied corporate lobbying, regulatory conduct and the Porter Hypothesis by a politico-economic model. Smith and Walsh (2000) reported an experimental test of the Porter Hypothesis that environmental regulation creates innovation offsets that would not otherwise be undertaken. Altman (2000) presented a behavioural model of the firm whereby x-inefficiency in production prevails even in a world with perfect product market competition that is dominated by rational economic agents. Ekins and Speck (1998) stated that the evidence for either first-mover competitive advantage or regulation-induced innovation is not strong enough to justify environmental policy on its own. The other element of the Porter Hypothesis, that environmental policy can stimulate innovation that more than offsets the costs of complying with the policy, is more difficult to analyse in general terms, not least because of the inherent unpredictability of innovation (Ekins and Speck, 1998).

Porter Hypothesis and National Economics

Jaffe et al. (1995) reviewed the literature of environmental regulation impacts on the competitiveness of U.S. manufacturing. They found that there is relatively little evidence to support the hypothesis that environmental regulation has had a large adverse effect on competitiveness, while not actually commenting on the Porter Hypothesis. Gardiner (1994) is a proponent of the view that not only can environmental regulation provide health and ecosystem protection, but that it can stimulate the economy and enhance U.S. competitiveness at the same time. Portney (1994) is more sympathetic to the traditional view that environmental regulation impedes economic growth. Nehrt (1998) examines the competitive conditions for firms in different countries and the unfair position of having to compete against rivals facing more lenient environmental regulations, and studies the Porter Hypothesis from that viewpoint at the national level. Romstad (1998) studied environmental regulation and competitiveness. His main conclusion is that the Porter Hypothesis may be valid in special cases, but that one cannot expect it to hold in general. Greaker (2003) studied the claim of the

Porter Hypothesis that a strong environmental policy best serves the interests of a nation's export industry.

6.6 Summary of Environmental Regulation, Environmental Technology and Company Competitiveness

Environmental regulation can be divided into three categories: command-and-control, market-based approach and partnership. Command-and-control regulation encourages end-of-pipe technology, while other approaches encourage pollution prevention.

Christiansen and Haveman (1981) argued that environmental regulations push organisation to investments, which increase the ratio of labour to conventional capital. The result is lower productivity. Since pollution control equipment requires manpower to operate it, employment levels rise with no addition to marketable output. Complying with these regulations requires information-gathering, administrative, and legal activities, which require inputs yielding no sellable output as well (Christiansen and Haveman, 1981).

With respect to the regulated sectors (Spengler, 1998), competitiveness effects will differ by industry according to a number of factors, including, for example, significance of environmental costs, offsetting effects, non-environmental factors, such as labour, capital and technology, and product differentiation.

The impacts of environmental regulation on company performance can be positive or negative (Barbera and McConnell, 1990), negative (Gray and Shadbegian, 1993, Brännlund and Grosskopf, 1995), not negative (European Commission, 1998) in the form of costs or loss in profit or productivity. Regulation has been shown have different impacts on plants employing different production technologies as well (Gray and Shadbegian, 2003). More-regulated plants have significantly lower productivity levels than less-regulated plants (Gray and Shadbegian, 1993). Some firms do encounter a cost, or loss in profit, due to the environmental regulations imposed on them. The large firms suffered more from the regulation than small firms. Impact on the mills varies substantially in individually regulated Swedish mills (Brännlund and Grosskopf, 1995). However, the heavily regulated EU's chemical industry, for example, has not suffered from environmental regulation (European Commission, 1998). Marklund's (1999) major conclusion is that there seems to be no obvious and clear relationship between environmental regulation and efficiency in the Swedish pulp and paper industry.

Environmental regulation can encourage to pollution-abatement technology or pollution-prevention technology. The most important driving factors of the environmental technology market are legislation and cost (Helmut Kaiser Consulting, 1991; Kemp, 1993). According to Kemp (1993), the best environmental policy is mixture of economic, regulatory and information policies. Technology-facing standards are likely to lead to high costs for firms. Regulation creates the possibility of achieving first-mover advantage (Nehrt, 1996) by implementing the best available technology (Klassen and McLauhghlin, 1996) and of erecting entry barriers (Deans and Browns, 1995). The regulation, which allows solutions of the innovative technologies of pollution prevention rather than fulfilling stringent regulation of end-of-pipe emissions, will result the best benefits for the regulated organisations (Kemp, 1993; Hanmer, 1997; Rondinelli and Berry, 2000). Xapapadeas and Zeeuw (1999) found that although a stricter environmental policy cannot be expected to provide a win-win situation in the sense of both reducing emissions and increasing profitability in an industry, they may expect increased productivity from the capital stock, along with a relatively less severe impact on profits and more emission reductions, when the stricter policy induces modernisation of the capital stock. Two models of competition resulting from traditional technology based on technology and environmental initiative based regulation is presented by Bonifant (1996). Gray and Shadbegian (2003) found that plants with higher pollution abatement costs have significantly lower productivity levels. This relationship differs greatly, based on a plant’s technology, with productivity at integrated mills being greatly affected by abatement costs, while the impact at non-integrated mills is negligible.

Porter (1991, 1991b) has presented the following win-win statements, which are known the Porter Hypothesis: Turning environmental concern into competitive advantage demands that the right kinds of regulations, i.e., those that stress pollution prevention rather than merely abatement or clean-up, are established.

The Porter Hypothesis is explored from various points of view and approaches at the level of national economy and companies. Oates et al. (1993) presented a simple economic model in which the Porter Hypothesis in shown to be false. In testing the hypothesis, the supporting aspects of both sides of debate can be found (Boyd and McClellend, 1999). The results in Xepapadeas and de Zeeuw (1999) indicate that although a stricter environmental policy may expect increased productivity of the capital stock. Murty and Kumar (2003) concluded that endogenous technical change makes the Porter Hypothesis feasible. There seems to be a lack of understanding through which mechanisms inside companies create advantages from the pressure of environmental regulation (Hillard, 2004). According to Roediger-Schluga (2003) the absence of a negative impact on the competitiveness of regulated firms may also be due to 'innovation offsets', as predicted by the Porter Hypothesis.

7 Goals of the Study and Research Questions

The aims of the study are to investigate the impacts of environmentally sound technologies on the competitiveness of companies. The research focus is on the environmentally sound technologies in the value chain of printed paper from forest to market. The value chain is divided into four sections: forest harvesting, pulp mill, paper mill and printing house.

The research questions are as follows (1)-(5):

1) Which are environmentally sound technologies the most important for environmental impacts in the value chain of printed paper from forest to market?

2) How do environmentally sound technologies impact on the competitiveness of companies through cost factors of raw material, energy, staff, capital and other costs and differentiation factors of product characteristics, product image, company image and differentiation factor?

3) How do the environmentally sound technologies differ among the parts of the value chain of printed paper?

4) Do the environmentally sound technologies impact on competitiveness of companies in the other part of the value chain?

5) Do pollution-prevention technologies and pollution-abatement technologies differ in competitiveness impacts, when they have legal incentive impacted or not have them? Is this part of Porter Hypothesis acceptable?

8 Materials and Methods

8.1 Research Approach

The research approach was partly inductive and partly deductive. In the inductive part of the study, the aim was to understand the competitiveness impacts of environmentally sound technologies. Furthermore, the competitiveness impacts of environmentally sound technologies in the value chain were studied. The measured dimensions of competitiveness were based on the literature. The research question numbers 1, 2, 3 and 4 were examined inductively. In the deductive part of the study, research question number 5, relationships among legal incentives, function mechanisms of pollution prevention and pollution abatement, and competitiveness factors were examined at the company level as a part of the so-called Porter Hypothesis.

8.2 Selection of Respondents

The non-probability and purposeful sampling was used for the selection of the respondents. In non-probability sampling, the researcher uses subjective methods, such as personal experience, convenience, expert judgment, and so on, to select the elements in the sample (Hair et al., 2003).

In purposeful sampling samples are selected because they are 'information rich' and illuminative, that is, they offer useful manifestations of the phenomenon of interest. Sampling then aims to gain insight into the phenomenon, rather than making non-empirical generalisations from the sample to a population (Patton, 2002). It means that information-rich samples—here the respondents—are selected strategically and purposefully with the objective that they offer useful manifestations of the phenomenon of interest.

The criteria for the selection of the respondents were

- all the countries of respondents had similar environmental regulation
- pollution prevention approaches are used in the countries of respondents

- the countries of respondents have a long history as a user of forest resources and/or printed paper
- there exists a strong technology industry and know-how relating to the sector of the value chain in the countries of respondents
- developed environmental legislation is in place in the country of respondent
- there exists an environmentally conscious market area
- the respondent is a well-known expert in the field of science concerning their expertise of the value chain of printed paper
- the respondent has competence in various production processes and technologies concerning their expertise of the value chain of printed paper
- the respondent has a deep perspective into the past and future development of his/her expertise area
- the respondent has an independent status as a university professor or a research professor.

As a result of the selection criteria, eight professors were selected for interviewing, two from each part of the value chain in which they were well-known specialists. The selected countries of the respondents were Finland, Sweden and Germany. All of these countries have developed environmental regulation. Sweden and Finland have very strong pulp and paper technology industries and long histories as users of forest resources. Germany has a long history of printing technology.

Four selected respondents were from Finland, covering all parts of the value chain. Two of the respondents from Sweden were competent in forest harvesting and pulp mill, and two were from Germany, covering paper manufacturing and printing houses. Altogether eight interviews were carried out. In Table 8.2.1 the respondents are presented, together with the part of the value chain of their focus and expertise, country of respondent, and the response frequency of environmentally sound technologies they identified that was effective during the period 1980-1999 and that is likely to be effective during the period 2000-2019.

Table 8.2.1 Respondents, Part of the Value Chain, Country of Respondent and Response Frequency of Technologies Identified for the Time Periods 1980-1999 and 2000-2019

Respondent	**Part of the Value Chain**	**Country of Respondent**	**Response Frequency of Technologies Identified in the Time Periods**	
			In 1980-1999	**In 2000-2019**
Respondent 1	Forestry harvesting	Finland	3	5
Respondent 2	Forestry harvesting	Sweden	5	5
Respondent 3	Pulp mill	Sweden	5	3
Respondent 4	Pulp mill	Finland	5	5
Respondent 5	Paper mill	Finland	5	5
Respondent 6	Paper mill	Germany	4	4
Respondent 7	Printing house	Germany	4	5
Respondent 8	Printing house	Finland	3	3
		Total number of technologies	**34**	**35**

The interviews were carried out in autumn 1998 and spring 1999. The respondent identified 69 environmentally sound technologies: 18 in forestry harvesting, 18 in pulp mill, 18 in paper mill and 15 in printing houses. Table I-1 of Appendix I presents the information of the value chain, code and the names of the respondents.

8.3 Concepts Measured, Research Design and Data Collection

Concepts Measured

The technologies that the respondents identified as the most important environmentally sound technological changes were studied, focusing on their parts of the value chain. The term 'environmentally sound technological change' is later replaced by 'environmentally sound technology' because the respondents called the technological change as the technology. The main questions in the interviews were the following: the identification of five of the most important environmentally sound technologies in the period 1980-1999 and, looking to the future as well, in the period 2000-2019, a description of the technologies and the assessment of their impacts on the competitiveness of companies.

The respondents were asked to put the identified technologies in order according to their importance on environmental impacts. The qualitative descriptions of technologies were categorised. The variables are part of value chain, effective time period, technological category, environmental aspect, function mechanism, breakthrough time period, legal incentive, other-than-legal incentive, categorised other-than-legal incentives, impact on competitiveness of companies in the other part of the value chain and categorised impacts on competitiveness of companies in the other part of the value chain. The questionnaire for identifying environmentally sound technological changes is presented in Appendix II.

The concept of competitiveness of companies was predetermined to have two main categories: cost competitiveness and differentiation competitiveness. The questionnaire for assessing competitiveness impacts is presented in Appendix III. The measured cost-competitiveness factors were as follows: raw material factor (Peattie, 1995; Bragdon and Marlin, 1972; Porter, 1985; Porter and van der Linde, 1995), energy factor (Peattie, 1995), staff factor (Bragdon and Marlin, 1972), capital factor (Kemp, 1993; Bragdon and Marlin, 1972; Florida, 1996) and other cost-competitiveness factors.

The measured differentiation competitiveness factors (Hill & Jones, 1999) were as follows: product characteristic factor (Peattie, 1995; Hill & Jones, 1999; Spengler, 1998; Shrivastava, 1995 b), product image factor (Peattie, 1995; Hill and Jones, 1999; Spengler, 1998; Bansal and Roth, 2000; Ytterhus, 1997), company image factor (Peattie, 1995; Spengler, 1998; WBCD, 1996; Kemp, 1993; Pansal and Roth, 2000) and other differentiation competitiveness factors.

The respondents were asked to evaluate competitiveness impacts of the identified environmentally sound technologies. Competitiveness impacts were measured by assessing them along a five-stage scale.

Porter's arguments (1991 a, 1991 b) were operationalised as follows
Turning environmental concern into competitive advantage (variables of cost competitiveness and differentiation competitiveness) demands that the right kind of regulation (variable of legal incentive) is established.

According to Porter (1991a, 1991 b), these regulations should:
1) stress pollution prevention rather than merely abatement or clean-up (variable of function mechanism of pollution prevention or pollution abatement)
2) not constrain the technology used to achieve them, or else innovation will be stifled
3) be sensitive to the costs involved (variable of cost-competitiveness) and
4) use market incentives to contain them (variable of differentiation competitiveness)

The model for testing the Porter Hypothesis was determined and operationalised as shown in Figure 8.3.1. The specification of measurement construct uses the competitive advantage patterns of cost advantage and differentiation advantage presented by Porter (1985). Competitive advantage was measured through the variables of cost competitiveness, such as raw material, energy, staff, capital and other costs and differentiation competitiveness, such as product characteristic, product image, company image and other differentiation factors. Environmental regulation was measured by the variable 'having or not having legal incentive', while the impact of pollution-prevention technology and pollution-abatement technology were measured by the variable 'function mechanism' of environmentally sound technology. The questionnaire for assessing the competitiveness of environmentally sound technological changes is presented in Appendix III.

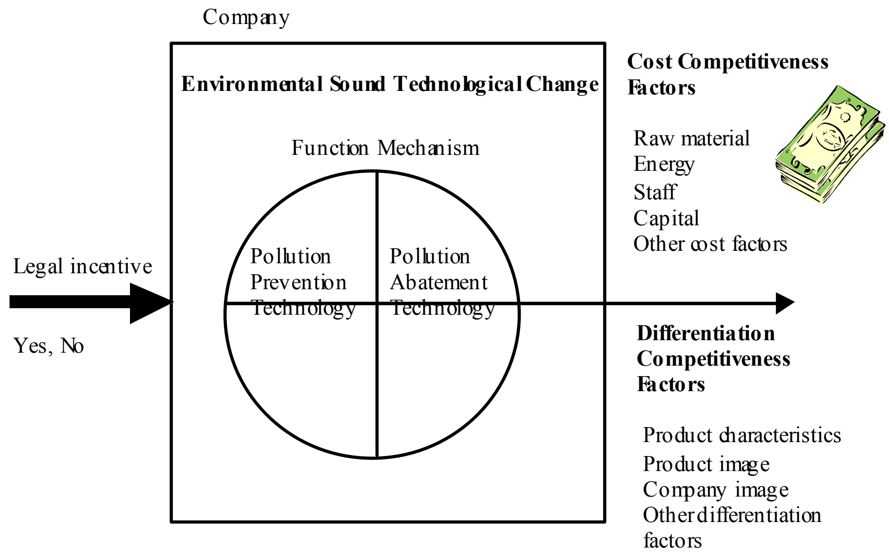

Figure 8.3.1 Model for testing the 'Porter Hypothesis'

Research Design and Data Collection

The data were collected from acknowledged experts using structured interviews. Face-to-face interviews were used to gather the data when the technology and competitiveness issues were very complicated. For structured interviews, the interviewer used an interview form with predetermined questions. The questions included were both close-ended and open-ended, which yield quantitative and qualitative data (Fowler and Magione, 1990; Fowler, 1993; Oppenheim, 1997). Two sorts of questionnaires were designed for data collection interviews: a questionnaire for identifying environmentally sound technologies and putting them in order of importance of environmental impact and a questionnaire for assessing the competitiveness impact of each identified technology. The questionnaires are presented in appendixes II and III.

The permission to interview was sought from the selected respondents by e-mail or telephone. All of the asked respondents were available for the interview. The questionnaires were sent to the respondents in advance and the interviews took place in their offices.

At first the respondents were asked to identify five of the most important for environmental impacts of environmentally sound technologies that had been implemented since 1980 (1980-1999). Furthermore, they were asked to identify five of the most important for environmental impacts environmentally sound technologies, which were expected to be implemented before 2020 (2000-2019). The type of question was open-ended. Then the respondents were asked to rank the technologies in order, from the most important to the fifth important according to environmental impacts. This means that the ordinal scaling was used here. The respondents were asked to describe what has been changed to which technology. The questions were open-ended. The respondent was asked to answer or familiarise herself or himself beforehand with Questionnaire number 1, shown in Appendix II.

The next step of the interview dealt with the impacts of the environmentally sound technology on the competitiveness factors of companies. The interviews focused on identified environmentally sound technologies and their impacts on competitiveness. The respondents were asked to describe the technology in terms of environmental aspects affected, breakthrough time period and legal and other incentives for implementation. The influence mechanisms of the technology were also asked about, resulting in qualitative data about the technology for categorising according to function mechanism of pollution prevention and pollution abatement. The interview phase was carried out by closed-ended, structured questions, but also some open-ended questions were included. The used question types were factual questions based on facts given by the respondents and non-factual questions based on the opinion or belief of the respondents. Competitiveness impacts were measured by assessing them along a five-stage scale of significantly decreasing (-2), a little decreasing (-1), no effect

(0), a little increasing (1) and significantly increasing (2) impact on competitiveness of companies). Questionnaire number 2, shown in Appendix III, presents the detailed questions about competitiveness impacts.

The duration of interviews varied from two-and-a-half to four hours. The interviews of Finnish respondents were carried out in Finnish. The German and Swedish interviews were carried in English and were taped.

8.4 Data Analysis

The descriptive data of technologies was transformed to quantitative data by categorising them. Categorised data and measurement data were analysed by frequencies and statistical tests (Agresti, 1996).

Data Categorising

The data relating to the environmentally sound technologies were classified as the following technological categories: automation, measurement and information technology, operation, energy technology, chemical-elimination technology, closing-up technology, wastewater technology, wood- and recycled-fibre technology, solid-waste technology, and emission-control technology. The definitions of categories of variables, such as part of value chain, technological category, effective time period, environmental aspect, function mechanism, breakthrough time period, legal incentive, other-than-legal incentive, categorised other-than-legal incentive, impact on competitiveness of company in the other part of value chain, categorised impact on competitiveness of company in the other part of the value chain, significantly competitiveness-increasing technology, significantly competitiveness-decreasing technology, joint variable of function mechanism and legal incentive (Porter Hypothesis) and competitiveness factors are all presented in Tables IV-1…15 in Appendix IV.

The value chain was categorised as parts of forest harvesting, pulp mill, paper mill and printing house. The technological categories were automation, measurement and information technology, operation, energy technology, chemical-elimination technology, closing-up technology, wastewater technology, wood- and recycled-fibre-using technology, solid-waste technology, and emission-control technology. Time period was categorised as 1980-1999 and 2000-2019.

The environmentally sound technologies were categorised as the environmental aspects that they basically controlled. An environmental aspect is, by definition, an element of an organisation's activities, products or services that can interact with the environment (Suomen Standardisoimisliitto, 2004). Environmental aspects were categorised as follows: emissions to air, releases to water, waste management, use of energy, use of raw materials and natural resources, use of fresh water, biodiversity, contamination of land and landscape.

The environmentally sound technologies were classified into pollution-prevention technology and pollution-abatement technology. The researcher classified the environmentally sound technologies based on the responses of the questions: 'What has been changed to which?' and 'Description of mechanism influencing a part of the value chain?' The breakthrough time period was divided into the following time periods: before 1980, 1980-1989, 1990-1999, 2000-2009 and 2010-2019.

In this study, legal incentive means any kind of legislative stimulation focused on the technology. Respondents were asked whether there had been or will be legal incentives that impact on environmentally sound technology. The categories were 'yes' or 'no'. When respondents were asked the question 'What kind of legal incentives has been…', their answers included 'penalties', too. The responses were categorised from the data.

It was asked whether there have been or will be other incentives that impact on the technology. The categories were 'Yes' or 'No'. Respondents were asked to identify the other-than-legal incentives. The 'other-than-legal' incentives were categorised from data, such as cost, public image, ability to operate, financial or other subvention, market pressure, energy supply and development of technology.

In cost-competitiveness assessment, the raw material variable was divided into material efficiency and material change. The categories were formulated from the data. The material efficiency was classified into material consumption, waste production and material management. The energy variable was divided into energy efficiency, energy consumption and energy production. The staff variable was divided into number of staff, and education and skills. Capital cost was divided into intensified capital and released capital. In cost-competitiveness assessment, the respondents mentioned various types of other cost-competitiveness factors, which were classified into operation cost and transportation. All categories were formulated from the data. The categories were partly overlapping.

In the differentiation competitiveness assessment, the product characteristic variable was classified into quality and use. The product image variable was divided into environmental image and high-technology image. The company image variable was divided into good citizenship, environmental image and high-technology image. The other differentiation factors were classified as transportation and ability to operate. All categories were formulated from the data.

It was asked if an environmentally sound technology impacts on competitiveness of company in the other part of the value chain or not and how has it affected factors of cost and differentiation. The categorised impacts were raw material in the following phase, environmental image, ability to operate, cost, paper market, logistic and other. The technologies were categorised as significantly competitiveness-increasing technologies and other investigated technologies, and significantly competitiveness-decreasing technologies and other investigated technologies in order to a study the best and the worst technologies for the companies.

For testing the Porter Hypothesis the technologies were clustered into categories of pollution-prevention technology with and without legal incentives and pollution-abatement technologies with and without legal incentives. All definitions of the categories of variables are presented in Tables IV-1…15 of Appendix IV.

Statistical Analysis of Data

Responses of respondents to the interview questions were coded, the qualitative data categorised and coded and all the data put into a database of the SPSS (2002) program. The descriptive statistics were used to describe data. The scores of each category as a single variable were summarised into frequencies and the distribution of scores was presented as histograms. The frequencies and distributions were analysed. The description of the data took the form of response frequencies in various categories of the measurement scale, mean and contingency tables (Fitz-Gibbon and Morris, 1987; Hildebrand and Ott, 1996; Järvenpää and Kosonen, 1996; Karma, 1980; Laitinen, 1998).

All the tested variables, their measurement, a number of response categories, type of measurement scale and used tests are presented in Appendix V. Statistical tests were used to study the relationships among variables. The acceptable risk level is classified (Grönroos, M, 2004) as follows: evidence suggestive ($0.1>p>0.05$), evidence moderate, almost significant ($0.05>p>0.01$), evidence strong, significant ($0.01>p>0.001$) and very significant ($0.001>p$).

Pearson Chi-Square Test was used in analysing the contingency tables. It was used to test the statistical significance of difference between the frequency distribution of two or more groups (Siegel, 1956). When the use of Chi-Square test was not acceptable because of the small size of the sample, other tests were used.

Fisher's exact significance test was used to analyse binominal two-way contingency tables, when the use of the Pearson Chi-Square was not acceptable. The tested variables were time period, function mechanism, legal incentives, other-than-legal incentives, impact on competitiveness of companies in the other parts of significantly competitiveness-increasing technology and significantly competitiveness-decreasing technology.

Likelihood-ratio G2 statistics were used for analysing small samples when the Chi-Square test and Fisher's exact significance test were not possible from that data. The likelihood-ratio G2 statistic was used especially for analysing k sample contingency tables measured on a nominal scale (Siegel, 1956). The two- and three-way contingency tables were analysed.

The Mann-Whitney U test was used for analysing the difference between binominal variables, such as time period, function mechanism, legal incentive, other-than-legal incentives, impact on competitiveness on companies in the other part of the value chain, significantly competitiveness-increasing technology, significantly competitiveness-decreasing technology, and variables of competitiveness and the importance on environmental impact measured on an ordinal scale.

The Kruskal-Wallis H one-way analysis of variance was used for analysing the significance of differences among multinomial variables (Siegel, 1956), such as the value chain, technological category, environmental aspect, breakthrough time period, categorised other-than-legal incentives, categorised impact on other part-of the value chain, a variable of Porter Hypothesis consisting function mechanism and legal incentive, in variable values of competitiveness assessment and importance on environmental impacts measured on an ordinal scale.

Spearman rho correlation test was used to analyse correlations among variables of competitiveness and also importance on environmental impacts measured on an ordinal scale.

9 Results

9.1 Environmentally Sound Technologies

Eight experts were interviewed resulting in 69 environmentally sound technologies in the time periods 1980-1999 and 2000-2019 (Table 9.1.1). The interview covered the value chain of printed paper divided into four parts: forest harvesting, pulp mill, paper mill and printing house. In Appendix I, the respondents are presented, while in Appendix VI identified environmentally sound technologies, their importance on environmental impacts, time period of and technological category are presented.

Table 9.1.1 Response Frequencies of the Mentioned Environmentally Sound Technologies in the Value Chain of Printed Paper in the Time Periods 1980-1999 and 2000-2019

Part of Value Chain	**Time Period 1980-1999**	**Time Period 2000-2019**	**Total**
Forest harvesting	8	10	18
Pulp mills	10	8	18
Paper mills	9	9	18
Printing houses	7	8	15
Total	34	35	69

The identified environmentally sound technologies over the value chain of printed paper are classified into technological categories (Table IV-3 in Appendix IV). The most frequently mentioned technologies were automation, measurement and information technology (16 responses) and energy technology (13 responses) and closing-up technologies (nine responses). The response frequencies of technological categories are presented in Table 9.1.1.

Table 9.1.1 Response Frequencies of Environmentally Sound Technologies in Technological Categories

Technological Category	Response Frequency
Automation, measurement and information technology	16
Energy technology	13
Closing-up technology	9
Wood and recycled-fibre technology	8
Operation	8
Chemical-elimination technology	6
Emission-control technology	4
Wastewater technology	3
Solid-waste technology	2

The differences among technological categories in effective time period and in breakthrough time period were tested. There is no significant difference between technological categories in the time period 1980-1999 and the time period 2000-2019 (likelihood ratio G2 = 12.770, df = 8, symp.sign (two-sided) = 0.120) and breakthrough time period (likelihood ratio G2 = 24.838, df = 28, symp.sign. (two-sided) = 0.637).

Importance on Environmental Impacts

The respondents were asked to put environmentally sound technologies in order of importance on environmental impact. The weighted means of variable values of importance on environmental impact and the technological category are presented in Figure 9.1.2. By weighted means, automation, measurement and information technology, closing-up technology, and energy technology were the most important for environmental impacts among technological categories.

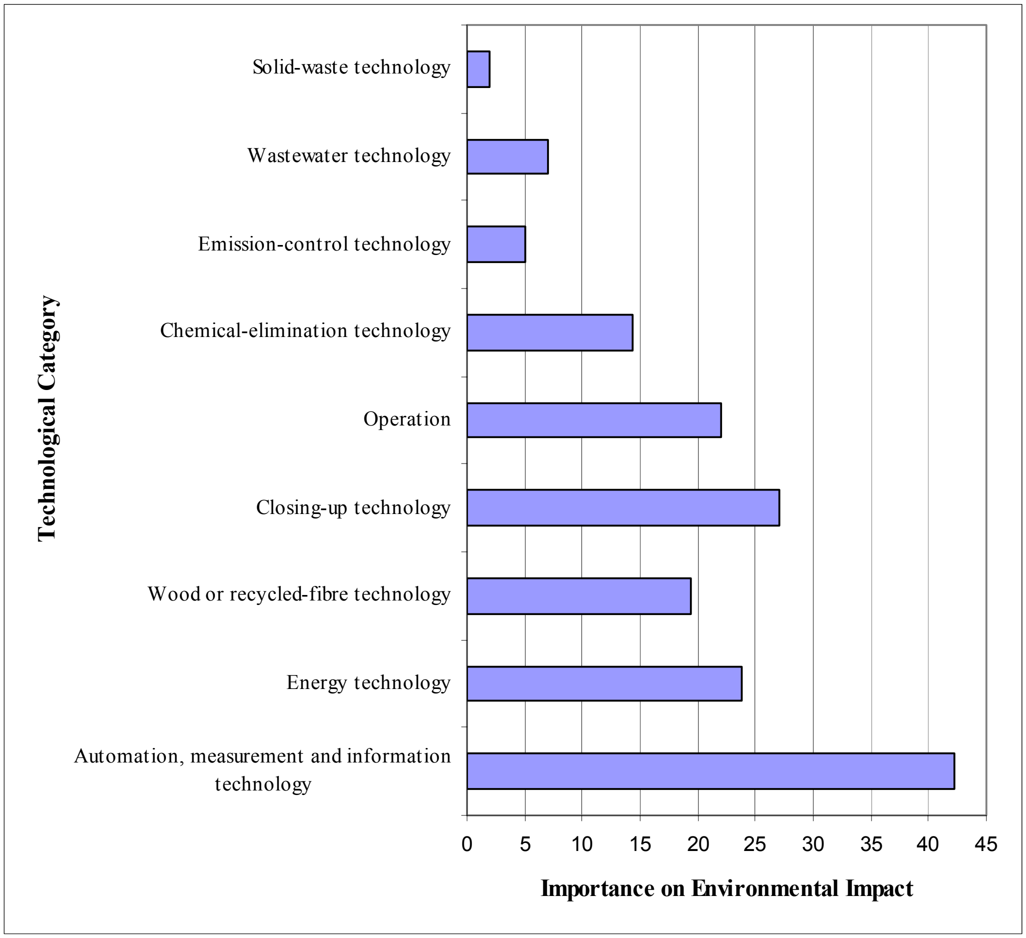

Figure 9.1.2 Weighted means of importance on environmental impacts and technological categories

The importance on environmental impact of environmentally sound technologies did not differ in time periods 1980-1999 and 2000-2019 (Mann-Whitney U = 425.000, asymp.sig. (two-tailed) = 0.711), in function mechanism (Mann-Whitney U = 135.500, asymp.sig. (two-tailed) = 0.256), in legal incentive (Mann-Whitney U = 389.500, asymp.sig. (two-tailed) = 0.765), in other-than-legal incentives (Mann-Whitney U = 24.000, asymp.sig. (two-tailed) = 0.341) and in impact on competitiveness of company in the other part of the value chain (Mann-Whitney U = 402.500, asymp.sig. (two-tailed) = 0.954), chemical-elimination.

Environmental Aspects

It was asked what environmental aspect the technological change affected. Figure 9.1.4 presents response frequencies of environmental aspects controlled by environmentally sound technologies in the time periods 1980-1999 and 2000-2019. Use of raw materials and natural resources (25 responses) was mentioned the most frequently as the environmental aspect controlled by the environmentally sound technologies. Emissions to air (ten responses) was the second most frequent category of environmental aspects controlled and releases to water and emissions to air were the third. Moderate evidence was found for a difference among environmental aspects in the time period 1980-1999 and 2000-2019 (Likelihood ratio $G2 = 15.952$, $d = 8$, asym.sign. (two-sided) = 0.043).

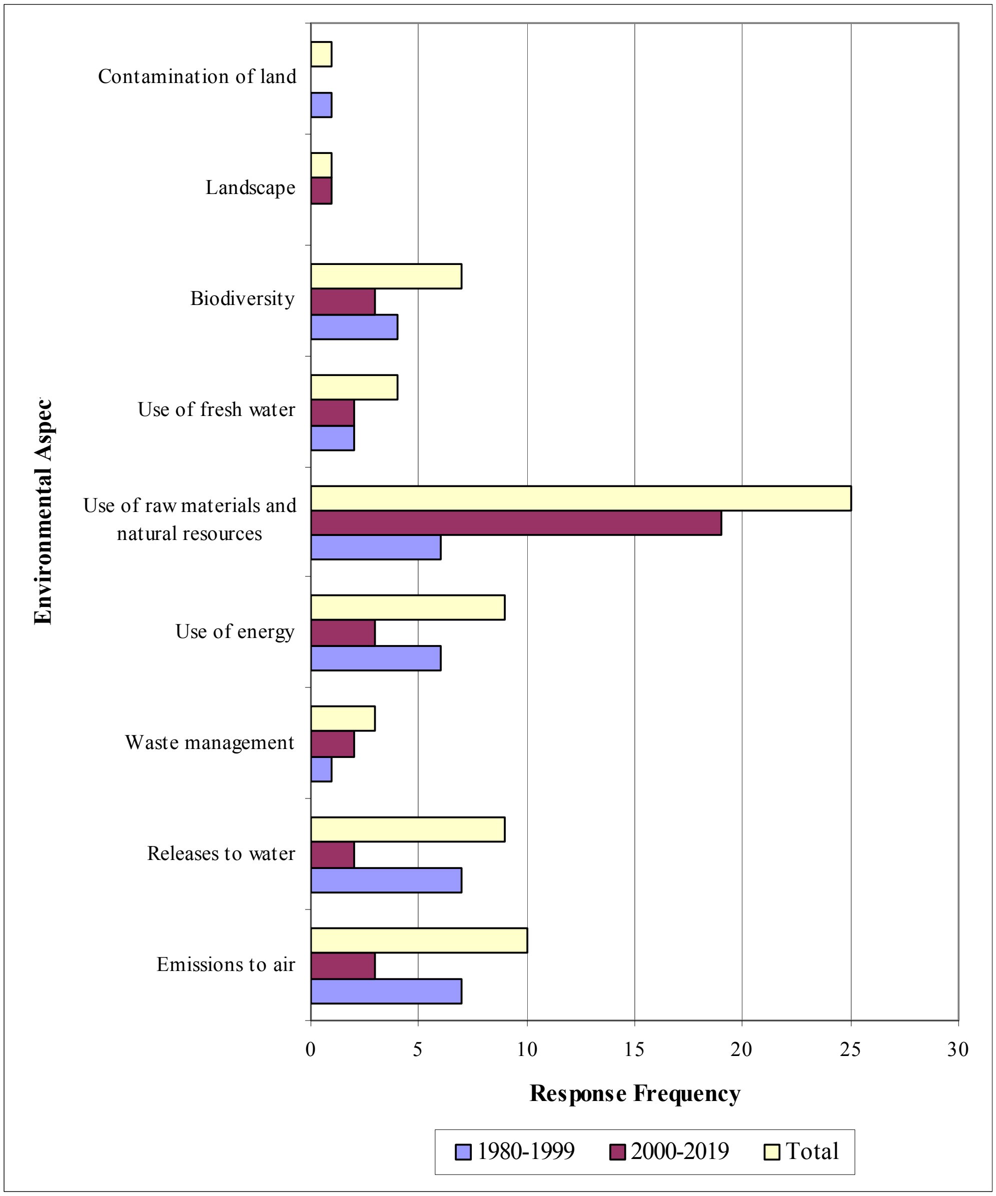

Figure 9.1.4 Response frequencies of environmental aspects controlled by environmentally sound technologies in time periods 1980-1999 and 2000-2019.

In the time period 1980-1999, the most frequently mentioned environmental aspects were emissions to air (seven responses) and releases to water (seven responses). In the time period 2000-2019, the most frequently mentioned aspect was use of raw material and natural resources (19 responses), and the second use of energy (three responses), emissions to air (three responses) and biodiversity (three responses). It was found that there were more responses to use of raw material in the time period 2000-2019 (19 responses) than in the time period 1980-1999 (six responses). There were fewer responses to emissions to air, releases to water, use of energy and biodiversity in the time period 2000-2019 than in the time period 1980-1999. Landscape was a new environmental aspect controlled by environmentally sound technologies in the time period 2000-2019.

There was a very significant differences among technological categories in environmental aspects (likelihood ratio G2 = 136.904, df = 64, asym.sign. (two-sided) = 0.000). In Table VII-1 in Appendix VII the response frequencies of environmental aspects controlled by the technological categories of environmentally sound technologies are presented. Automation, measurement and information technologies control mainly the use of raw materials and natural resources (11 responses). Energy technologies control the use of energy (six responses) and use of raw material and natural resources (five responses). Wood and recycled-fibre technologies control mainly use of raw material and natural resources (six responses). Closing-up technologies control releases to water (four responses) and use of fresh water (four responses). Operations control biodiversity (four responses). Chemical-elimination technologies control emissions to air (four responses) and releases to water (four responses). Emission-control technology emissions to air (four responses). Wastewater technology control releases to water (two responses) and solid-waste technologies waste management (two responses).

9.2 Incentives for Environmentally Sound Technologies

9.2.1 Legal Incentives

It was asked what kind of legal incentive impacted on the environmentally sound technology. In 26 out of 67 technologies, legal incentive was mentioned as impacting on the environmentally sound technology, and in 41 responses there was no legal incentive impacting on the technology. The respondents specified the legal incentives, which are presented in Table VIII-1 of Appendix VIII.

It was found that there was almost significant differences among technological categories in having legal incentives and not having legal incentives (Figure 9.2.1.1) (likelihood ratio G2 = 18.947, df = 8, asym.sign. (two-sided) = 0.015). The categories of automation, measurement and information technology (15 responses) and closing-up technology (six responses) are not very frequently impacted by legal incentives but categories of operation (six responses) and chemical-elimination technology (four responses) are. Energy technologies are not impacted (nine responses) by legal incentives, but there are energy technologies, which are impacted by legal incentives (four responses).

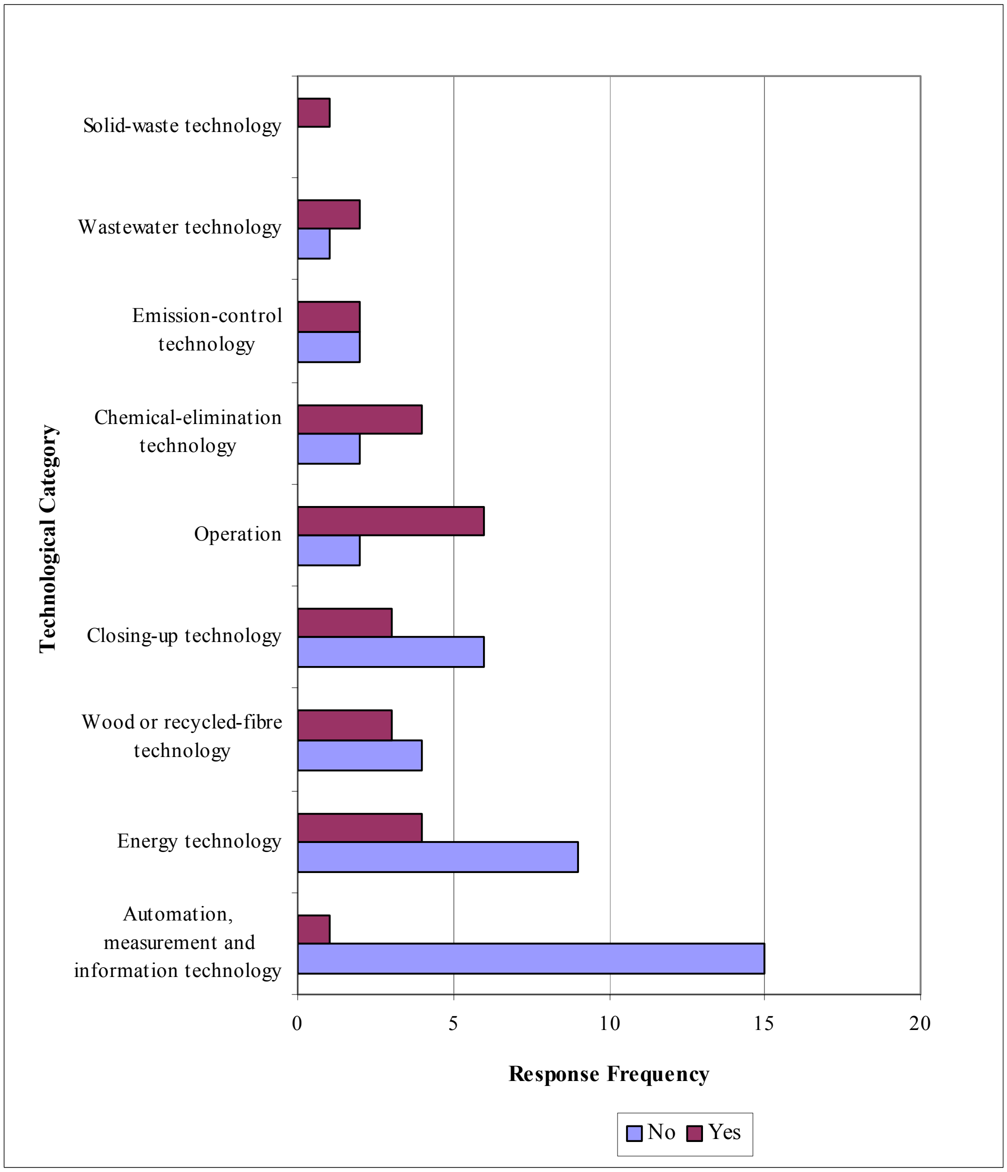

Figure 9.2.1.1 Response frequencies of technological categories in having legal incentive (yes) and not having legal incentive (no).

Suggestive evidence was found for a difference between having legal incentive and not having legal incentive in environmental aspects (Figure 9.2.1.2) (G2 = 13.332, df = 8, asymp.sign. (two-sided) = 0.101). Environmentally sound technologies controlling raw material and natural resources have the most frequently not legal incentives impacted on (17 responses), but also legal incentives impacted (seven responses). The technologies controlling use of energy have the second frequently not legal incentives impacted on (seven responses). The technologies controlling releases to water (six responses) are the second frequently impacted on by legal incentives. The technologies controlling emissions to air are impacted by legal incentives (five responses), but are not impacted (five responses), too.

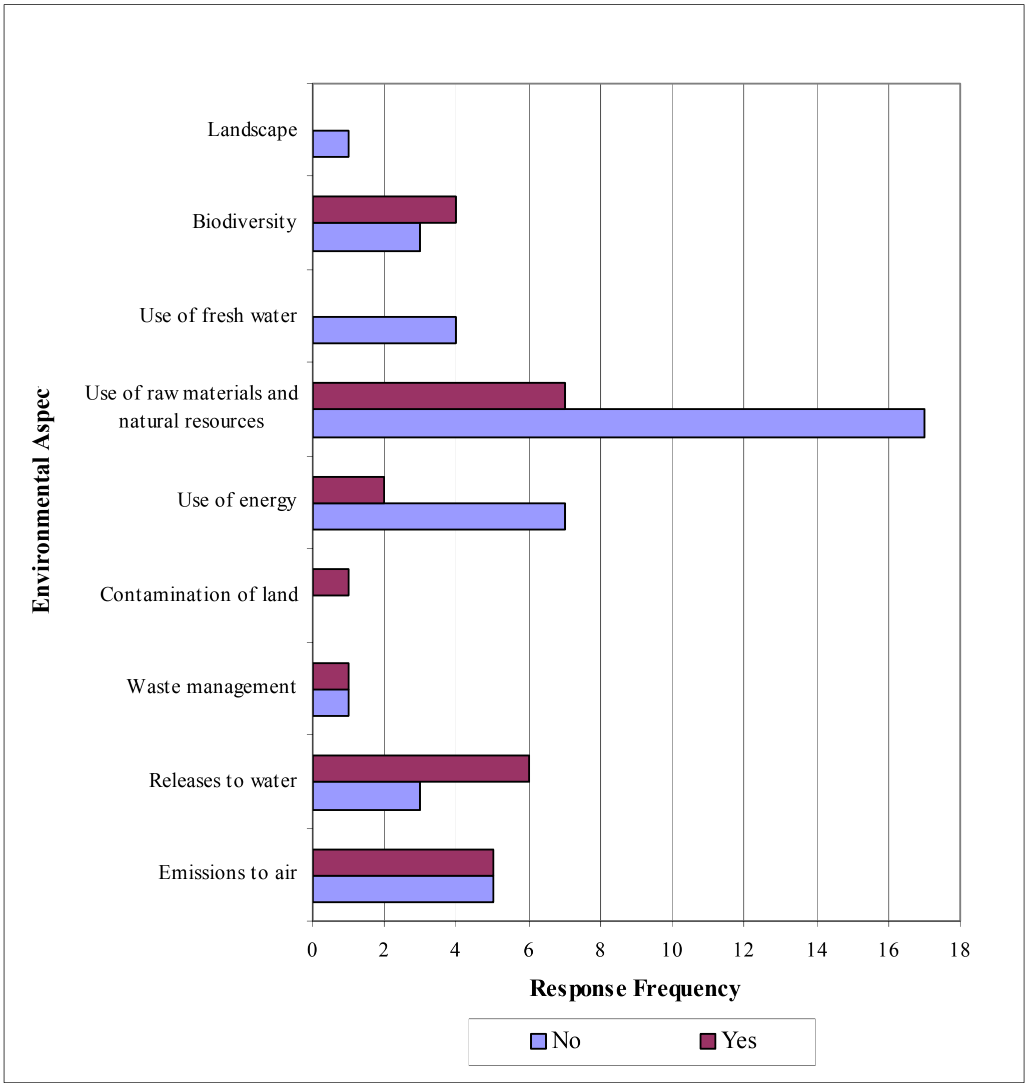

Figure 9.2.1.2 Response frequencies of environmental aspects controlled by environmentally sound technologies divided into categories having legal incentive (yes) and not having legal incentive (no).

Suggestive evidence was found for a difference between *function mechanism of pollution prevention* and *pollution abatement* in *having legal incentives* and *not* *having legal incentive* related to environmentally sound technologies (Fisher's exact sig. (two-sided) = 0.099). Pollution-prevention technologies were less impacted by *legal incentives* than *pollution-abatement technologies* were. The frequencies are presented and these differences later tested as a variable of Porter Hypothesis.

There is difference between having legal incentive and not having legal incentive in breakthrough time period (likelihood ratio G2 = 3.974, df = 4,asymp.sign. (two-sided) = 0.410), and in the time period of 1980-1999 and 2000-2019 (Chi-Square $\chi 2$ = 0.820, df = 1, asymp.sign. (two-sided) = 0.365).

9.2.2 Other-than-Legal Incentives

It was asked what kind of other-than-legal incentives affected the technologies. Fifty responses out of 54 mentioned other-than-legal incentives affecting technologies. There was no difference between having other-than-legal incentive and not having them in the time periods 1980-1999 and 2000-2019 (Fisher's exact test p (two-sided) = 1.000), in technological categories (likelihood ratio G2 = 3.721, df = 8, asym.sign. (two-sided) = 0.881), in environmental aspects (likelihood ratio G2 = 3.300, df = 8, asymp.sig. (two-sided) = 0.914), in breakthrough time periods (likelihood ratio G2 = 2.501, df = 4, asymp.sig. (two-sided) = 0.644) and in having legal incentive (Fisher's exact test p(two-sided) = 1.000).

Other-than-legal incentives are classified into categories (Figure 9.2.2.1). The most frequently mentioned other-than-legal incentives are cost (19 responses), the second public image (12 responses), and the third market pressure (five responses).

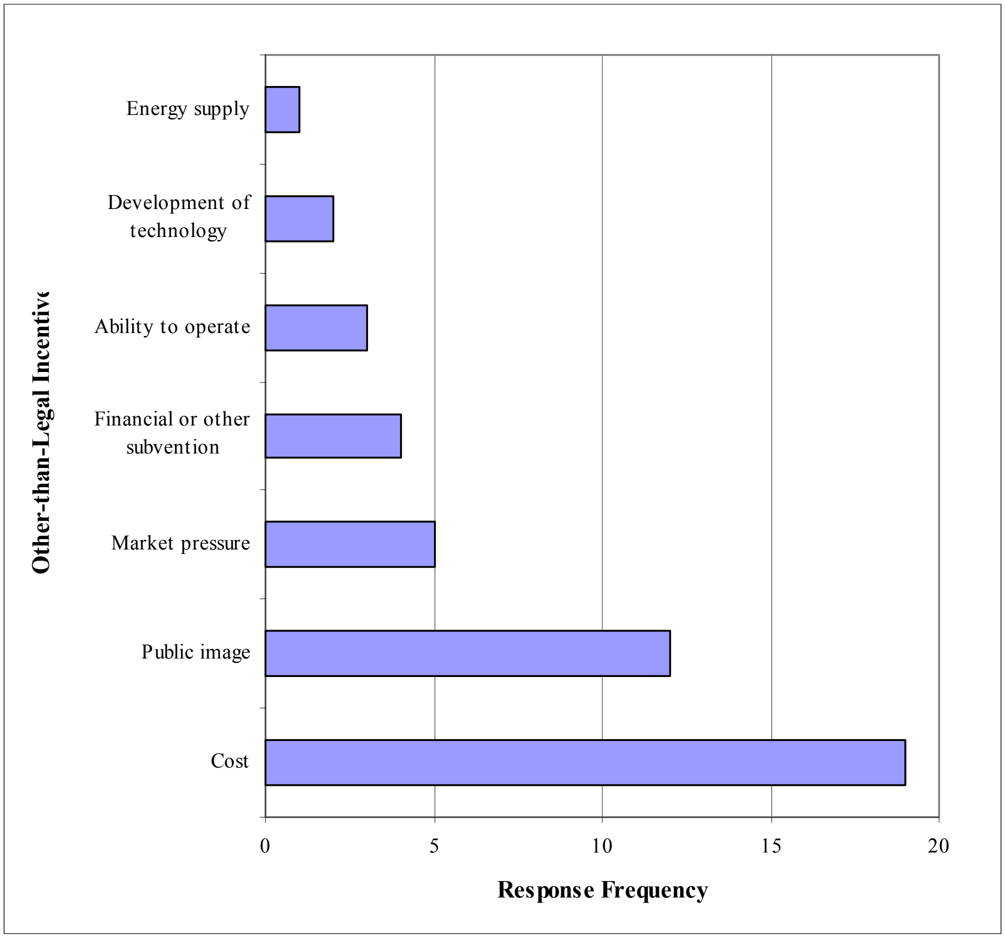

Figure 9.2.2.1. Response frequencies of categorised other-than-legal incentives

Suggestive evidence was found for differences among categorised other-than-legal incentives in technological categories (G2 = 73.289, df = 56,asymp.sign. (two-sided) = 0.060). In Table VII-2 of Appendix VII, the response frequencies of categorised other-than-legal incentive divided into technological categories are presented.

Cost was the most frequently mentioned other-than-legal incentive for automation, measurement and information technologies (11 responses) but also important for energy technologies (five responses). Public image was an important incentive for closing-up technologies (four responses) and operations (three responses). Market pressure was an important incentive for automation, measurement and information technologies (two responses) and chemical-elimination technologies (two responses).

There was no difference among categorised other-than-legal incentives in the time period 1980-1999 and 2000-2019 (likelihood ratio G2 = 9.458, do = 7, asym.sign. (two-sided) = 0.221), in environmental aspects (likelihood ratio G2 = 61.557, df = 56, asymp.sig. (two-sided) = 0.284), in breakthrough time (likelihood ratio G2 = 26.891, df = 28, asymp.sig. (two-sided) = 0.524) and in having legal incentive (likelihood ratio G2 = 10.244, df = 7, asymp.sig. (two-sided) = 0.175).

9.3 Function Mechanism of Pollution Prevention and Pollution Abatement

A description of the influencing mechanism of environmentally sound technology was asked for. The data was categorised into function mechanism of pollution-prevention technology and pollution-abatement technology. Most of the technologies represented pollution-prevention technology (62 responses out of 69). Only seven out of 69 technologies represented the pollution abatement mechanism.

Almost significantly suggestive evidence was found for a difference between the time periods 1980-1999 and 2000-2019 in the function mechanisms (Fisher's exact test significance (two-sided) = 0.055). In six responses out of seven, pollution-abatement technologies are from the time period 1980-1999. In 32 responses out of 60, pollution-prevention technologies are from the time period 2000-2019.

Very significantly evidence was found for differences among technological categories in the function mechanisms (Figure 9.3.1) (likelihood ratio G2 = 35.394, df = 8, asymp.sign. (two-sided) = 0.000). Automation, measurement and information technologies (16 responses), energy technologies (13 responses), closing-up technologies (nine responses) wood and recycled-fibre-using technologies (eight responses) and operations (eight responses), solid-waste technologies (two responses) are all pollution-prevention technologies. Wastewater technologies (three responses) and emission-control technologies (three responses and chemical-elimination technology (one response) were pollution-abatement technologies in their function mechanisms.

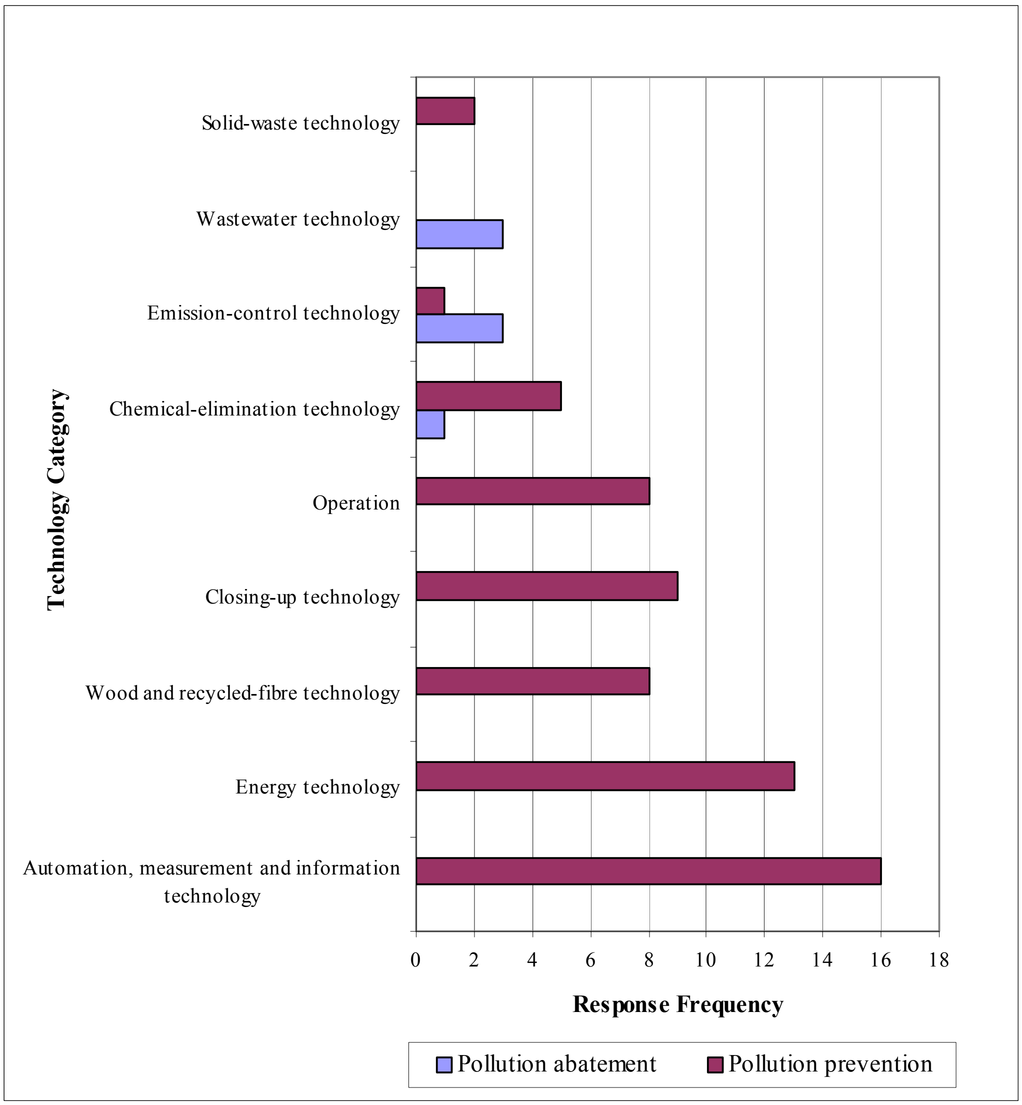

Figure 9.3.1 Response frequencies of technological categories divided into the function mechanisms of pollution prevention and pollution abatement

Almost significant evidence was found for differences among environmental aspects in function mechanisms (likelihood ratio G2 = 18.485, df = 8, asymp.sign. (two-sided) = 0.018). The pollution-abatement type of technology is used to control emissions to air (four responses), releases to water (two responses) and waste management (one response). Pollution-prevention technology is used to control all other environmental aspects (Figure 9.3.2) and most frequently use of raw material and natural resources.

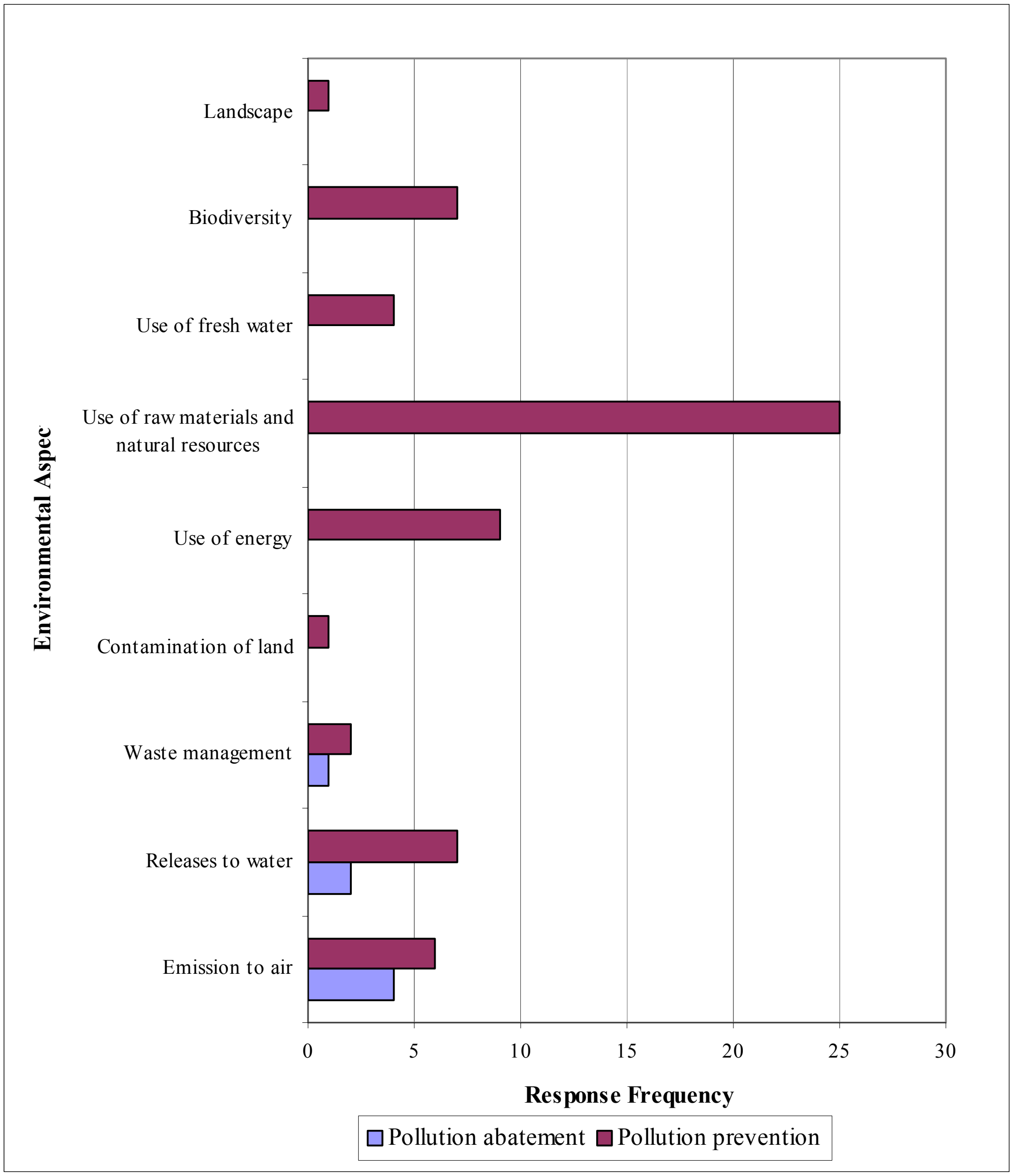

Figure 9.3.2 Response frequencies of environmental aspects controlled by technological categories divided into function mechanisms of pollution prevention and pollution abatement

Almost significantly suggestive evidence was found for differences among breakthrough time periods in function mechanisms of pollution prevention and pollution abatement (likelihood ratio G2 = 9.125, df = 4, asym.sign. (two-sided) = 0.058). The major breakthrough time for pollution-abatement technology is in the time period 1980-1990 (three responses), for pollution-prevention technology the time period 1990-1999 (16 responses) and the time period 2000-

2009 (15 responses). In Table VII-3 of Appendix VII, the response frequencies of function mechanisms divided into breakthrough time periods are presented.

It was found that there was no difference between function mechanisms of pollution prevention and pollution abatement in categorised other-than-legal incentives (likelihood ratio G2 = 10.303, df = 7, asym.sign. (two-sided) = 0.172).

9.4 Relationships Between Environmentally Sound Technologies and Competitiveness Factors of Companies

In the study, the respondents were asked to assess the competitiveness impacts of environmentally sound technologies they had identified. The competitiveness factors of companies were classified into cost-competitiveness factors and differentiation factors. Cost-competitiveness factors included raw material, energy, staff, and capital and other cost-competitiveness factors. Differentiation factors included product characteristic, product image, company image and other differentiation factors.

In the 66 out of 69 responses, the competitiveness of environmentally sound technologies was assessed to increase a little or significantly. In 35 out of 69 technologies, competitiveness was assessed to decrease a little or significantly. All technology affected competitiveness at least to some degree. There were three environmentally sound technologies, which the respondents could not assess.

9.4.1 Impact of Environmentally Sound Technologies on Cost-Competitiveness of Companies

Raw Material as a Cost-Competitiveness Factor

Respondents were asked to assess the direction and significance of the competitiveness impact caused by the raw material factor related to environmentally sound technology. In 43 out of 66 responses, the environmentally sound technologies were assessed to affect cost competitiveness of companies through raw material. In most of these technologies (32 responses), competitiveness increases through raw material, in thirteen technologies, significantly. In eleven technologies, the environmentally sound technology decreases competitiveness, in three technologies, significantly. In 23 responses, the raw material factor as a cost factor did not have an effect on competitiveness. The mean of competitiveness assessment was 0.47, which is indicative of increasing competitiveness. Figure 9.4.1.1 presents the response frequencies of competitiveness assessment of the raw material factor related to environmentally sound technologies.

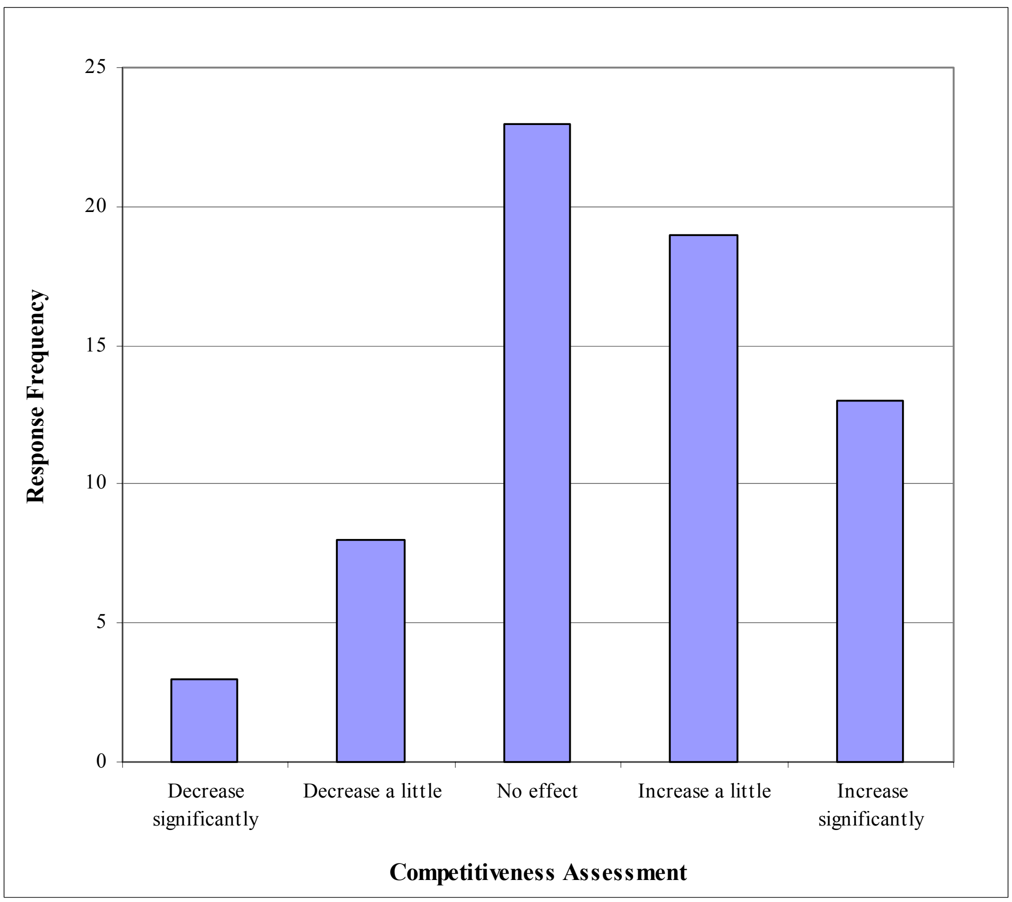

Figure 9.4.1.1 Response frequencies of competitiveness assessment of the raw material factor related to environmentally sound technologies

The raw material variable was classified into the categories of material efficiency (30 responses), change of material (18 responses), material consumption (24 responses), waste (15 responses) and material management (10 responses). The categories were partly overlapping.

Almost significantly evidence was found that the technological categories of environmentally sound technologies differed almost significantly when the competitiveness impacts of raw material factor were assessed (Kruskall-Wallis, $\chi 2 = 18.803$, df = 8, asymp.sig. = 0.016). Wood and recycled fibre technologies increased competitiveness through raw material mostly, but also through automation, measurement and information technologies and emission-control technologies. The only competitiveness-decreasing technologies were operations (Figure 9.4.1.2).

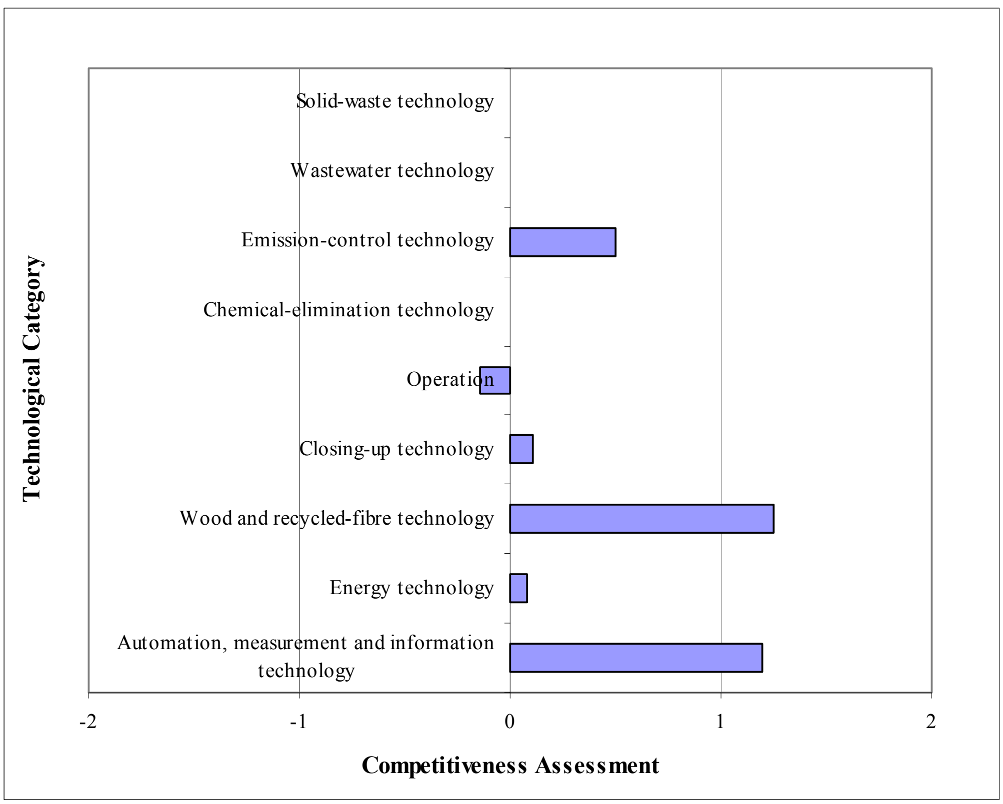

Figure 9.4.1.2 Means of competitiveness assessment of the raw material factor related to environmentally sound technologies divided into technological categories. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

Suggestive evidence was found for the environmental aspect of environmentally sound technologies differing when the competitiveness impacts of the material factor are assessed (Kruskall-Wallis, $\chi 2 = 12.573$, df = 6, asymp.sig.= 0.068). The environmentally sound technologies controlling the use of raw material and natural resources, use of energy and emissions to air increase the competitiveness of companies mostly through raw material and decrease it mostly through contamination of land and use of fresh water (Figure 9.4.1.3).

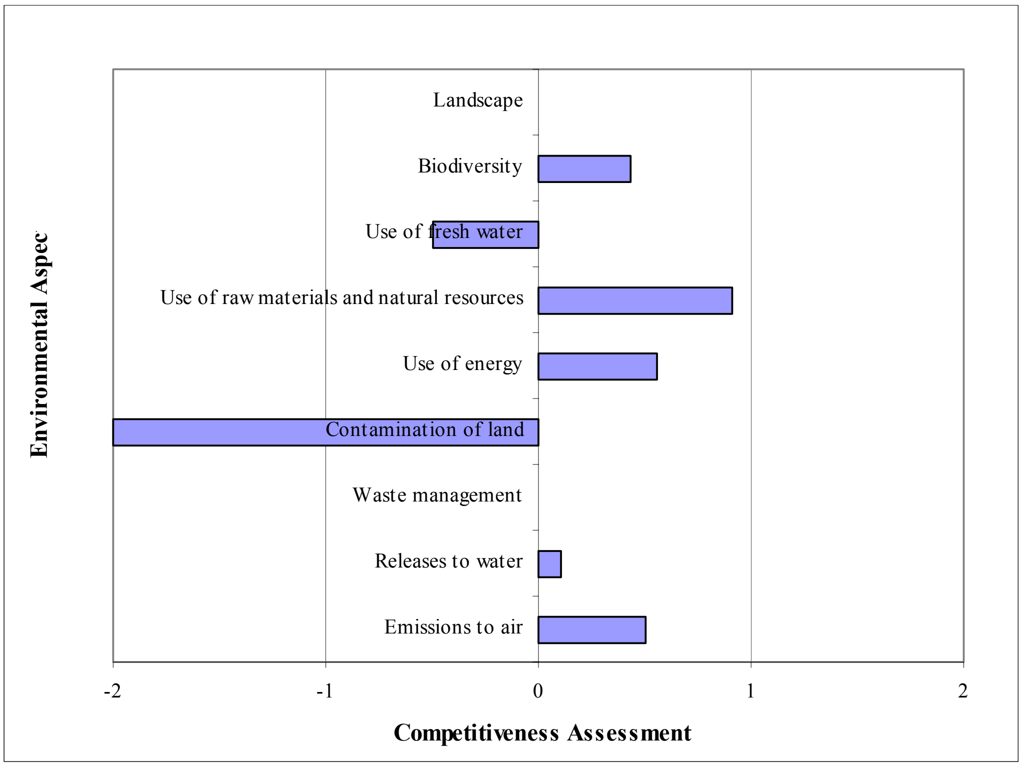

Figure 9.4.1.3 Means of competitiveness assessment of the raw material factor related to environmentally sound technologies divided into environmental aspects. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

When the competitiveness impacts of the raw material factor were assessed, the environmentally sound technologies did not differ in the time periods 1999 and 2000-2019 (Mann-Whitney U = 510.000, asymp.sig. (two-tailed) = 0.650), in breakthrough time periods (Kruskall-Wallis, $\chi 2 = 5.618$, df = 4, asymp.sig. = 0.230), in having legal incentive (Mann-Whitney U = 418.000, asymp.sig. (two-tailed) = 0.250), in having other-than-legal incentive (Mann-Whitney U =

52.500, asymp.sig. (two-tailed) = 0.429) and in function mechanism (Mann-Whitney U = 191.000, asymp.sig. (two-tailed) = 0.737).

Evidence for an association was not found between the competitiveness factor of raw material and importance on environmental impacts of environmentally sound technology (Spearman's rho = -0.093, Sig. (two-tailed) = 0.492).

Energy as a Cost-Competitiveness Factor

It was asked to assess the direction and significance of competitiveness impact caused by the energy factor related to environmentally sound technology. In 41 out of 65 environmentally sound technologies, the energy factors affect the cost competitiveness of companies. In most of these technologies (27 responses), cost competitiveness increases in ten responses significantly. In 14 technologies, the cost competitiveness is decreased by environmentally sound technology in four technologies significantly. In 24 technologies, the energy factor has no effect on competitiveness. The mean of competitiveness assessment was 0.29, which is indicative of increasing competitiveness. Figure 9.4.1.4 presents the response frequency of competitiveness assessment of the energy factor related to environmentally sound technologies.

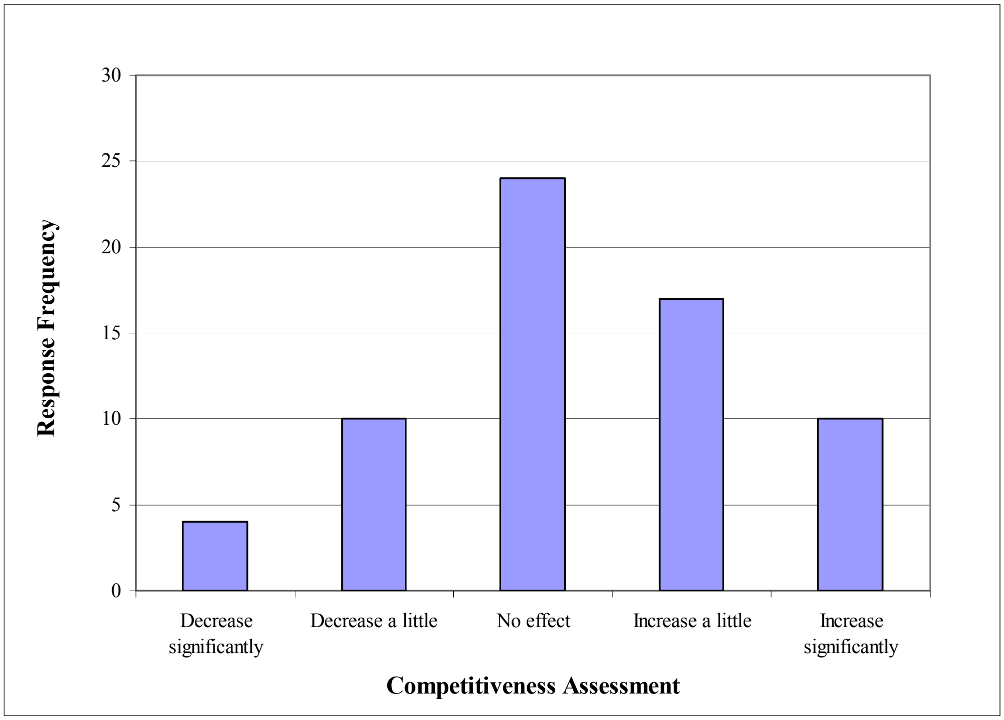

Figure 9.4.14. Response frequencies of competitiveness assessment of the energy factor related to environmentally sound technologies

The energy variable is classified into the categories of energy efficiency (38 responses), energy consumption (27 responses) and energy production (12 responses). The variables are partly overlapping.

Strong evidence was found that the environmental aspects of environmentally sound technologies differed significantly when the competitiveness impacts of energy factor were assessed (Kruskall-Wallis, $\chi 2 = 20.326$, df = 8, asymp.sig. = 0.009) (Figure 9.4.1.5). The technologies that control contamination of land and emissions to air decrease the competitiveness of companies through energy. Competitiveness through energy increasing Technologies that control use of energy, waste management, and use of raw material and natural resources increase competitiveness through energy factor.

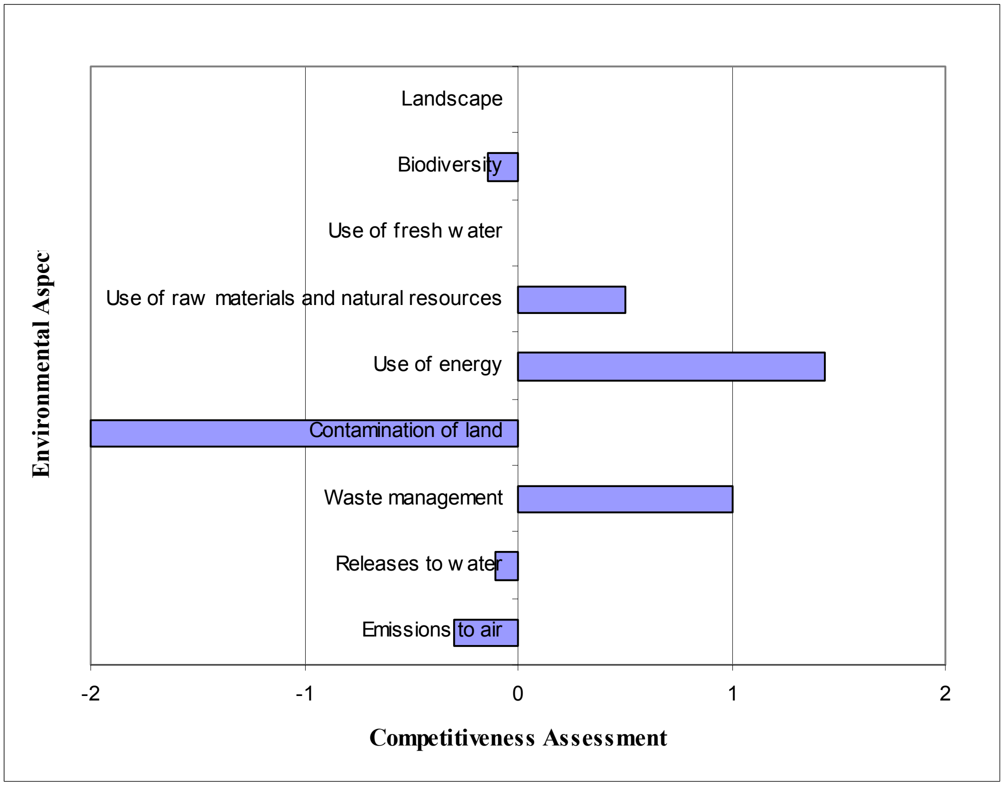

Figure 9.4.1.5 Means of competitiveness assessment of the energy factor related to environmentally sound technologies divided into environmental aspects. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

When the competitiveness impacts of the energy factor were assessed, environmentally sound technologies did not differ in having legal incentive (Mann-Whitney U = 399.000, asymp.sig. (two-tailed) = 0.242), in having other-than-legal incentives (Mann-Whitney U = 47.000, asymp.sig. (two-tailed) = 0.323), in the time periods 1980-1999 and 2000-2019 (Mann-Whitney U = 516.500, asymp.sig. (two-tailed) = 0.886), in technological categories (Kruskall-Wallis, $\chi 2$ = 10.497, df = 8, asymp.sig. = 0.232) and in categorised other-than-legal incentives (Kruskall-Wallis, $\chi 2$ = 15.523, df = 7, asymp.sig. = 0.030), in breakthrough time period (Kruskall-Wallis, $\chi 2$ = 3.552, df = 4, asymp.sig. = 0.470) and in function mechanism (Mann-Whitney U = 150.500, asymp.sig. (two-tailed) = 0.248).

Evidence for an association was not found between the competitiveness factor of energy and importance on environmental impact of environmentally sound technology (Spearman's rho = 0.007, Sig. (two-tailed) = 0.961).

Staff as a Cost-Competitiveness Factor

Respondents were asked to assess the direction and significance of the competitiveness impact caused by the staff factor related to environmentally sound technology. In 30 out of 66 environmentally sound technology technologies, the staff factors were found to affect the cost competitiveness of companies. In most of these technologies (23 responses), cost competitiveness increases, in eight technologies, significantly. In seven technologies, the cost competitiveness is decreased by environmentally sound technology. In 36 technologies, the staff factor had no effect on competitiveness. The mean of competitiveness assessment was 0.36, which is indicative of increasing competitiveness (Figure 9.4.1.6). The staff variable is classified into the categories of amount of staff (23 responses) and education and skills (nine responses).

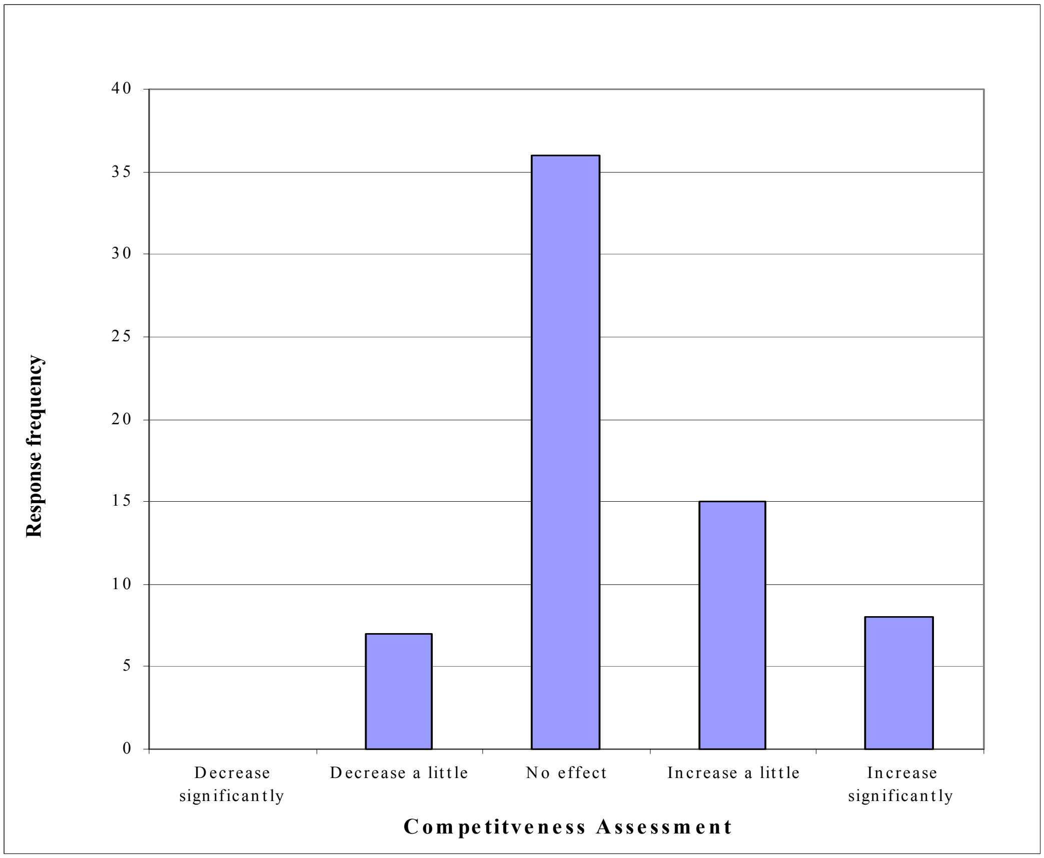

Figure 9.4.1.6 Response frequency of competitiveness assessment of staff factor related to environmentally sound technologies staff as a cost-competitiveness factor

Strong evidence was found that technological categories of environmentally sound technologies differed when the competitiveness impacts of staff factor were assessed (Kruskall-Wallis, $\chi 2 = 27.311$, df = 8, asymp.sig. = 0.001) (Figure 9.4.17).

Competitiveness of companies increases through staff using automation, measurement and information technologies, wood and recycled-fibre technologies, operations and energy technologies, but decreases competitiveness using solid-waste technologies, wastewater technologies and emission-control technologies.

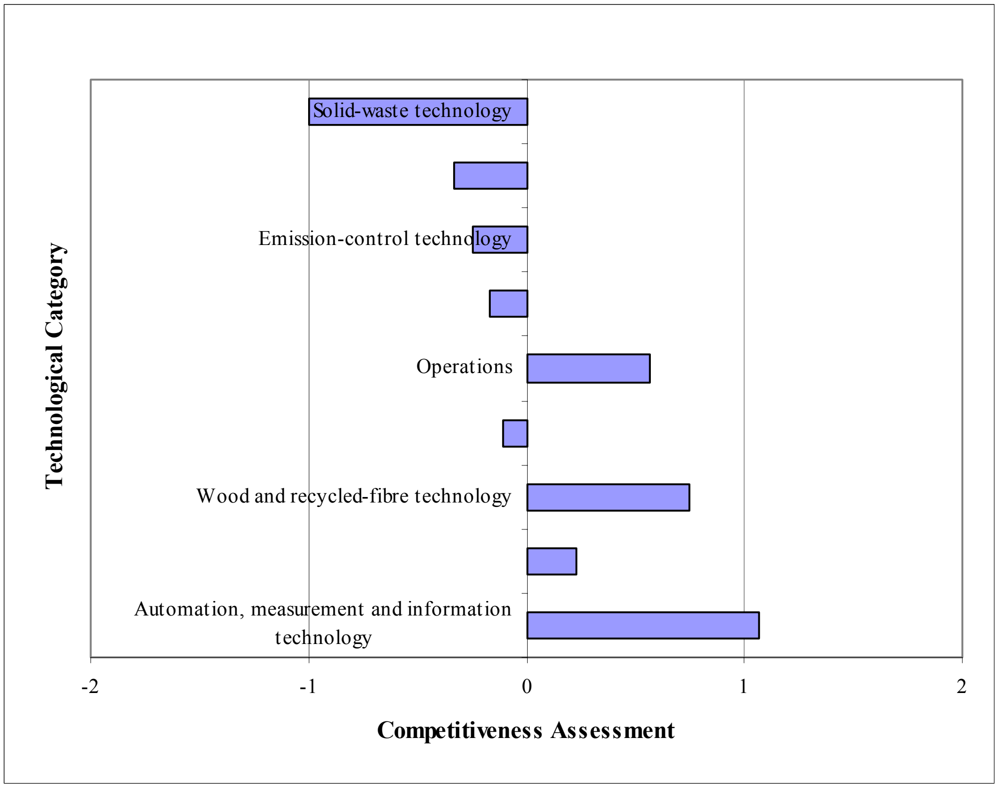

Figure 9.4.1.7 Means of competitiveness assessment of staff factor related to environmentally sound technologies divided into technological categories. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

Strong evidence was found that environmental aspects differed significantly when the competitiveness impacts of staff factor were assessed (Kruskall-Wallis, $\chi 2 = 23.989$, df = 8, asymp.sig. = 0.002) (Figure 9.4.1.8). The technologies that controlled waste management, releases to water and emissions to air decreased competitiveness through the staff factor. The technologies that controlled the environmental aspects of contamination of land, landscape, and use of raw material and natural resources increased competitiveness.

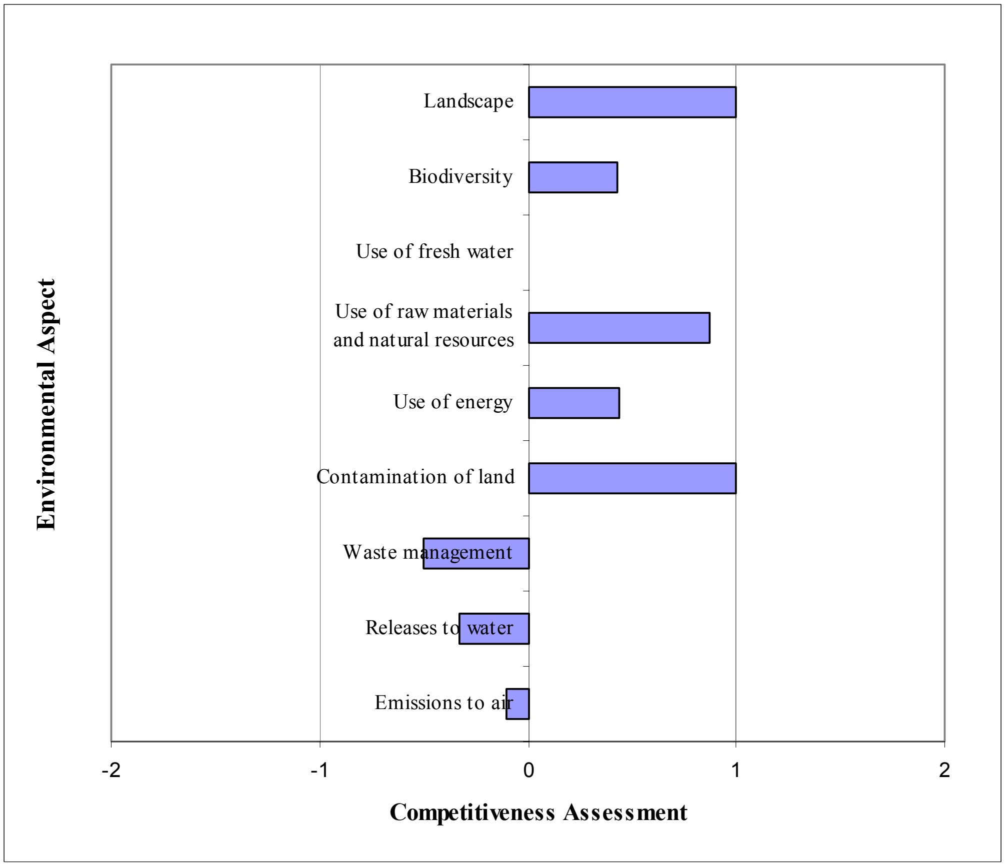

Figure 9.4.1.8 Means of competitiveness assessment of staff factor related to environmentally sound technologies divided into environmental aspects. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

Evidence was found that environmentally sound technologies differed in function mechanisms when the competitiveness impacts of the staff factor were assessed (Mann-Whitney U = 107.500, asymp.sig. (two-tailed) = 0.023). The mean of competitiveness assessment of pollution-prevention technologies was 0.45 (competitiveness increasing) and pollution-abatement technologies -0.35 (competitiveness decreasing).

When the competitiveness impacts of the staff factor were assessed, environmentally sound technologies did not differ in having legal incentive (Mann-Whitney U = 416.000, asymp.sig. (two-tailed) = 0.210), in having other-than-legal incentives (Mann-Whitney U = 51.000, asymp.sig. (two-tailed) = 0.406), in the time periods 1980-1999 and 2000-2019 (Mann-Whitney U =

534.000, asymp.sig. = 0.888), in breakthrough time periods (Kruskall-Wallis, $\chi2 = 4.514$, df = 4, asymp.sig. = 0.341) and in categorised other-than-legal incentives (Kruskall-Wallis, $\chi2 = 7.783$, df = 7, asymp.sig. = 0.352).

Evidence for an association was not found between the competitiveness factor of staff and importance on environmental impact of environmentally sound technology (Spearman's rho = -0.056, Sig. (two-tailed) = 0.678).

Capital as a Cost-Competitiveness Factor

It was asked to assess the direction and significance of the competitiveness impact caused by the capital factor related to environmentally sound technology. In 43 out of 64 environmentally sound technology technologies, the capital factors affected increasingly or decreasingly the cost competitiveness of company. In most of these technologies (28 responses), cost competitiveness decreased, in nine technologies, significantly. In 15 technologies, the cost competitiveness was increased by environmentally sound technology, in four technologies, significantly. In 21 technologies, the capital factor had no effect on competitiveness. The mean of competitiveness assessment was -0.28, which is indicative of decreasing competitiveness (Figure 9.4.1.9). The capital variable was classified into the categories of intensified capital (30 responses) and released capital (seven responses).

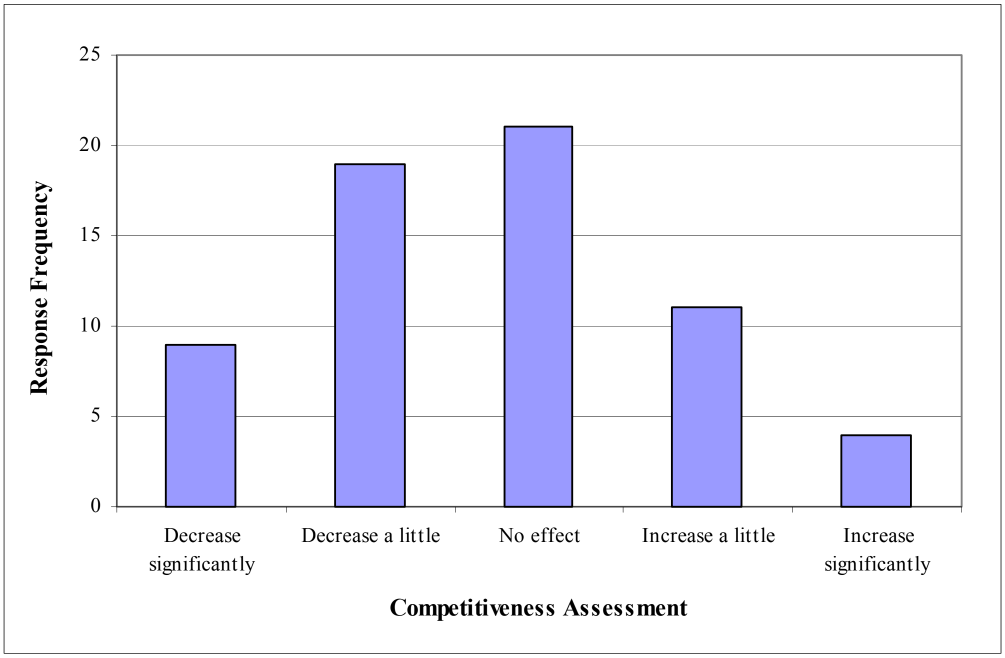

Figure 9.4.1.9 Response frequency of competitiveness assessment of capital factor related to environmentally sound technologies.

When the competitiveness impacts of the capital factor were assessed, environmentally sound technologies did not differ in the time periods 1980-1999 and 2000-2019 (Mann-Whitney U = 502.500, asymp.sig. (two-tailed) = 0.900), in technological categories (Kruskall-Wallis, $\chi 2$ = 12.312, df = 8, asymp.sig. = 0.138), having legal incentives (Mann-Whitney U = 414.000, asymp.sig. (two-tailed) = 0.374), in having other-than-legal incentive (Mann-Whitney U = 53.500, asymp.sig. (two-tailed) = 0.478), in breakthrough time periods (Kruskall-Wallis, $\chi 2$ = 7.380, df = 4, asymp.sig. = 0.117) in environmental aspect (Kruskall-Wallis, $\chi 2$ = 12.914, df = 8, asymp.sig. = 0.115) and in function mechanism (Mann-Whitney U = 149.000, asymp.sig. (two-tailed) = 0.289).

Evidence for an association was not found between the competitiveness factor of capital and importance on environmental impact of environmentally sound technology (Spearman's rho = -0.024, Sig. (two-tailed) = 0.859).

Other Cost-Competitiveness Factors

Respondents were asked to assess the direction and significance of the competitiveness impact caused by the other cost-competitiveness factor related to environmentally sound technology. In 33 out of 55 environmentally sound technologies, the other cost factor was affected increasingly or decreasingly by the competitiveness of companies. In 18 responses, competitiveness increased in six responses significantly. In 22 responses, there was no effect on competitiveness (Figure 9.4.1.10). The mean of competitiveness assessment was 0.16, which means no impact on competitiveness. The other cost competitiveness variable was categorised as the other operation cost (23 responses) and transportation (four responses).

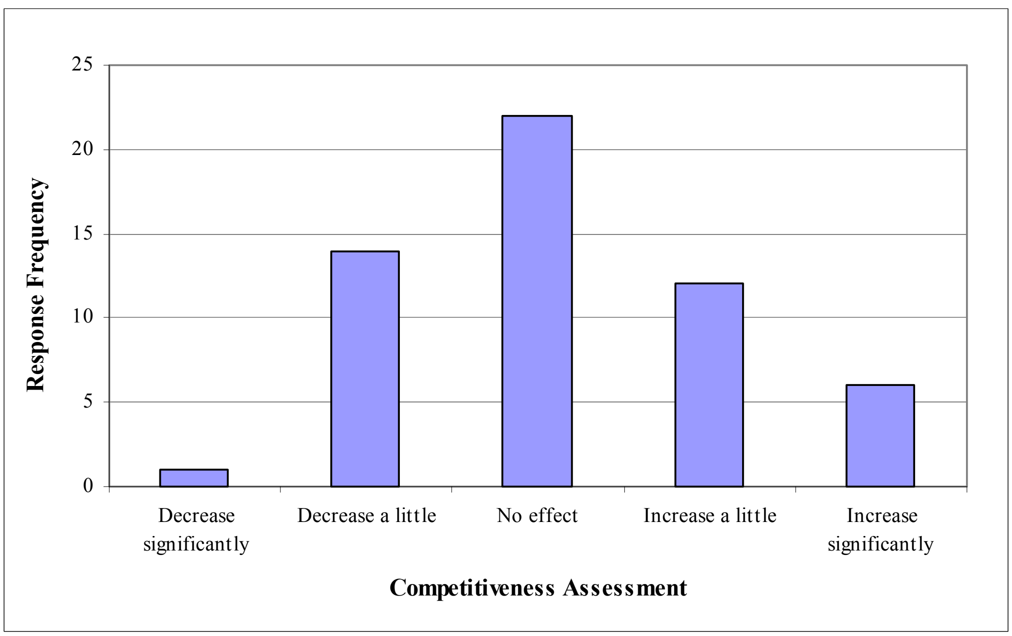

Figure 9.4.1.10 Response frequency of competitiveness assessment of other cost factor related to environmentally sound technologies.

When the competitiveness impacts of other cost factors were assessed, environmentally sound technologies did not differ in the time periods 1980-1999 and 2000-2019 (Mann-Whitney U = 337.000, asymp.sig. (two-tailed) = 0.469), in technological categories (Kruskall-Wallis, $\chi2$ = 6.952, df = 9, asymp.Sig. = 0.642), in environmental aspects (Kruskall-Wallis, $\chi2$ = 13.437,df = 8, asymp.Sig. = 0.098), having legal incentive (Mann-Whitney U = 299.500, asymp.sig. (two-tailed) = 0.268), in having other-than-legal incentives (Mann-Whitney U = 42.000, asymp.sig. (two-tailed) = 0.978), in breakthrough time periods (Kruskall-Wallis, $\chi2$ = 7.380,df = 4, asymp.sig. = 0.114), in function mechanisms (Mann-Whitney U = 138.500, asymp.sig. (two-tailed) = 0.465), and in categorised other-than-legal incentives (Kruskall-Wallis, $\chi2$ = 8.438,df = 6, asymp.sig. = 0.208).

Evidence for an association was not found between the competitiveness factor of other cost factors and importance on environmental impact of environmentally sound technology (Spearman's rho = -0.168, Sig. (two-tailed) = 0.248).

9.4.2 Impact of Environmentally Sound Technologies on Differentiation Competitiveness of Companies

Product Characteristics

Respondents were asked to assess the direction and significance of the competitiveness impact caused by product characteristics related to environmentally sound technology. In 27 out of 65 environmentally sound technologies, product characteristics were affected increasingly or decreasingly by the differentiation competitiveness of the companies. In 18 technologies, the competitiveness increased, in 11 technologies significantly. In nine technologies, the competitiveness was decreased a little by environmentally sound technology. There was no technology in which the competitiveness decreased significantly through product characteristics. In 38 technologies, product characteristics did not impact on the competitiveness (Figure 9.4.2.1). The mean of competitiveness assessment was 0.31, which is indicative of increasing competitiveness. The most frequent category is no effect, but the second frequent is significantly competitiveness-increasing impact. The product characteristics variable is categorised as product use (12 responses) and product quality (27 responses).

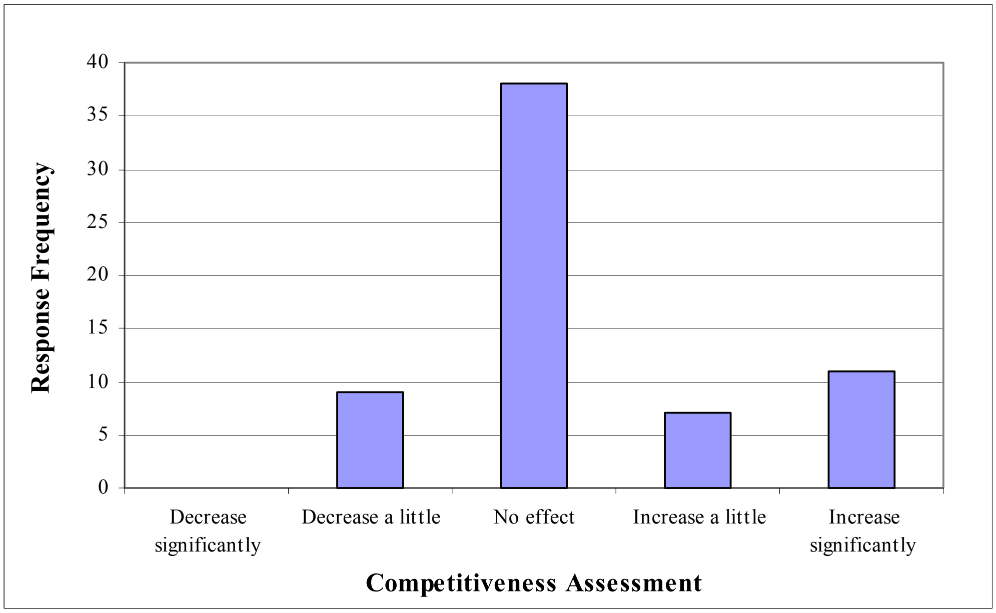

Figure 9.4.2.1 Response frequency of competitiveness assessment of product characteristic related to environmentally sound technologies.

Evidence was found that the technological categories of environmentally sound technologies differed significantly when the competitiveness impacts of the product characteristic factor were assessed (Kruskall-Wallis, $\chi 2$ = 26.779, df = 8, asymp.Sig. = 0.001) (Figure 9.4.2.2). Automation, measurement and information technologies increased competitiveness through product characteristics as well as operations and energy technologies Chemical-elimination technologies, closing-up technologies and wood and recycled-fibre technologies decreased competitiveness through product characteristics. Thirty-six out of 63 responses did not impact competitiveness through product characteristics.

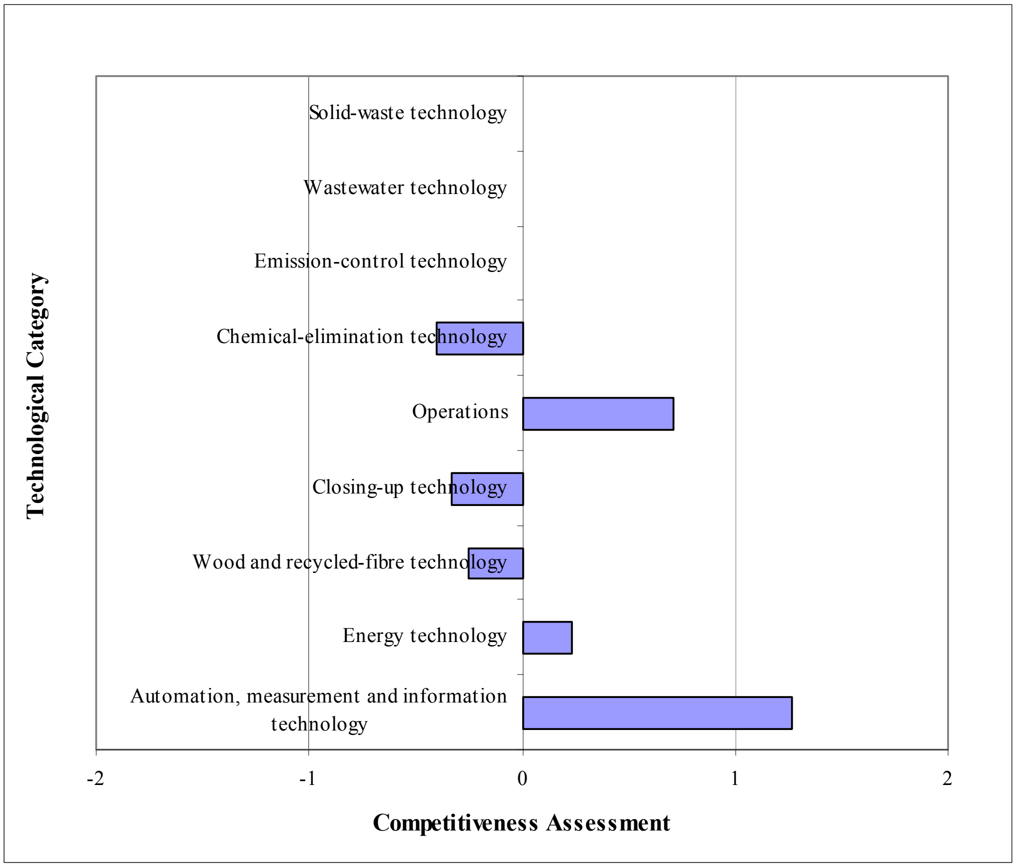

Figure 9.4.2.2 Means of competitiveness assessment of product characteristic factor related to environmentally sound technologies divided into technological categories. Scale of competitiveness assessment is significantly decreasing (-2), = a little decreasing (-1), no effect (0), a little increasing (1) =, significantly increasing (2).

When the competitiveness impacts of the product characteristics factor were assessed, environmentally sound technologies did not differ in the time periods 1980-1999 and 2000-2019 (Mann-Whitney U = 451.000, asymp.sig. (two-tailed) = 0.262), environmental aspects (Kruskall-Wallis, $\chi 2$ = 12.139, df = 8, asymp.sig.= 0.145), in having legal incentive (Mann-Whitney U = 391.000, asymp.sig. (two-tailed) = 0.167), in having other-than-legal incentives (Mann-Whitney U = 41.000, asymp.sig. (two-tailed) = 0.213) in breakthrough time periods (Kruskall-Wallis, $\chi 2$ = 1.202, df = 4, asymp.sig. = 0.878), in function mechanisms (Mann-Whitney U = 171.500, asymp.sig. (two-tailed) = 0.454), and categorised other-than-legal incentives (Kruskall-Wallis, $\chi 2$ = 7.983, df = 7, asymp. sig.= 0.334).

Evidence for an association was not found between the competitiveness factor of product characteristics and importance on environmental impact of environmentally sound technology (Spearman's rho = -0.065, Sig. (two-tailed) = 0.633).

Product Image

Respondents were asked to assess the direction and significance of the competitiveness impact caused by the product image factor related to environmentally sound technology. In 33 out of 66 technologies, the mentioned environmentally sound technologies affected increasingly the competitiveness of companies through product image as a differentiating factor. In 25 technologies, the competitiveness increased a little, in eight technologies, significantly. There was no environmentally sound technology that decreased competitiveness through product image factor. The mean of competitiveness assessment was 0.62, which means increasing competitiveness (Figure 9.4.2.3). The product image variable was categorised as environmental image (12 responses) and high-technology image (six responses).

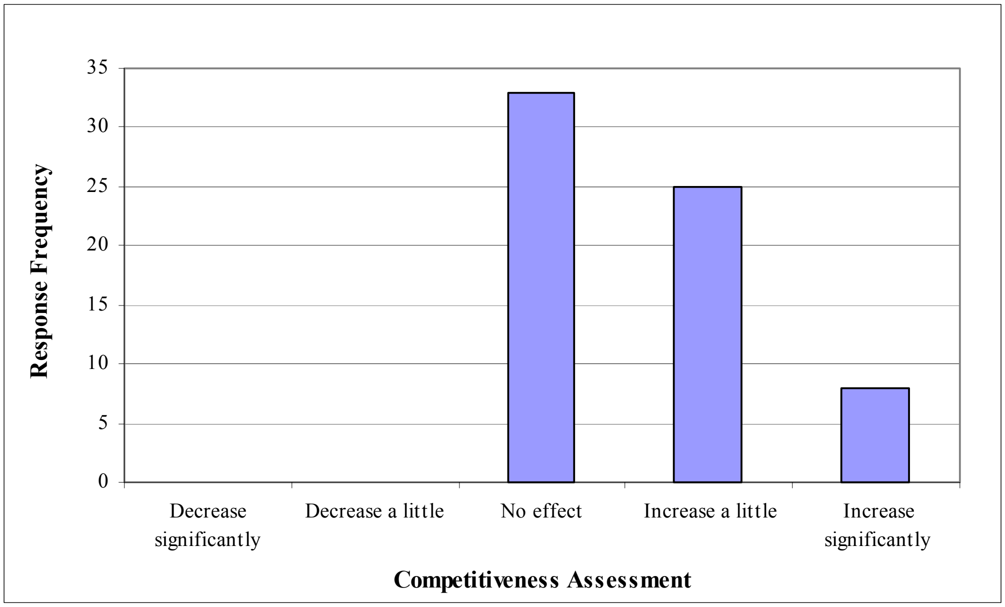

Figure 9.4.2.3 Response frequency of competitiveness assessment of product image related to environmentally sound technologies

Moderate evidence was found that the technological categories of environmentally sound technologies differed when the competitiveness impacts of the product image factor were assessed (Kruskall-Wallis, $\chi 2 = 17.115$, df = 8, asymp.Sig.= 0.029). Closing-up technology and solid-waste technologies were assessed as increasing competitiveness through product image the most, while emission-control technologies were assessed as increasingly it not at all. The other technologies increased competitiveness through product image at some extent. Figure 9.4.2.4 presents the means of variable values of the product image factor in competitiveness assessment related to environmentally sound technologies divided into technological categories.

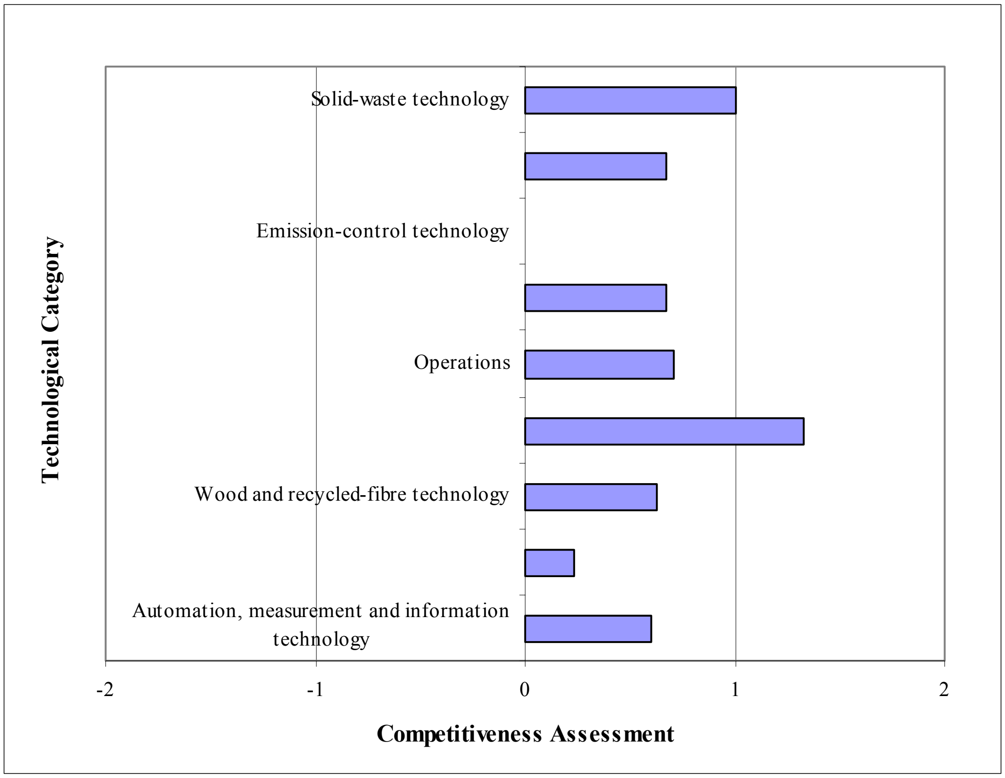

Figure 9.4.2.4 Means of competitiveness assessment of product image factor related to environmentally sound technologies divided into technological categories. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

Suggestive evidence was found that environmental aspects of environmentally sound technologies differed when the competitiveness impacts of the product image factor were assessed (Kruskall-Wallis, $\chi 2$ = 14.586, df = 8, asymp.sig.= 0.068). Figure 9.4.2.5 presents the means of competitiveness assessment of the product image factor related to environmentally sound technologies divided into environmental aspects. Environmentally sound technologies controlling use of fresh water landscape and released to water increased competitiveness mostly through product image. There was no environmentally sound technology that decreased competitiveness through product image factor. The technologies controlling contamination of land did not impact on competitiveness through product image. The technologies controlling the other aspects increased competitiveness through product image weakly positively.

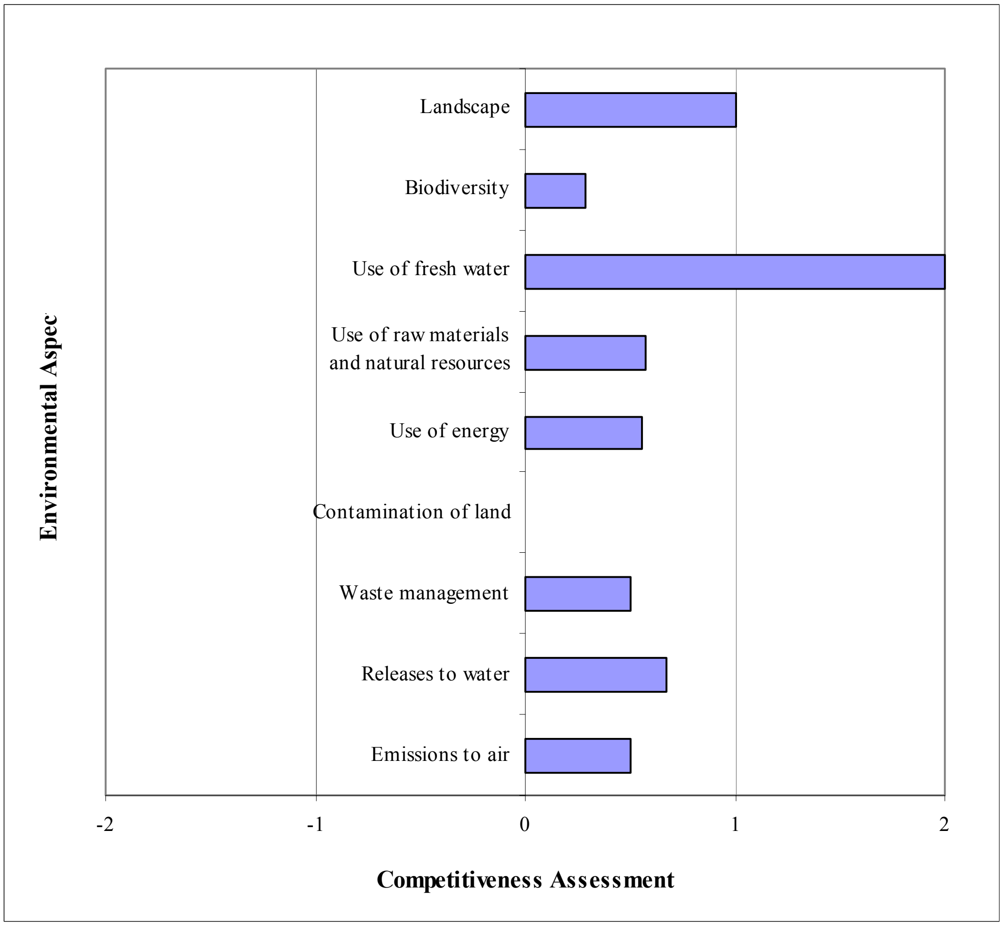

Figure 9.4.2.5 Means of product image factor in competitiveness assessment divided into environmental aspects. Scale of competitiveness assessment is significantly decreasing (-2), = a little decreasing (-1), no effect (0), a little increasing (1) =, significantly increasing (2).

Suggestive evidence was found that when the competitiveness impacts of the product image factor were assessed, environmentally sound technologies differed between the time periods 1980-1999 and 2000-2019 (Mann-Whitney U = 426.500, asymp.sig.(two-tailed) = 0.094). The mean of product image in competitiveness assessment in the time period 1980-1999 was 0.50, while in the time period 2000-2019 it was 0.75, which suggests that environmentally sound technologies will increase competitiveness through product image in the future more than in the past.

When the competitiveness impacts of the product image factor were assessed, environmentally sound technologies did not differ in having legal incentive (Mann-Whitney U = 486.000, asymp.sig. (two-tailed) = 0.840), in having other-than-legal incentive (Mann-Whitney U = 71.000, asymp.sig. (two-tailed) = 0.914), in breakthrough time period (Kruskall-Wallis, $\chi 2$ = 4.088, df = 4, asymp.sig.= 0.394), in function mechanism (Mann-Whitney U = 265.500, asymp.sig. (two-tailed) = 0.345), and in categorised other-than-legal incentive (Kruskall-Wallis, $\chi 2$ = 7..716, df = 7, asymp.sig.= 0.358).

Evidence was found that the product image factor had a correlation to the importance of environmentally sound technology on environmental impact (Spearman's rho = -0.320, Sig. (two-tailed) = 0.015), which means that the more important for environmental impact the technology is, the more competitiveness-increasing it is through product image.

Company Image

Respondents were asked to assess the direction and significance of the competitiveness impact caused by the company image factor related to environmentally sound technology .In 36 out of 65 technologies, the environmentally sound technologies affected increasingly the competitiveness of companies through company image as a differentiating variable, in seven technologies, significantly so (Figure 9.4.2.6). There was no environmentally sound technology that decreased competitiveness through company image factor. The mean of competitiveness assessment was 0.66, which means increasing competitiveness. Company image was categorised as environmental image (12 responses), good citizenship (11 responses) and high-technology image (seven responses).

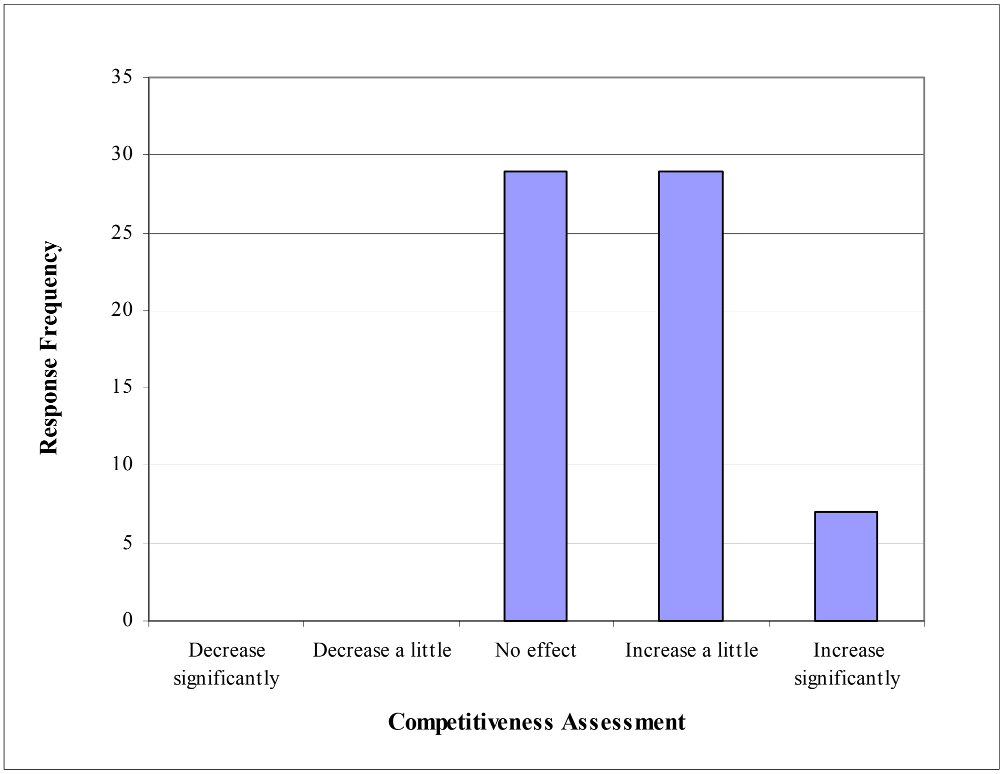

Figure 9.4.2.16 Response frequency of competitiveness assessment of company image related to environmentally sound technologies

When the competitiveness impacts of the company image variable were assessed, environmentally sound technologies did not differ in the time periods 1980-1999 and 2000-2019 (Mann-Whitney U = 517.000, asymp.sig. (two-tailed) = 0.873), in technological categories (Rockall-Wallis, $\chi 2$ = 7.846, do = 8, asymp.sig.= 0.449), in environmental aspects (Rockall-Wallis, $\chi 2$ = 7.539, do = 8, asymp.sig.= 0.480), in having legal incentive (Mann-Whitney U = 454.000, asymp.sig. (two-tailed) = 0.616), in having other-than-legal incentive (Mann-Whitney U = 69.000, asymp.sig. (two-tailed) = 0.846), in breakthrough time period (Kruskall-Wallis, $\chi 2$ = 2.905, df = 4, asymp.sig. = 0.574), in function mechanism (Mann-Whitney U = 195.000, asymp.sig. (two-tailed) = 0.852), and in categorised other-than-legal incentives (Kruskall-Wallis, $\chi 2$ = 5.468, df = 7, asymp.sig.= 0.603).

Evidence for an association was not found between the competitiveness factor of company image and importance on environmental impact of environmentally sound technology (Spearman's rho = -0.028, Sig. (two-tailed) = 0.837).

Other Differentiation Factors

It was asked in the interviews to assess the direction and significance of the competitiveness impact of other differentiation factor concerning identified environmentally sound technology. In 14 out of 55 technologies, the environmentally sound technologies affected either increasingly or decreasingly the competitiveness of companies through other differentiation factors (Figure 9.4.2.7). The other differentiation factors were categorised as transportation (one response) and ability to operate (three responses). There was no environmentally sound technology that decreased competitiveness through other differentiation factor. The mean of competitiveness assessment was 0.33, which is indicative of increasing competitiveness.

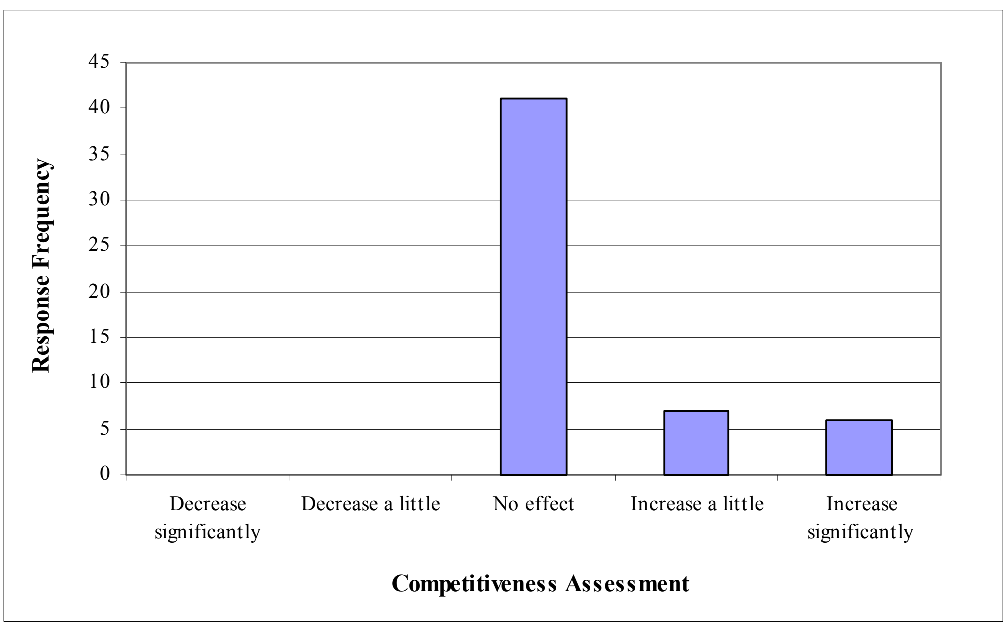

Figure 9.4.2.7 Response frequency of competitiveness assessment of company image related to environmentally sound technologies.

When the competitiveness impacts of the other differentiation variable were assessed, environmentally sound technologies differed in having other-than-legal incentive (Mann-Whitney U = 26.000, asymp.sig. (two-tailed) = 0.057) and in impact on competitiveness in the other part of the value chain (Mann-Whitney U = 291.500, asymp.sig. (two-tailed) = 0.056).

When the competitiveness impacts of the other differentiation factor were assessed, environmentally sound technologies did not differ in the time periods (Mann-Whitney U = 337.000, asymp.sig. (two-tailed) = 0.469), in technological categories (Kruskall-Wallis, $\chi 2$ = 7.691, df = 8, asymp.sig.= 0.464), in environmental aspects (Kruskall-Wallis, $\chi 2$ = 7.135, df =, asymp.Sig. = 0.522), in having legal incentive (Mann-Whitney U = 343.500, asymp.sig. (two-tailed) = 0.945), in breakthrough time periods (Kruskall-Wallis, $\chi 2$ = 4.669, df = 4, asymp.sig. = 0.323), in function mechanisms (Mann-Whitney U = 141.500, asymp.sig. (two-tailed) = 0.885), in categorised other-than-legal incentives (Kruskall-Wallis, $\chi 2$ = 5.468, df = 7, asymp.sig.= 0.603), in categorised impacts on competitiveness of company in the other part of the value chain (Kruskall-Wallis, $\chi 2$ = 4.664, df = 5, asymp.sig.= 0.458).

Evidence for an association was not found between the competitiveness factor of other differentiation factors and importance on environmental impacts of environmentally sound technology (Spearman's rho = -0.211, Sig. (two-tailed) = 0.159).

9.4.3 Association among Competitiveness Factors of Environmentally Sound Technologies

The associations among competitiveness factors were analysed using Spearman's correlation test (Spearman's rho) (in Table 9.4.3.1). The strongest positive correlations were between factors of capital and staff (Spearman's rho = 0.468, Sig. (two-tailed) = 0.000) and raw material and staff (Spearman's rho = 0.334, Sig. (two-tailed) = 0.006). Evidence for positive correlations were found also between raw material and capital (Spearman's rho = 0.257, Sig. (two-tailed) = 0.040), energy and capital (Spearman's rho = 0.248, Sig. (two-tailed) = 0.050), energy and other cost (Spearman's rho = 0.295, Sig. (two-tailed) = 0.050), staff and product characteristics (Spearman's rho = 0.253, Sig. (two-tailed) = 0.034), staff and company image (Spearman's rho = 0.242, Sig. (two-tailed) = 0.052), capital and other cost (Spearman's rho = 0.453, Sig. (two-tailed) = 0.001), capital and product characteristics (Spearman's rho = 0.250, Sig. (two-tailed) = 0.049) and other cost and product characteristics (Spearman's rho = 0.244, Sig. (two-tailed) = 0.076), and other cost and other differentiation (Spearman's rho = 0.365, Sig. (two-tailed) = 0.013). Image factors of product and company correlated strongly with each other (Spearman's rho = 0.425, Sig. (two-tailed) = 0.000). Evidence was found for negative correlation between raw material and product image (Spearman's rho = -0.207, Sig. (two-tailed) = 0.096) and energy and company image (Spearman's rho = -0.244, Sig. (two-tailed) = 0.052).

Table 9.4.3.1 Correlation Coefficients and Significances of Spearman's Correlation Test among Competitiveness Variables

Competitiveness Factor	**Raw Material**	**Energy**	**Staff**	**Capital**	**Other Costs**	**Product Charac- -teristics**	**Product Image**	**Company Image**	**Other Different- tiation**
Raw material									
Correlation Coefficient	1	0.170	0.334	0.257*	0.216	0.122	-0.207	-0.131	0.200
Sig. (two-tailed)	.	0.176	0.006	0.040	0.113	0.334	0.096	0.298	0.143
Energy									
Correlation Coefficient	0.170	1	0.112	0.248	0.295**	0.096	-0.154	-0.244	-0.063
Sig. (two-tailed)	0.176	.	0.375	0.050	0.031	0.448	0.221	0.052	0.648
Staff									
Correlation Coefficient	0.334**	0.112	1	0.468**	0.181	0.263*	-0.004	0.242	-0.025
Sig. (two-tailed)	0.006	0.375	.	0.000	0.186	0.034	0.973	0.052	0.856
Capital									
Correlation Coefficient	0.257*	0.248	0.468**	1	0.453**	0.250*	0.051	-0.074	0.191
Sig. (two-tailed)	0.040	0.050	0.000	.	0.001	0.049	0.689	0.562	0.171
Other costs									
Correlation Coefficient	0.216	0.295*	0.181	0.4523**	1	0.244	0.162	0.127	0.365*
Sig. (two-tailed)	0.113	0.031	0.186	0.001	.	0.076	0.238	0.359	0.013
Product characteristics									
Correlation Coefficient	0.122	0.096	0.263**	0.250*	0.244	1	-0.092	-0.026	0.073
Sig. (two-tailed)	0.334	0.448	0.034	0.049	0.076	.	0.466	0.841	0.601
Product image									
Correlation Coefficient	-0.207	-0.154	-0.004	0.051	0.162	-0.092	1	0.425**	0.109
Sig. (two-tailed)	0.096	0.221	0.973	0.689	0.238	0.466	.	0.000	0.430
Company image									
Correlation Coefficient	-0.131	-0.244	0.242	-0.074	0.127	-0.026	0.425**	1	0.088
Sig. (two-tailed)	0.298	0.052	0.052	0.562	0.359	0.841	0.000	.	0.523.
Other differentiation									
Correlation Coefficient	0.200	-0.063	-0.025	0.191	0.365**	0.073	0.109	0.088	1
Sig. (two-tailed)	0.143	0.648	0.856	0.171	0.013	0.601	0.430	0.523	.

** Correlation is significant at the 0.01 level (two-tailed).

* Correlation is significant at the 0.05 level (two-tailed).

9.4.4 Comparison of Competitiveness Significantly Increasing and Significantly Decreasing Environmentally Sound Technologies

The technologies were divided into two groups of technologies according to competitiveness impacts. Another category increased competitiveness significantly and another decreased competitiveness significantly. The technologies in these categories were investigated and compared with the category of the other mentioned technologies.

In the study, there were 40 technology responses, which were assessed to increase competitiveness significantly through any measured competitiveness factor. There were 11 technology responses, which significantly decreased competitiveness through any measured competitiveness factor. The biggest differences between these categories were in cost-competitiveness factors of capital, energy, raw material, and staff. These categories did not differ in competitiveness impacts of company image and product image. There were three technology responses, which decreased and increased competitiveness significantly through different factors of competitiveness. Figure 9.4.4.1 presents the means of variable values of competitiveness assessment divided into competitiveness-decreasing and -increasing environmentally sound technologies.

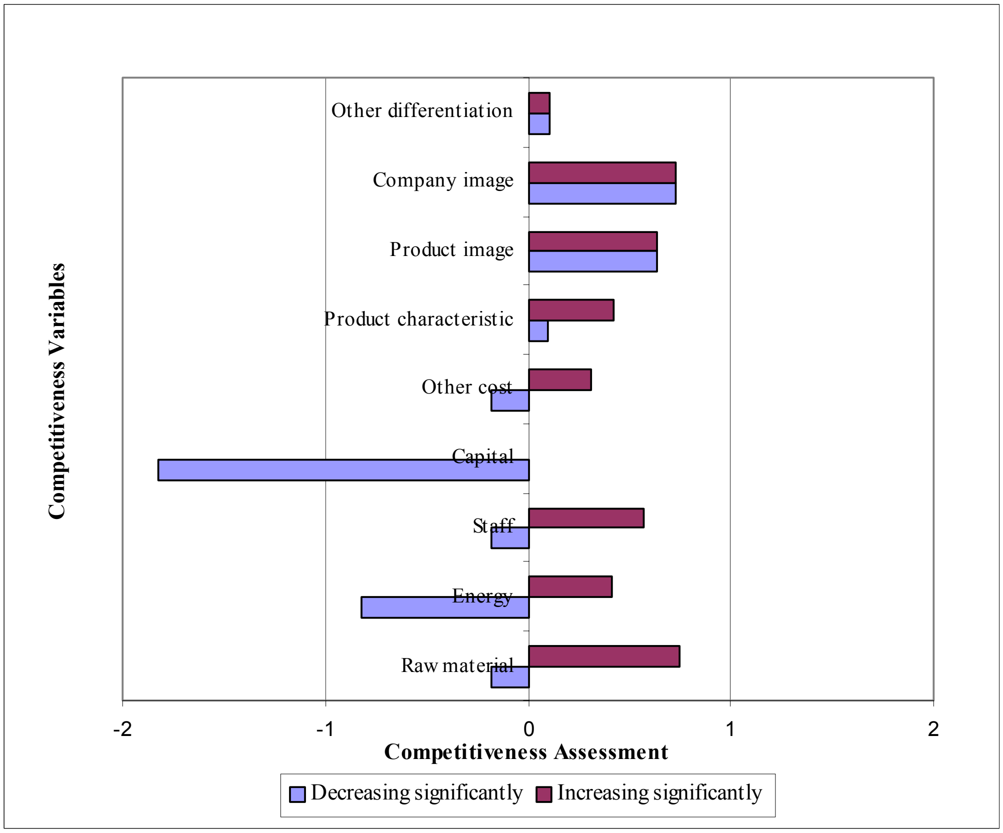

Figure 9.4.4.1 Means of variable values of competitiveness factors divided into significantly competitiveness-decreasing and significantly competitiveness-increasing environmentally sound technologies. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

Significantly competitiveness-decreasing technologies decreased it through all cost-competitiveness factors, such as raw material, energy, staff, other cost and mostly capital, but increased competitiveness through differentiation factors, such as product characteristics, product image, company image and other differentiation factors. Significantly competitiveness-increasing technologies increased competitiveness through all the factors, such as raw material, energy, staff, other costs, product characteristics, product image, company image and other differentiation factors, and the capital factor did not impact on competitiveness in these technologies. Significantly competitiveness-increasing technologies increased it through product characteristics more than significantly competitiveness-decreasing technologies.

Significantly Competitiveness-Increasing Technologies

Significantly competitiveness-increasing technologies were compared with other investigated technologies. Moderate evidence was found that significantly competitiveness-increasing technologies differed from other investigated technologies in importance on environmental impacts (Mann-Whitney U = 272.000 asymp.sign. (two-tailed) = 0.021). Twelve responses out of 15 indicated that the technologies having the most frequently importance on environmental impacts were also significantly competitiveness-increasing technologies. The mean of variable values of importance on environmental impact among significantly competitiveness-increasing technologies was 2.71 and among the others investigated technologies it was 1.81. The value varies from five (the most important) to one (fifth important). The evidence was found that significantly competitiveness-increasing technologies are the more important on environmental impact than the less competitiveness-increasing technologies.

Strong evidence was found that significantly competitiveness-increasing technologies differed from other investigated technologies in the technological categories (likelihood ratio G2 = 26.032, df = 8, asymp.sign. (two-sided) = 0.001). Table VII-4 of Appendix VII presents response frequencies of significantly competitiveness-increasing technologies divided into technological categories. Fourteen responses out of 16 indicated automation, measurement and information technology increased competitiveness significantly, while seven out of nine closing-up technologies, and six out of eight wood and recycled-fibre technologies, increased competitiveness significantly. Only three out of 13 energy technologies increased competitiveness significantly.

Moderate evidence was found to indicate that significantly competitiveness-increasing technologies differed from other investigated technologies in parts of value chain (likelihood ratio G2 = 6.965, df = 3, asymp.sign. (two-sided) = 0.073). Table VII-5 of Appendix VII presents response frequencies of significantly competitiveness-increasing technologies divided into the parts of value chain. Twelve responses out of 40 indicated that significantly competitiveness-increasing technologies are in paper mills (12 responses) and printing houses (12 responses), nine in forest harvesting (nine responses) and seven in pulp mills (seven responses).

Evidence that significantly competitiveness-increasing technologies differed from the other investigated technologies was found in raw material (Mann-Whitney U = 342.000, asymp sig. (two-tailed) = 0.015), in staff (Mann-Whitney U = 357.500, asymp sig. (two-tailed) = 0.019), in capital (Mann-Whitney U = 331.000, asymp sig. (two-tailed) = 0.021), in product image (Mann-Whitney U = 78.000, asymp sig. (two-tailed) = 0.000), in company image (Mann-Whitney U = 358.000, asymp sig. (two-tailed) = 0.028) and in other differentiation variable (Mann-Whitney U = 281.000, asymp sig. (two-tailed) = 0.052). In Figure 9.4.4.2, means of the variable values of competitiveness assessment related to significantly competitiveness-increasing and the other investigated technologies are presented.

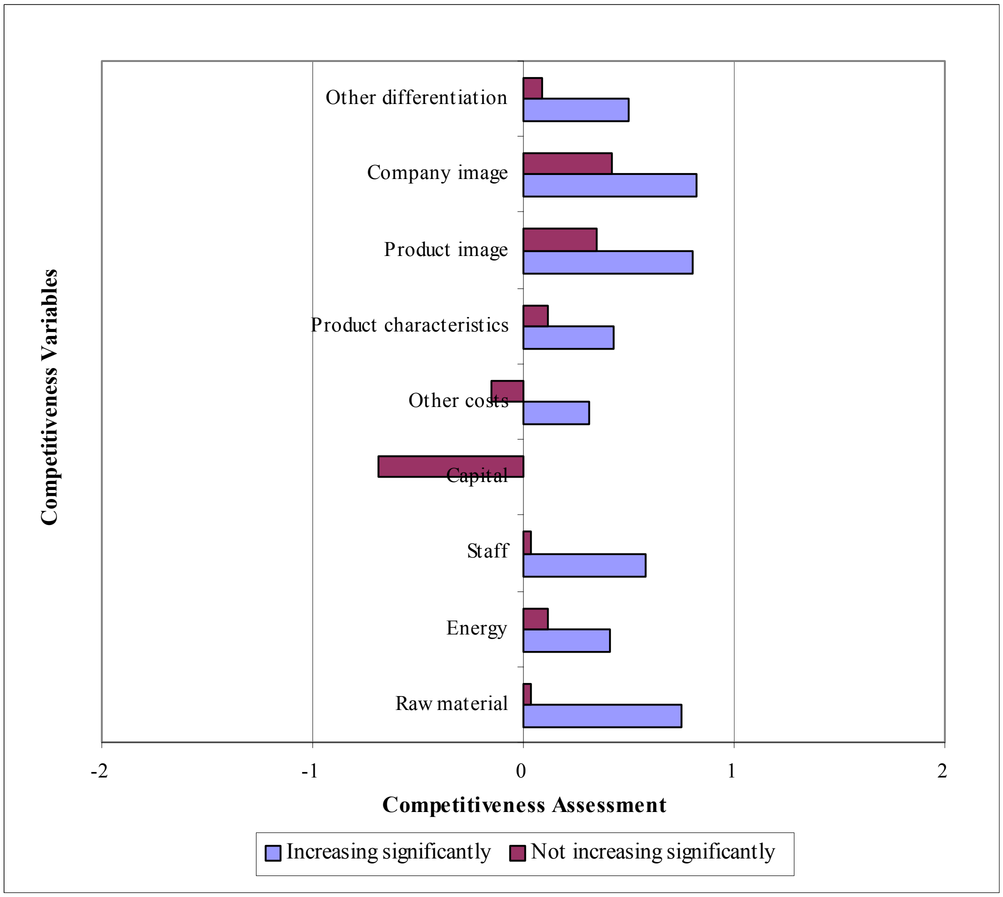

Figure 9.4.4.2 Means of the variable values of the competitiveness assessment related to significantly competitiveness-increasing and the other investigated technologies. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

The significantly competitiveness-increasing technologies increase competitiveness mostly among cost factors by raw material and staff. They do not decrease competitiveness through a factor of capital as the other technologies do. They create more competitiveness through product image and company image than the other investigated technologies do, when measured competitiveness impacts by means of competitiveness assessment.

It was found that significantly competitiveness-increasing technologies did not differ from other investigated technologies in environmental aspects (G2 =

12.675, df = 8, asymp.sig. = 0.124), in legal incentive (Fisher's exact test (two-sided) = 0.317) in breakthrough time periods (G2 = 2.848, df = 4,asymp.sig. (two-sided) = 0.584) and in function mechanisms (Fisher's exact test (two-sided) = 0.690). Significantly competitiveness-increasing technologies did not differ from the other investigated technologies in the competitiveness factors of energy (Mann-Whitney U = 447.500, asymp sig. (two-tailed) = 0.407 and product characteristics (Mann-Whitney U = 453.000, asymp sig. (two-tailed) = 0.476).

Significantly Competitiveness-Decreasing Technologies

Significantly competitiveness-decreasing technologies were compared with other investigated technologies. They differed from other investigated technologies in breakthrough time periods (likelihood ratio G2 = 14.059, df = 8, asymp.sig. (two-sided) = 0.080) in environmental aspects (G2 = 15.206, df = 8, asymp.sig.(two-sided) = 0.055), in legal incentive (Fisher's exact sig, (two-sided) = 0.092) and in parts of value chain (likelihood ratio G2 = 9.819, df = 3, asymp.sig. (two-sided) = 0.020).

Breakthrough time period of significantly competitiveness-decreasing technologies was in mentioned in three out of 11 responses relating to the time period 1980-1999 (three responses) and 1990-1999 (three responses). Table VII-6 of Appendix VII presents response frequencies of significantly competitiveness-increasing technologies divided into breakthrough time period. Significantly competitiveness-decreasing technologies (Table VII-7 of Appendix VII) control emissions to air (six responses out of 11), releases to water (three responses) but do not control raw material and natural resources (only one response) In seven out of 11 responses (Table VII-8 of Appendix VII), significantly competitiveness-decreasing technologies have legal incentive, but only in 19 out of 56 responses of other investigated technologies have legal incentive. The five responses mentioned significantly competitiveness-decreasing technologies in printing house, four in pulp mill and two in forest harvesting. There is no significantly competitiveness-decreasing technology in paper mill (Table VII-9 of Appendix VII).

Significantly competitiveness-decreasing technologies differed from other investigated technologies in variable values of raw material (Mann-Whitney U = 203.000, asymp. sig. (two-tailed) = 0.075), energy (Mann-Whitney U = 116.000, asymp. sig. (two-tailed) = 0.001), staff (Mann-Whitney U = 169.500, asymp. sig. (two-tailed) = 0.012), capital (Mann-Whitney U = 17.000, asymp sig. (two-tailed) = 0.000), and other cost (Mann-Whitney U = 78.000, asymp sig. (two-tailed) = 0.000). In Figure 9.4.4.3, means of the variable values of competitiveness assessment of significantly competitiveness-decreasing and the other investigated technologies are presented.

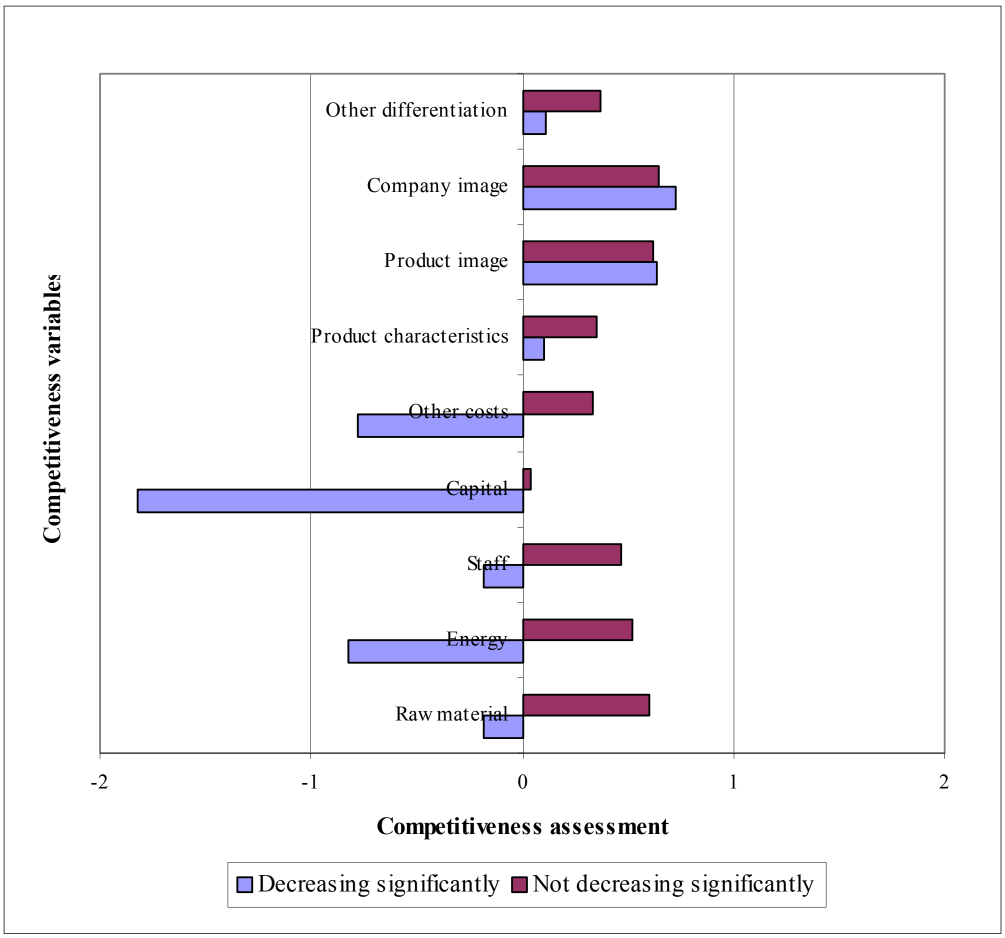

Figure 9.4.3 Means of the values of competitiveness variables of significantly competitiveness decreasing and the other investigated technologies not decreasing competitiveness significantly. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

The significantly competitiveness-decreasing technologies decrease competitiveness mostly through cost factors of capital and energy but also decrease competitiveness through the other cost factors of raw material, staff and other costs.

Significantly competitiveness-decreasing technologies did not differ from other investigated technologies in variables values of importance on environmental impacts (Mann-Whitney U = 163.000, asymp.sig. (two-tailed) = 0.569), technological categories (G2 = 9.699, df = 8, asymp.sig. (two-sided) = 0.287) and function mechanisms (Fisher's exact sig (two-sided) = 0.309). Significantly competitiveness-decreasing technologies did not differ from the other competitiveness-decreasing technologies in variables values of product characteristics (Mann-Whitney U = 237.000, asymp sig. (two-tailed) = 0.437), product image (Mann-Whitney U = 293.500, asymp sig. (two-tailed) = 0.864), company image (Mann-Whitney U = 285.000, asymp sig. (two-tailed) = 0.817) and other differentiation (Mann-Whitney U = 163.500, asymp sig. (two-tailed) = 0.185).

9.4.5 Summary of Relationships Between Environmentally Sound Technologies and Competitiveness Factors of Companies

Competitiveness impacts of environmentally sound technologies were investigated through the cost competitiveness variables, such as raw material, energy, staff, capital and other cost and through differentiation competitiveness variables as product characteristics, product image, company image and other differentiation factor. In Figure 9.4.5.1, means of variable values of competitiveness assessment concerning environmentally sound technologies are presented.

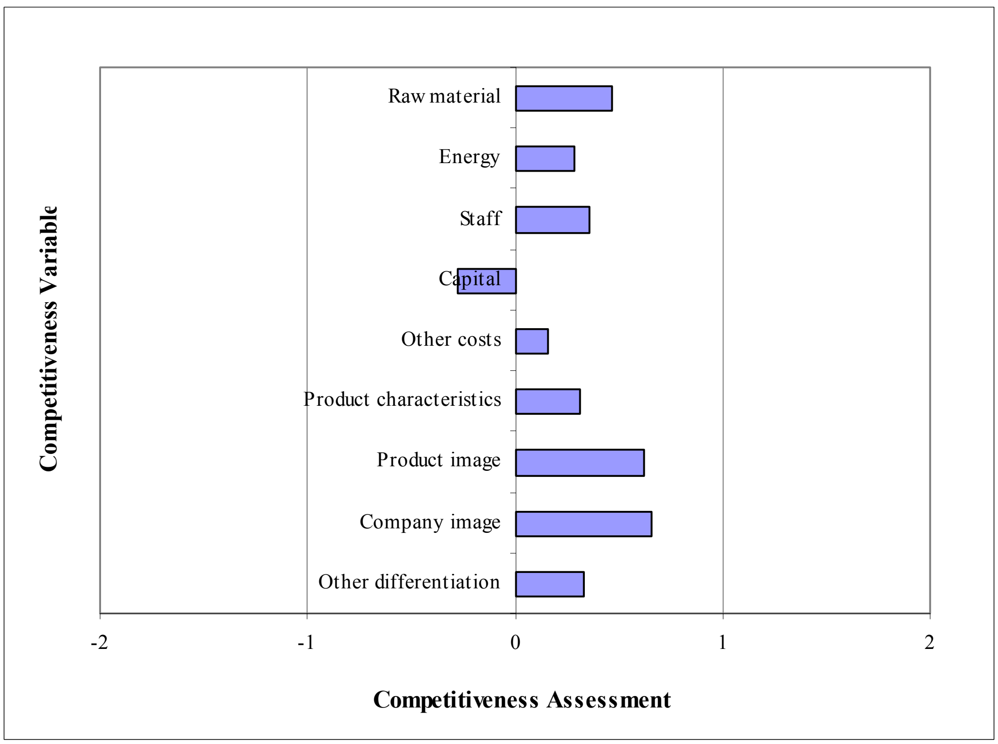

Figure 9.4.5.1 Means of variable values of competitiveness assessment concerning environmentally sound technologies. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

All explored competitiveness factors save for capital of environmentally sound technologies increased suggesting competitiveness of companies. The mostly competitiveness-increasing factors were company image, product image and raw material and the only competitiveness-decreasing factor was capital.

Technological Category

The technological categories of environmentally sound technologies differ when they are assessed through the competitiveness impacts of raw material, staff factor, product characteristics and product image, but do not differ when the competitiveness impacts of capital, other cost, company image and other differentiation are assessed. The means of competitiveness factors divided into technological categories are presented in Appendix IX. Raw material impacts in a competitiveness-increasing way in automation, measurement and information technologies, wood and recycled-fibre technologies, emission-control technologies and closing-up technologies and in a competitiveness-decreasing way in operations. Staff impacts in a competitiveness-increasing way in automation, measurement and information technologies, wood and recycled-fibre technologies, operations and energy technologies, but in a competitiveness-decreasing way in solid-waste technologies, wastewater technologies, emission-control technologies and closing-up technologies. Product characteristics impact in a competitiveness-increasing way in automation, measurement and information technologies, operations, energy technologies, but in a competitiveness-decreasing way in chemical-elimination technologies, closing-up technologies and wood and recycled-fibre technologies. Product image impacts in a competitiveness-increasing way in all technological categories, but mostly in closing-up technology.

Environmental Aspects

Suggestive evidence was found that environmental aspects of environmentally sound technologies differed when the competitiveness impacts of raw material, energy, staff, other cost and product image were assessed, but no evidence was found that environmental aspects of environmentally sound technologies differed when the competitiveness impacts of capital, other cost, product characteristics, company image and other differentiation were assessed. The technologies controlling use of raw material and natural resources, use of energy, biodiversity and releases to water increase competitiveness, while those controlling contamination of land and use of fresh water decreased competitiveness through raw material. The technologies controlling use of energy, waste management and raw material and natural resources increase competitiveness, while those controlling contamination of land, emissions to air, biodiversity and releases to water decrease competitiveness through energy. The technologies controlling landscape, contamination of land, use of raw material and natural resources, use of energy and biodiversity increase competitiveness, while those controlling waste management, releases to water and emissions to air decrease competitiveness through staff. The technologies controlling use of fresh water, landscape and releases to water increase competitiveness mostly and contamination of land at least.

Time Periods 1980-1999 and 2000-2019 and Breakthrough Time Period

Suggestive evidence was found that time periods 1980-1999 and 2000-2019 of environmentally sound technologies differ when the competitiveness impact of product image is assessed, but no evidence was found of this when the other competitiveness variables are assessed. No evidence was found that breakthrough time periods of environmentally sound technologies differ when the competitiveness impacts are assessed.

Legal Incentive and Other-than-Legal Incentives

Evidence was not found that environmentally sound technologies having legal incentive and those not having them differ when the competitiveness impacts are assessed. Similarly, no evidence was found that environmentally sound technologies having other-than-legal incentives and those not having other-than-legal incentives differed when the competitiveness impacts were assessed.

Function Mechanism of Pollution Prevention and Pollution Abatement

It may be said that, among environmentally sound technologies, there is a difference between function mechanism and impact of staff on competitiveness, but there is no a difference between function mechanism and the other competitiveness factors. Pollution-prevention technologies increase competitiveness of companies through staff, but pollution-abatement technologies decrease competitiveness of companies through it.

Association Between Competitiveness Factors and Importance on Environmental Impacts

The product image factor related to environmentally sound technologies has a correlation with the importance on environmental impacts among environmentally sound technologies, which means that the more important for environmental the technology is, the more competitiveness-increasing it is through product image. The other competitiveness factors do not correlate with the importance on environmental impacts.

Associations among Competitiveness Variables

The correlations among competitiveness factors were analysed by Spearman's correlation test. It was found the strongest positive association between factors of raw material and staff, and capital and staff.

Evidence for positive correlations were found between raw material and capital, energy and capital, energy and other cost, staff and product characteristics, staff and company image, capital and other cost, capital and product characteristics and other cost and other cost and other differentiation. Evidence was found for negative correlations between raw material and product image and energy and company image. Image factors of product and company correlated with each other.

Significantly Competitiveness-Increasing and Significantly Competitiveness-Decreasing Technologies

In the study, there were 40 technology responses mentioned that increase competitiveness significantly and 11 responses that decrease competitiveness significantly through any competitiveness variable. Significantly competitiveness-increasing technologies differ from other investigated technologies in terms of importance on environmental impacts, technological category and part of value chain. The evidence was found that significantly competitiveness-increasing technologies were the more important for environmental impacts than the less competitiveness-increasing technologies. These were automation, measurement and information technologies, closing-up technologies and wood and recycled-fibre technologies. The minority of energy technologies increases competitiveness significantly. The majority of significantly competitiveness-increasing technologies are in paper mills and printing houses. The significantly competitiveness-increasing technologies increased competitiveness mostly among cost factors by raw material and staff. They do not decrease competitiveness through a factor of capital as the other technologies do. They create more competitiveness through product image and company image than the other investigated technologies do, when measured competitiveness impacts by means of competitiveness assessment.

Significantly competitiveness-decreasing technologies differ from other investigated technologies in variable values of breakthrough time periods, legal incentive and parts of the value chain. The most frequently mentioned breakthrough time periods of significantly competitiveness-decreasing technologies are time periods 1980-1999 and 1990-1999. Almost half of the significantly competitiveness-decreasing technologies are in printing houses. There is no significantly competitiveness-decreasing technology in paper mills. Half of significantly competitiveness-decreasing technologies control emissions to air, and one-fourth releases to water, and half have legal incentive, but only the one-third of the other investigated technologies have legal incentive. The significantly competitiveness-decreasing technologies decrease competitiveness mostly through cost factors of capital and energy but also decrease competitiveness through the other cost factors of raw material, staff and other cost. Significantly competitiveness-decreasing technologies do not differ from the other investigated technologies in measured differentiation competitiveness factors of product characteristics, product image, company image and other competitiveness factor.

9.5 Comparison of Environmentally Sound Technologies in Different Parts of the Value Chain

The data of this study was collected from different parts of the value chain of printed paper. The investigated parts of the value chain were forest harvesting, the pulp mill, the paper mill and the printing house. Significantly strong evidence was found for differences among the parts of the value chain in technological categories (likelihood ratio G2 = 70.848, df = 24, symp.sign (two-sided) = 0.000). The category of automation, measurement and information technology was mostly implemented in the forest harvesting (seven responses) and printing house (seven responses) parts of the value chain and category of operation (six responses) in forest harvesting. Energy technologies, as well as wood or recycled-fibre technologies, were implemented all along the value chain, mostly in paper mills (both technologies five responses). Closing-up technologies were implemented in pulp mills (four responses) and paper mills (four responses). The greatest variety of technological categories was implemented in pulp mills (seven technological categories) and printing houses (six technological categories). Table VII-10 in Appendix VII presents response frequencies of technological categories divided into the parts of the value chain of printed paper.

Slight differences were found among the parts of the value chain in function mechanism of pollution prevention and pollution abatement (likelihood ratio G2 = 6.324, df = 3, asymp.sig. (two-sided) = 0.097). In forest harvesting, all the technologies (18 responses) were pollution-prevention technology. In pulp mills, one-fifth of the technologies (four responses out of 18) were pollution-abatement technology. In paper mills, almost all of the technologies (16 responses out of 18) were pollution-prevention technology. In printing houses, almost all of the technologies (14 responses out of 15) were pollution-prevention technology.

Significantly strong evidence was found for differences among the parts of the value chain in environmental aspects (likelihood ratio G2 = 96.503, df = 24, symp.sign (two-sided) = 0.000). Table VII-11 in Appendix VII presents response frequencies of environmental aspects controlled by environmentally sound technologies divided into the parts of the value chain of printed paper. In forest harvesting, the most frequently mentioned environmental aspects controlled by the technologies was the use of raw materials and natural resources (nine responses), in pulp mills, releases to water (eight responses), in paper mills, the use of energy (eight responses) and in printing houses, the use of raw materials and natural resources (nine responses).

Significantly moderate evidence was found for differences among the parts of the value chain in the categorised other-than-legal incentives (G2 = 33.027, df = 21, asymp.sig. (two-tailed) = 0.046). Costs were the most frequently mentioned other-than-legal incentive in forest harvesting (six responses), paper mills (six responses) and printing houses (five responses). In pulp mills, the most frequently mentioned other-than-legal incentive was public image (three responses). Market pressure was important in printing houses (three responses). Ability to operate was important in pulp mills (two responses). Financial or other support (four responses) and energy supply (one response) were important in forest harvesting. The Table VII-12 in Appendix VII presents response frequencies of the categorised other-than-legal incentives divided into the parts of value chain.

Evidence was found that the parts of the value chain of printed paper differed when the following competitiveness variables were assessed: energy (Kruskall-Wallis: χ_2 = 12.006, df = 3, asymp.sig. = 0.007), staff (Kruskall-Wallis: χ_2 = 18.895, df = 3, asymp.sig. = 0.000), other cost (Kruskall-Wallis: χ_2 = 8.251, df = 3, asymp.sig. = 0.041), product characteristics (Kruskall-Wallis: χ_2 = 8.348, df = 3, asymp.sig. = 0.039), product image (Kruskall-Wallis: χ_2 = 13.261, df = 3, asymp.sig. = 0.004) and company image (Kruskall-Wallis: χ_2 = 12.990, df = 3, asymp.sig. = 0.005).

Figure 9.5.1 presents the means of variables values of competitiveness assessment differed in parts of the value chain related to environmentally sound technologies. The energy factor of environmentally sound technology increases competitiveness the most in paper mills and decreases competitiveness in printing houses. The staff factor increases competitiveness the most in printing houses and decreased competitiveness the most in pulp mills. The other cost factor increases competitiveness a little in paper mills and decreases competitiveness the most in pulp mills. The product characteristics factor increases competitiveness the most in printing houses and decreases competitiveness in pulp mills. The product image factor increases competitiveness the most in paper mills as well as in printing houses. The company image factor increases competitiveness the most in printing houses.

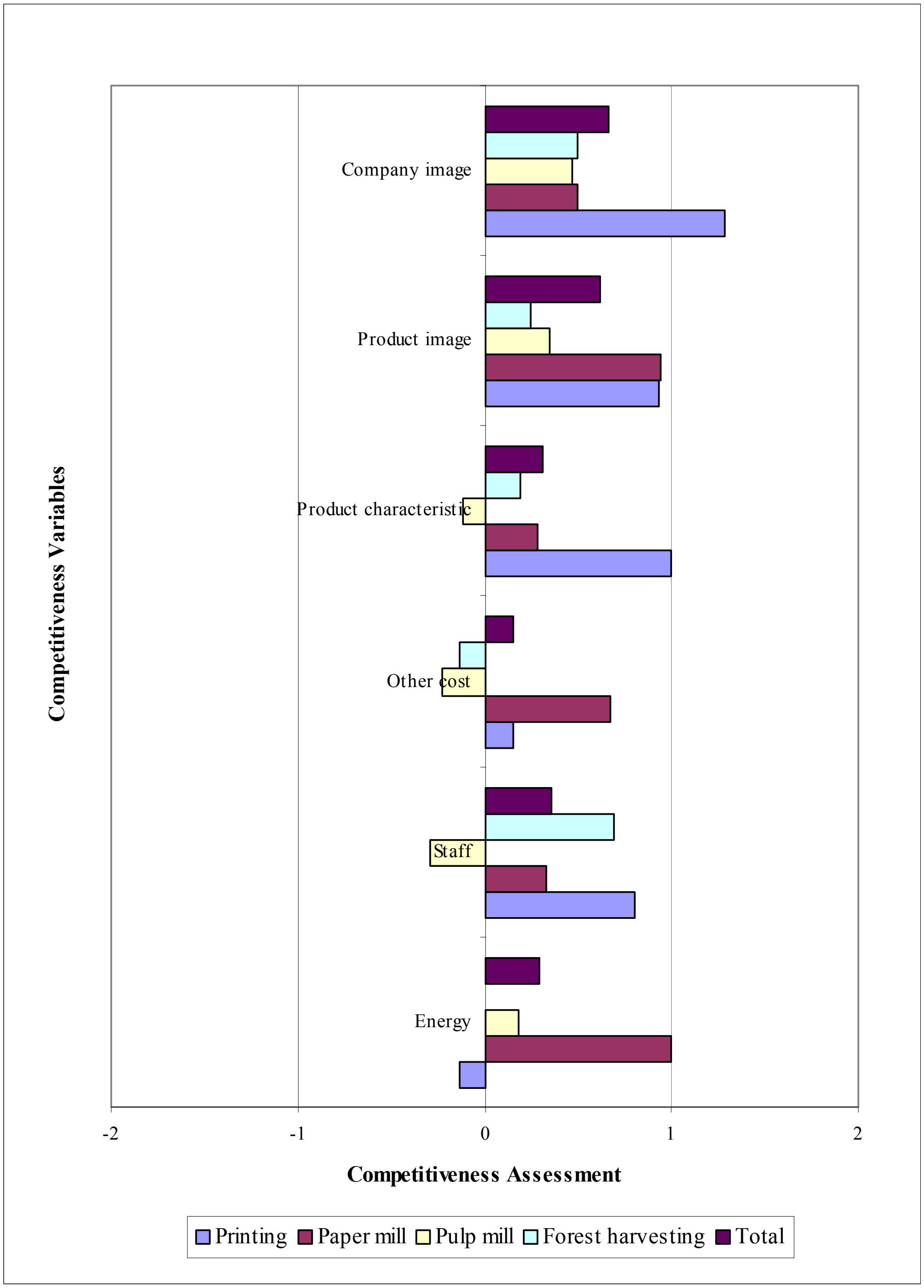

Figure 9.5.1 Means of variable values of competitiveness assessment related to environmentally sound technologies divided into the parts of value chain. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

The parts of the value chain of printed paper did not differ when the following variables of competitiveness were assessed: the raw material (Kruskall-Wallis,

χ_2 = 1.720, df = 3, asymp.sig. = 0.623), capital (Kruskall-Wallis, χ_2 = 3.264, df = 3, asymp.sig. = 0.353) and the other differentiation factor (Kruskall-Wallis: χ_2 = 1.853, df = 3, asymp.sig. = 0.603).

When comparing the parts of the value chain, environmentally sound technologies did not differ in variables of the time periods 1980-1999 and 2000-2019 (Chi-square $\chi2$ 0.497, df = 3, asymp.sig. (two-sided) = 0.920), having legal incentive (Chi-Square: $\chi2$ = 4.982, df = 3, asymp.sig.= 0.173) and having other-than-legal incentives (likelihood ratio G2 = 2.311, df = 3, asymp.sig. (two-sided) = 0.510) and breakthrough time periods (likelihood ratio G2 = 15.693, df = 12, asymp.sig. (two-sided) = 0.206).

9.5.1 Summary of Comparison of Environmentally Sound Technologies in the Different Parts of the Value Chain

Evidence was found for difference among the parts of the value chain in technological categories. The category of automation, measurement and information technology is mostly implemented in forest harvesting and printing parts of the value chain, and the category of operation in forest harvesting. Category of energy technology is implemented all along the value chain, mostly in paper mills, as well as in wood or recycled-fibre technology. Closing-up technology is implemented in pulp mills and paper mills. The most varied types of technological categories are implemented in pulp mills and printing houses.

Evidence was found that there was a difference between the function mechanisms of environmentally sound technologies in the parts of the value chain. In forest harvesting and printing houses, almost all the technologies are pollution prevention. The technologies of pulp mills are the most frequently mentioned pollution-abatement technologies.

Differences among the parts of the value chain in having legal incentives and not having legal incentives was found. There is almost significant differences among the parts of the value chain in categorised other-than-legal incentives. The costs are the most frequently mentioned other-than-legal incentives in forest harvesting, paper mill and printing houses. In pulp mills, the most frequently mentioned other-than-legal incentive is public image.

Significant differences were found among the parts of the value chain in the environmental aspects. In forest harvesting, the most frequently mentioned environmental aspects controlled by the technologies was the use of raw materials and natural resources, in pulp mills, releases to water, in paper mills, the use of energy and in printing houses, the use of raw materials and natural resources.

The environmentally sound technologies in the parts of the value chain differ when the competitiveness impacts of energy, staff, and other cost and product image are assessed. Competitiveness of companies related to environmentally sound technologies increases mostly through factors of company image, product image, product characteristics and staff in printing houses and through factors of energy and product image in paper mills. Competitiveness of companies decreases mostly through factors of staff, other costs and product characteristics in pulp mills.

9.6 Impacts of Environmentally Sound Technologies on the Competitiveness of Companies in the Other Parts of the Value Chain

Respondents were asked if the environmentally sound technology had an impact on competitiveness of companies in other part of the value chain than where the technology is positioned. Half of the technologies (34 responses) were assessed to have an impact on the competitiveness of companies in other part of the value chain.

Suggestive evidence was found that the parts of the value chain of printed paper differed when technology had an impact on competitiveness of companies in the other parts of the value chain (Chi-Square: $\chi_2 = 6.967$, asymp.sig.= 0.073). The environmentally sound technologies of forest harvesting (11 responses out of 16) and printing houses (10 responses out of 15) had the most frequently impacts to other part of the value chain and environmentally sound technologies of pulp mills have less impacts on competitiveness of companies in the other part of the value chain. Figure 9.6.1 presents the response frequencies when environmentally sound technology had an impact on the competitiveness of companies in other part of the value chain divided into *position of technology* in the value chain of printed paper. The technological categories that had impact on competitiveness of companies in the other part of the value chain were wood and recycled-fibre technology (seven responses out of eight), automation, measurement and information technology (eight responses out of 15), energy technology (five responses out of 13), closing-up technology (four responses out of nine), operation (five responses out of 17), and chemical-elimination technology (five responses out of six). Emission-control technology, wastewater technology and solid-waste technology did not have impacts on the competitiveness of companies in the other part of the value chain.

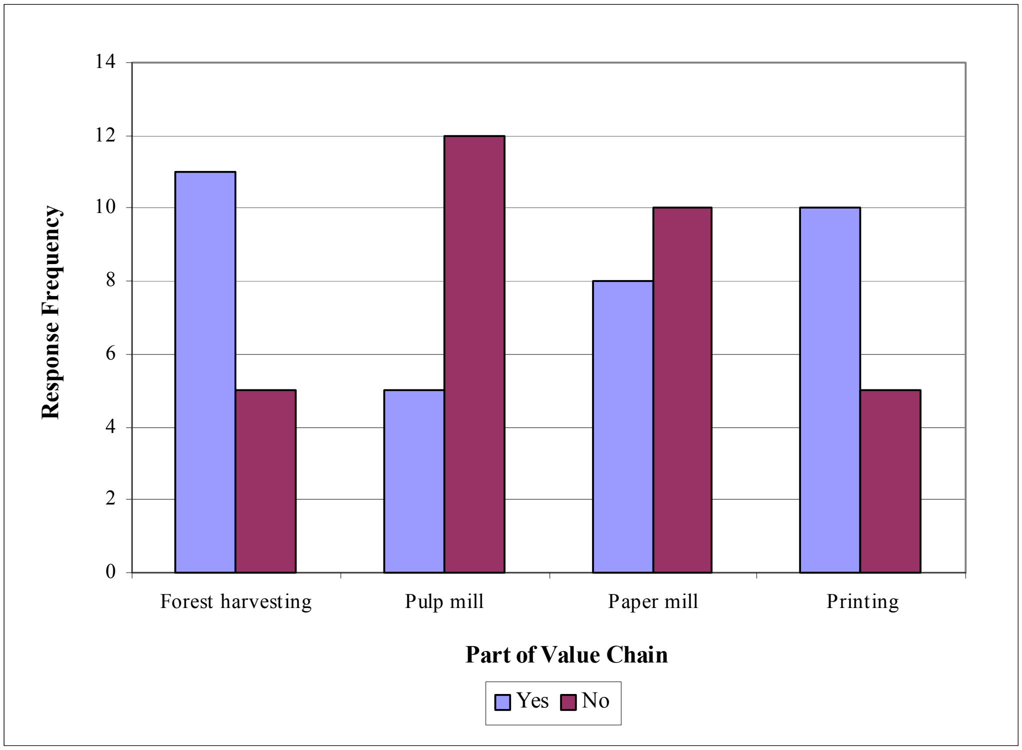

Figure 9.6.1 Response frequencies when environmentally sound technology has an impact on competitiveness of companies in the other part of value chain (yes or no) divided into the parts of the value chain where the technology was positioned.

Suggestive evidence was found that environmentally sound technologies are having an impact on the competitiveness of companies in the other part of the value chain and not having that impact differed significantly among technological categories (likelihood ratio G2 = 21.208, df = 8, asymp. sig. (two-sided) = 0.007). Emission-control technologies, wastewater technologies and solid-waste technologies did not have impacts at all on the competitiveness of companies in other parts of the value chain. The most frequently mentioned impacts had automation, measurement and information technologies, and wood and recycled-fibre technologies. Figure 9.6.2 presents response frequencies when environmentally sound technologies had an impact on competitiveness of companies in the other part of the value chain divided into technology categories.

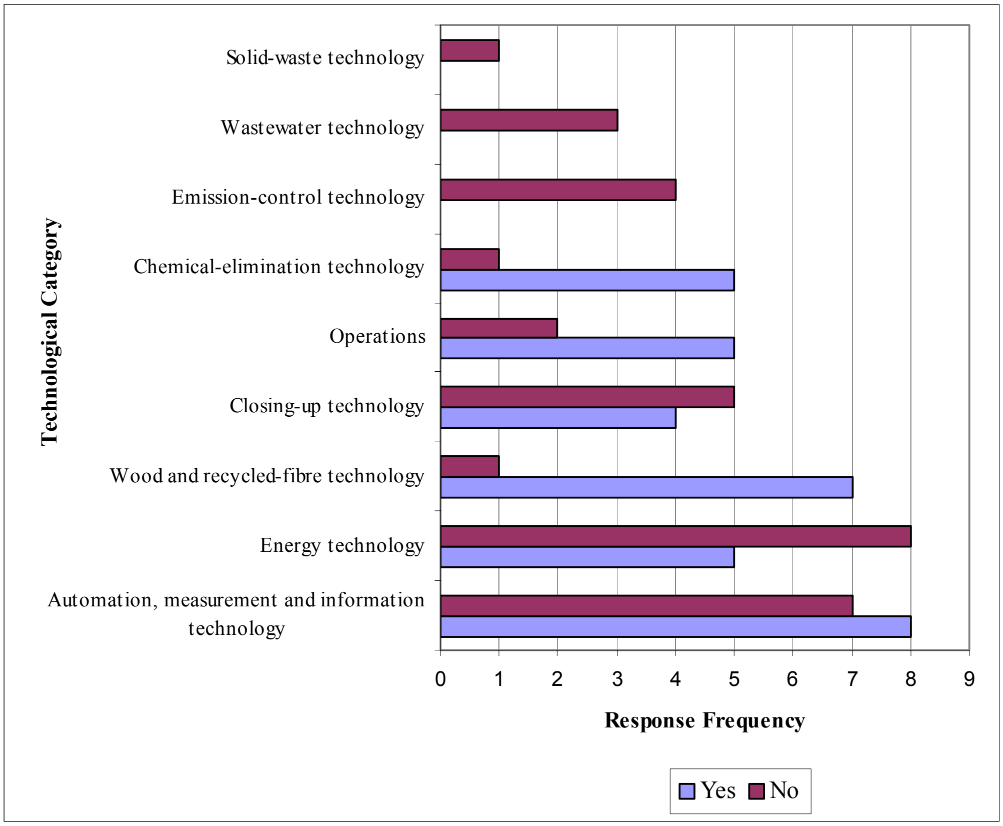

Figure 9.6.2 Response frequencies when environmentally sound technology has an impact on competitiveness of company in the other part of the value chain divided into technology categories.

Evidence was found for a difference between having an impact on the competitiveness of companies in the other part of the value chain and not having that impact in the function mechanisms of pollution prevention or pollution abatement (Fisher's exact test (two-sided) = 0.051). In 33 out of 59 responses, pollution-prevention technology had an impact on the competitiveness of companies in the other part of value chain and, in one out of seven responses, pollution-abatement technology had an impact on the competitiveness of companies in the other part of the value chain.

Suggestive evidence was found for a difference between having an impact on the competitiveness of companies in the other part of value chain and having not that impact in time periods (Chi-Square $\chi 2$ = 3.001, df = 1, asymp.sig.= 0.083). When the technology had an impact on the competitiveness of companies in the other part of value chain, in 20 responses out of 32, these are mentioned to be implemented in the time period 2000-2019. When the technology had not an impact on the competitiveness of companies in the other part of the value chain, 20 responses out of 34 indicated it was implemented in the time period 1980-1999. This may indicate that, in future, changes that impact on the competitiveness of companies may occur in the structure of the value chain of printed paper.

Moderate evidence was found that environmentally sound technologies are having an impact on the competitiveness of companies in the other parts of the value chain and are not having an impact on the competitiveness of companies in the other parts of the value chain differ significantly in the breakthrough time period (likelihood ratio G2 = 10.856, df = 4, asymp. sig. (two-sided) = 0.028). Figure 9.6.3 presents response frequencies when environmentally sound technology has an impact on the competitiveness of companies in the other part of the value chain divided into breakthrough time periods environmentally sound technology. The technologies that will have a breakthrough in the time period 2000-2009 had the most frequent impacts on the competitiveness of companies in the other part of the value chain; also, the future technologies will have an impact on the competitiveness of companies in the other part of the value chain.

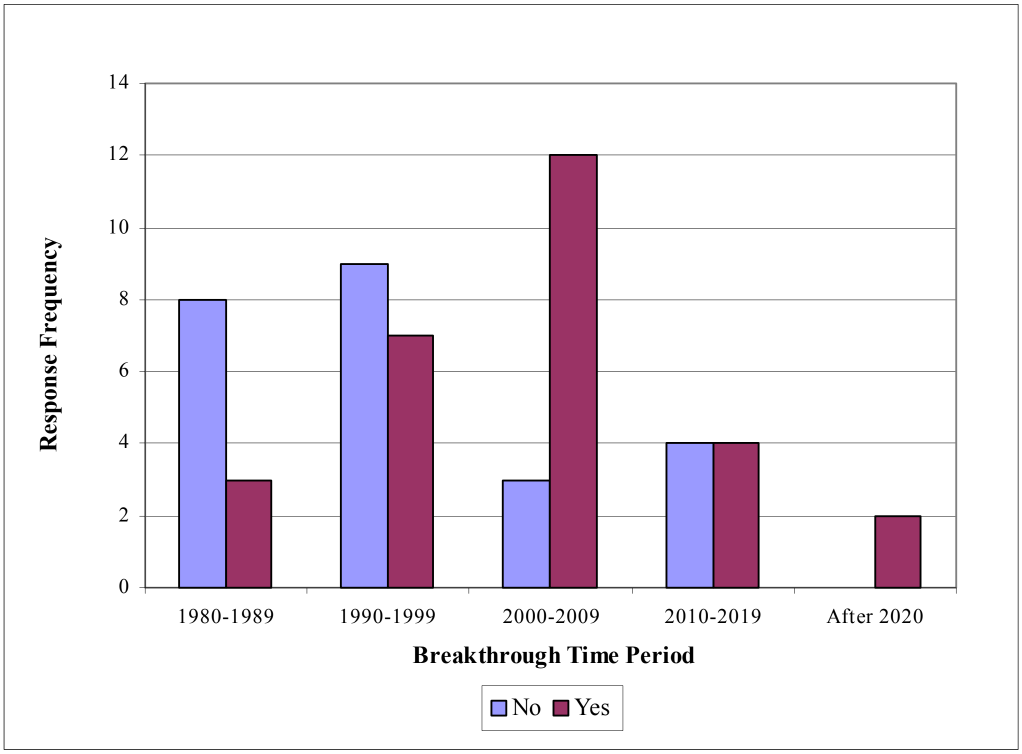

Figure 9.6.3 Response frequencies when environmentally sound technology has an impact on competitiveness of company in the other part of value chain divided into breakthrough time of environmentally sound technology

The environmentally sound technologies having an impact on competitiveness of company in the other part of the value chain or not having it differed when the following variables of competitiveness of company were assessed: the raw material (Mann-Whitney U = 408.000 asymp.sign. (two-tailed) = 0.070), energy (Mann-Whitney U = 392.000 asymp.sign. (two-tailed) = 0.063), capital (Mann-Whitney U = 350.500 asymp.sign. (two-tailed) = 0.026), product image (Mann-Whitney U = 413.500 asymp.sign. (two-tailed) = 0.064) and other differentiation (Mann-Whitney U = 291.500 asymp.sign. (two-tailed) = 0.056). =). Figure 9.7.2.4 presents the means of variables values of competitiveness assessment of the factors related to environmentally sound technologies categorised according to whether environmentally sound technology had an impact on the competitiveness of companies in the other part of the value chain. The environmentally sound technologies having an impact on the competitiveness of companies in the other part of the value chain increase competitiveness of company implemented the technology more through factors of raw material, product image and other differentiation than the technologies that do not have that impact on other part of value chain. The technologies having not an impact on the competitiveness of companies in the other part of the value chain decrease competitiveness of company implemented the technology more through factor of capital but increase competitiveness through a factor of energy.

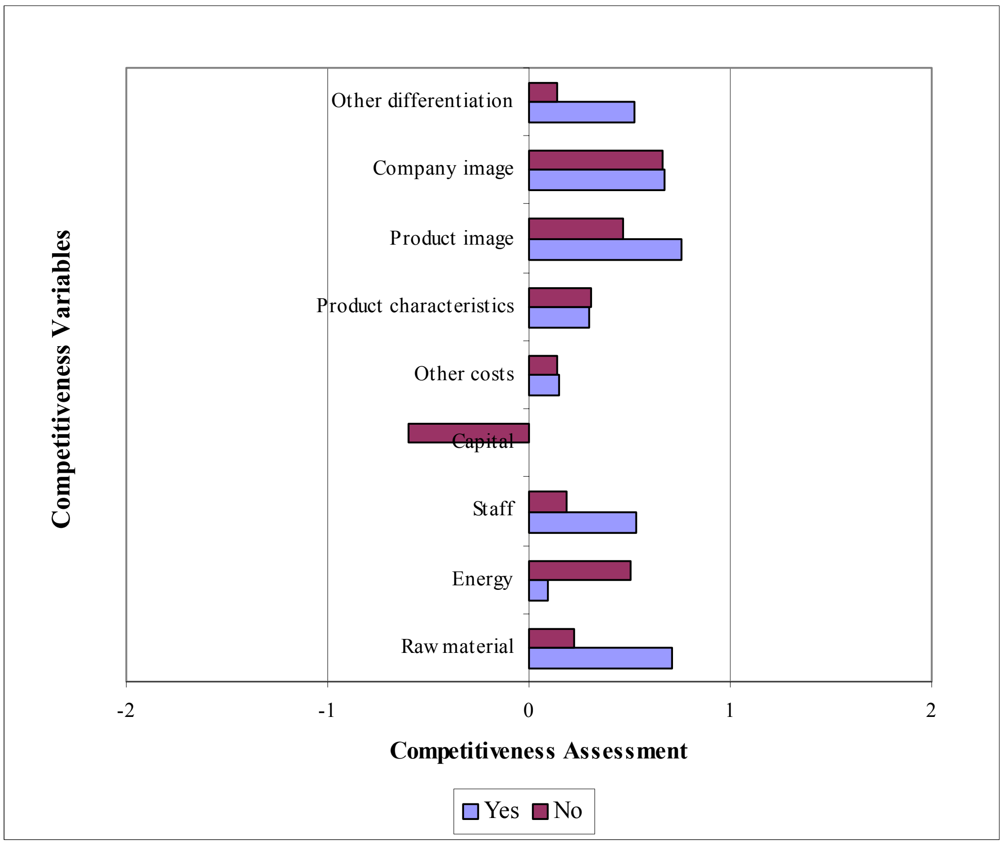

Figure 9.6.4 Means of variable values of competitiveness assessment of the factors related to environmentally sound technologies categorised according to whether environmentally sound technology has an impact on the competitiveness of companies in the other part of the value chain. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

The environmentally sound technologies having an impact on the competitiveness of companies in the other parts of the value chain and not having that impact do not differ when the following aspects of the competitiveness of companies were assessed: staff (Mann-Whitney U = 433.000 asymp.sign. (two-tailed) = 0.116), the other cost (Mann-Whitney U = 373.000

asymp.sign. (two-tailed) = 0.930), the product characteristics (Mann-Whitney U = 501.000 asymp.sign. (two-tailed) = 0.690), the company image (Mann-Whitney U = 528.000 asymp.sign. (two-tailed) = 1.000).

The environmentally sound technologies having an impact on competitiveness of companies in the other parts of the value chain and not having that impact did not differ when variables of having legal incentive (Chi-Square χ_2 = 0.125, df = 1, asymp.sig.= 0.724), having other-than-legal incentives (Fisher's exact test sig. (two-sided) = 0.558), categorised other-than-legal incentives (likelihood ratio G2 = 10.583, df = 7, asymp. sig. (two-sided) = 0.158), the environmental aspects (likelihood ratio G2 10.864, df = 8, asymp. sig. (two-sided) = 0.210) were tested.

When asked about the quality of impact on the competitiveness of companies in the other parts of the value chain, it was found that raw material at the following phase of the value chain was the most frequently mentioned response (17 responses). Also, paper market (seven responses), costs (two responses), environmental image (two responses), ability to operate (one response), and logistic (one response) were mentioned. Table VII-13 in Appendix VII presents the response frequency of the categorised impact on the competitiveness of companies in the other part of value chain divided into the parts of the value chain (likelihood ratio G2 = 44.748, df = 18, symp.sign (two-sided) = 0.003). The result means that customers at the following phase of value chain and the final customers of printed paper are the main objectives the environmentally sound technologies impacted when they impacted on competitiveness of companies in the other part of value chain.

The environmentally sound technologies having an impact on the competitiveness of companies in the other parts of the value chain and not having that impact do not differ when the categorised other-than-legal-incentive was assessed (likelihood ratio G2 = 34.160, df = 42, symp.sign (two-sided) = 0.800).

9.6.1 Summary of an Impact on Competitiveness of Companies in the Other Part of the Value Chain

Whether the environmentally sound technology has an impact on competitiveness of companies in the other part of the value chain than, where the technology is positioned, was investigated. The environmentally sound technologies of forest harvesting and printing houses had the most frequently impacts on competitiveness of company in the other part of the value chain and environmentally sound technologies of pulp mills have the least mentioned impacts on competitiveness of companies in the other part of value chain. The environmentally sound technologies having an impact on competitiveness in the other part of the value chain and not having that impact differ in technological categories. The technological categories that had the most frequently impact on competitiveness of companies in the other part of the value chain were automation, measurement and information technologies, wood and recycled-fibre technologies, energy technologies, closing-up technologies, operations, and chemical-elimination technologies. Emission-control technologies, wastewater technologies and solid-waste technologies do not have impacts on the competitiveness of companies in the other part of the value chain. Pollution-prevention technologies have more frequently an impact on the competitiveness of companies in the other part of the value chain than pollution-abatement technologies do The technologies that will have a breakthrough in the time period 2000-2009 have the most frequent impacts on the competitiveness of companies in the other part of the value chain; also, the future technologies will have an impact on the competitiveness of companies in the other part of the value chain.

The environmentally sound technologies having an impact on competitiveness in the other part of the value chain and those not having that impact differ when the competitiveness impacts of raw material, energy, capital, product image and other differentiation were assessed. The environmentally sound technologies having an impact on the competitiveness of companies in the other part of the value chain increased competitiveness of company implemented the technology more through factors of raw material, product image and other differentiation than the technologies that did not have that impact on other part of the value chain. The technologies having not an impact on the competitiveness of companies in the other part of the value chain decreased competitiveness of company implemented the technology more through factor of capital but increased competitiveness through a factor of energy. However, they do not differ when the competitiveness of companies was assessed by staff, other cost factor, product characteristics, and company image.

When respondents were asked about the quality of impact to other parts of the value chain, the raw material at the following phase was given as the main reason for the impact, but the paper market was also mentioned. Also, costs, environmental image, ability to operate, and logistics were mentioned. The evidence was found that customers at the following phase of the value chain and the final customers of printed paper are the objectives of the environmentally sound technologies impacted if they impacted on competitiveness of companies in the other part of the value chain.

9.7 Relationships Among Legal Incentive, Function Mechanism and Competitiveness Factors of Environmentally Sound Technologies—Testing Porter Hypothesis

The differences among variables of legal incentive, function mechanisms and competitiveness factors related to environmentally sound technologies were studied with reference to the 'Porter Hypothesis'.

The statement of Porter (1991a,b) was:

'Turning environmental concern into competitive advantage (variables of cost competitiveness and differentiation competitiveness) demands that it is established the right kind of regulations (variable legal incentive). They must stress pollution prevention rather than merely abatement or clean-up variable of function mechanism). They must not constrain the technology used to achieve them, or else innovation will be stifled. And standards must be sensitive to the costs involved (variable of cost competitiveness) and use market incentives (variable of differentiation competitiveness) to contain them (Porter, 1991, 1991b)'. The test variables were legal incentive, function mechanism and the competitiveness variables of environmentally sound technologies. The model is presented in Figure 8.3.1.

The environmentally sound technologies were classified to four categories: pollution-prevention technologies with legal incentives and without legal incentives and pollution-abatement technologies with legal incentives and without legal incentives. In the he study there are 39 responses of *pollution-prevention technologies without legal incentives*, 21 responses of *pollution-prevention technologies with legal incentives*, two responses of *pollution-abatement technology without legal incentives* and five responses of *pollution-abatement technology* with *legal incentives*.

Evidence was found that there was a difference among the four previous categories in technological categories (likelihood ratio G2 = 55.749, df = 24, asymp. sig. (two-sided) = 0.000), in parts of the value chain (likelihood ratio G2 = 14.717, df = 9, asymp. sig. (two-sided) = 0.099), in environmental aspect (likelihood ratio G2 = 38.033, df = 24, asymp. sig. (two-sided) = 0.034), in impact on competitiveness of company in the other part of the value chain (likelihood ratio G2 = 6.566, df = 3, asymp. sig. (two-sided) = 0.087). Response frequencies are presented in tables Vii-14…17 in Appendix VII.

Pollution-prevention technologies without legal incentives are mostly automation, measurement and information technologies (15 responses). Pollution-prevention technologies with legal incentive are mostly operations (six responses) Pollution-abatement technologies without legal incentive is emission-control technology (one response) and wastewater technology (one response). Pollution-abatement technologies with legal incentive are emission-control technologies (two responses) and wastewater technologies (two responses).

Pollution-prevention technologies without legal incentives are mostly mentioned in paper mills (12 responses). Pollution-prevention technologies with legal incentive are mostly mentioned in forest harvesting (nine responses). Pollution-abatement technologies without legal incentive are mentioned in pulp mill (one response) and paper mill (one response). Pollution-abatement technologies with legal incentive are mostly mentioned in pulp mill (four responses).

Pollution-prevention technologies without legal incentives are most frequently mentioned to manage use of raw material and natural resources (17 responses). Pollution-prevention technologies with legal incentive are mostly mentioned to manage use of raw material and natural resources (seven responses). Pollution-abatement technologies without legal incentive are mentioned to manage emissions to air (only one response) and waste management (one response). Pollution-abatement technologies with legal incentive are mentioned to manage emissions to air (four responses).

Pollution-prevention technologies without legal incentives are most frequently mentioned to impact on competitiveness of companies in the other part of the value chain (21 responses). Pollution-abatement technologies without legal incentive do not have an impact on competitiveness of companies in the other part of the value chain at all.

Evidence was not found that there was a difference among the four previous categories in time period (likelihood ratio G2 = 4.280, df = 3, asymp. sig. (two-sided) = 0.233), breakthrough time (likelihood ratio G2 = 18.025, df = 12, asymp. sig. (two-sided) = 0.115), other-than-legal incentive (likelihood ratio G2 = 1.128, df = 3, asymp. sig. (two-sided) = 0.770), categorised other-than-legal incentive (likelihood ratio G2 = 23.210, df = 21, asymp. sig. (two-sided) = 0.333), significantly competitiveness-increasing technologies (likelihood ratio G2 = 3.054, df = 3, asymp. sig. (two-sided) = 0.383). significantly competitiveness-decreasing technologies (likelihood ratio G2 = 3.911, df = 3, asymp. sig. (two-sided) = 0.271), in categorised impacts on competitiveness of company in the other part of the value chain and importance on environmental impact (Kruskall-Wallis, $\chi 2$ = 3.124, df = 3, asymp.sig.= 0.373).

Figure 9.7.1 presents means of variable values of competitiveness assessment concerning environmentally sound technologies divided into previous categories. Evidence was found that the four categories of pollution-prevention technologies with legal incentives and without legal incentives and pollution-abatement technologies with legal incentives and without differed when tested competitiveness impacts of staff factor (Kruskall-Wallis, $\chi 2$ = 8.242, df = 3, asymp.Sig.= 0.041). Among the environmentally sound technologies, that difference was not found among previous four categories when tested the competitiveness factors of raw material (Kruskall-Wallis $\chi 2$ = 2.448, df = 3, asymp.sig.= 0.485), energy (Kruskall-Wallis $\chi 2$ = 4.109, df = 3, asymp.sig.= 0.250), capital (Kruskall-Wallis $\chi 2$ = 3.027, df = 3, asymp.sig.= 0.388), other cost (Kruskall-Wallis $\chi 2$ = 1.594, df = 3, asymp.sig.= 0.661), product characteristics (Kruskall-Wallis $\chi 2 = 2.272$, df = 3, asymp.sig.= 0.518), product image (Kruskall-Wallis, $\chi 2 = 2.021$, df = 3, asymp.sig.= 0.568), company image (Kruskall-Wallis, $\chi 2 = 0.543$, df = 3, asymp.sig.= 0.909) and other differentiation (Kruskall-Wallis, $\chi 2 = 546$, df = 3, asymp.sig.= 0.909).

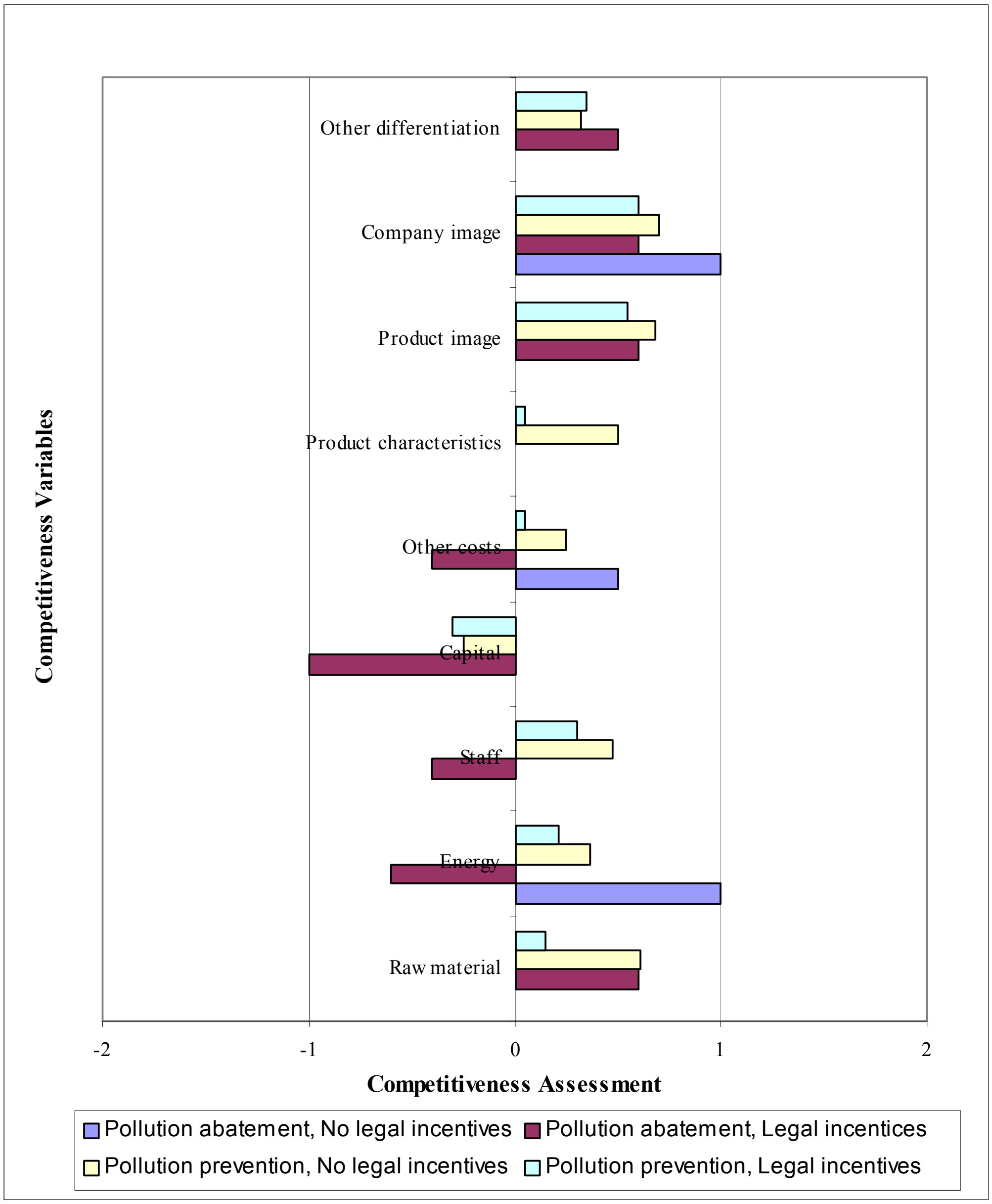

Figure 9.7.1 Means of variable values of competitiveness assessment concerning environmentally sound technologies divided into function mechanism of pollution prevention with legal incentive and without legal incentive and function mechanism of pollution abatement with legal incentive and without legal incentive. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

Staff factor decreased competitiveness mostly in pollution-abatement technologies with legal incentives and increased competitiveness mostly in pollution-prevention technologies without legal incentives. Pollution-abatement technologies without legal incentives increased competitiveness most of all through factors of energy and company image. Pollution-abatement technologies with legal incentives decreased competitiveness the most of all through factors of capital and energy (Figure 9.7.1).

The differences among the four categories of technologies and competitiveness factor of staff were analysed in greater detail. The data of competitiveness assessment of staff was reduced from five categories to three categories of increasing competitiveness, decreasing competitiveness and no impact. Evidence for differences was found in variable values of the value chain, time period, environmental aspect, breakthrough time, impact on competitiveness of company in the other part of the value chain and categorised impact on competitiveness of company in the other part of the value chain. The three-way contingency tables are presented in tables VII-18-22.

Evidence was found for differences among the four previous categories, competitiveness factor of staff in pulp mills (likelihood ratio G2 = 7.723, df = 3, asymp. sig. (two-sided) = 0.089), and printing houses (likelihood ratio G2 = 7.837, df = 3, asymp. sig. (two-sided) = 0.020), but not in forest harvesting (likelihood ratio G2 = 0.431, df = 2, asymp. sig. (two-sided) = 0.806) and paper mill (likelihood ratio G2 = 1.211, df = 3, asymp. sig. (two-sided) = 0.750).

Evidence was found for differences among the four previous categories, competitiveness factor of staff in time period of 1980-1999 (likelihood ratio G2 = 711.138, df = 6, asymp. sig. (two-sided) = 0.084), but not in time period 2000-2019 (likelihood ratio G2 = 3.668, df = 4, asymp. sig. (two-sided) = 0.453).

Evidence was found for differences among the four previous mentioned categories, competitiveness factor of staff in environmental aspects of releases to water, and waste management (likelihood ratio G2 = 2.773, df = 1, asymp. sig. (two-sided) = 00.96). Among the other studied environmental aspects that difference was not found concerning aspects of emissions to air (likelihood ratio G2 = 2.683, df = 3, asymp. sig. (two-sided) = 0.443), use of energy (likelihood ratio G2 = 0.309, df = 1, asymp. sig. (two-sided) = 0.578), use of raw materials and natural resources (likelihood ratio G2 = 0.279, df = 1, asymp. sig. (two-sided) = 0.597), biodiversity (likelihood ratio G2 = 1.234, df = 2, asymp. sig. (two-sided) = 0.537) or there was not enough data for analysis (contamination of land, use of fresh water and landscape).

Evidence was found for differences among the four previous mentioned categories, competitiveness factor of staff in breakthrough time period of 1980-1989 (likelihood ratio G2 = 8.509, df = 4, asymp. sig. (two-sided) = 0.075). Between the other studied breakthrough time periods that connection was not found. They were 1990-1999 (likelihood ratio G2 = 3.716, df = 2, asymp. sig. (two-sided) = 0.156), 2000-2009 (likelihood ratio G2 = 3.051, df = 2, asymp. sig. (two-sided) = 0.217), 2010-2019 (likelihood ratio G2 = 3.452, df = 4, asymp. sig. (two-sided) = 0.485). Breakthrough time of after 2020 there was not enough data for analysis.

Evidence was found for differences among the four previous mentioned categories, competitiveness factor of staff, when technologies did not impact on competitiveness of company in the other part of the value chain (likelihood ratio G2 = 11.439, df = 6, asymp. sig. (two-sided) = 0.076). This connection is not, when technologies impact on competitiveness of company in the other part of the value chain (likelihood ratio G2 = 3.024, df = 4, asymp. sig. (two-sided) = 0.554).

Evidence was found for differences among the four previous mentioned categories, competitiveness factor of staff, when categorised impact on competitiveness of company in the other part of the value chain was raw material at the following phase (likelihood ratio G2 = 4.534, df = 2, asymp. sig. (two-sided) = 0.104) and paper market (likelihood ratio G2 = 2.969, df = 1, asymp. sig. (two-sided) = 0.085). There was not enough data for analysing environmental image, ability to operate, logistic and cost.

9.7.1. Summary of Relationships Between Legal Incentive, Function Mechanism and Competitiveness Factors of Environmentally Sound Technologies—Testing Porter Hypothesis

For testing the Porter Hypothesis, the environmentally sound technologies were classified to four categories: pollution-prevention technologies with legal incentive and without legal incentive and pollution-abatement technologies with legal incentive and without legal incentive. Pollution-prevention technologies without legal incentive are mostly automation, measurement and information technologies in paper mills controlling raw material and natural resources and having an impact on competitiveness of companies in the other part of the value chain. Pollution-prevention technologies with legal incentive are mostly operations in forest harvesting controlling raw material and natural resources and having impacts on competitiveness of company in the other part of the value chain. Pollution-abatement technologies without legal incentive are emission-control technology and wastewater technology in pulp mill and paper mill controlling emissions to air and waste management, but have no frequent impact on competitiveness in the other part of the value chain. Pollution abatement with legal incentive are emission-control technologies and wastewater technologies in pulp mills controlling emissions to air and having not impact on competitiveness of company in the other part of the value chain.

Evidence was found that the four categories of technologies differed when tested competitiveness impacts of staff factor, but they did not differ when tested all the other competitiveness factors. Staff factor decreased competitiveness mostly in pollution-abatement technologies with legal incentive and increased competitiveness mostly in pollution-prevention technologies without legal incentive.

The Porter Hypothesis concerning function mechanism of technologies is confirmed only when competitiveness of companies is measured by the factor of staff. According to this study Porter Hypothesis (1991) can be reformulated as follows

'Turning environmental concern into competitive advantage through staff demands that it is established the right kind of regulations. They must stress pollution prevention rather than merely abatement or clean-up. They must not constrain the technology used to achieve them, or else innovation will be stifled. And standards must be sensitive to the staff costs involved'.

The detailed analysis resulted that there is a difference among the four previous categories of technologies when competitiveness factor of staff assessed in pulp mills and printing houses concerning in time period of 1980-1999 and when managing environmental aspects of releases to water and waste management. The breakthrough time period in such a case was time period of 1980-1989. When technology has impact on competitiveness of company in the other part of the value chain it because of is raw material at the following phase and paper market

Pollution-abatement technologies without legal incentives increased competitiveness the mostly of all factors through energy and company image. Pollution-abatement technologies with legal incentives decreased competitiveness the mostly of all factors through factors of capital and energy. As a conclusion for that result, a function mechanism of pollution-prevention technologies is not the one and only key for competitive advantage in companies; pollution-abatement technologies can also create value for companies. For the regulative point of view, this means that there in no need to tailor the environmental regulation for pollution-prevention technologies. Environmental regulation should focus on limitation of environmental impacts, not on ideas of win-win situations, which might not be capitalised ever.

10 Discussion and Conclusions

10.1 Main Results of the Study

The aim of the research was to investigate the impacts of environmentally sound technologies on the competitiveness of companies in terms of cost competitiveness and differentiation competitiveness in the value chain of printed paper from forest to market. The environmentally sound technologies were explored in technological categories. Relationships among factors related to environmentally sound technologies, such as environmental aspects, breakthrough time periods, time periods 1980-1999 and 2000-2019, legal incentive, other-than-legal incentives, and the function mechanisms of pollution prevention and pollution abatement were studied, too. The properties of significantly competitiveness-increasing and significantly competitiveness-decreasing environmentally sound technologies were investigated. The differences between environmentally sound technologies of four part of the value chain of printed paper were explored. They were forest harvesting, pulp mills, paper mills and printing houses. The impacts of environmentally sound technologies on the competitiveness of companies in the other part of the value chain, than where the technologies were positioned, were studied. The role of pollution-prevention technology and pollution-abatement technology in facing legal requirements was studied on as a part of the so-called 'Porter Hypothesis'. Data were collected from the value chain of printed paper divided into the following parts: forest harvesting, pulp mill, paper mill and printing house. Eight experts were interviewed resulting in 69 environmentally sound technologies in the time periods 1980-1999 and 2000-2019.

The study reviewed the existing literature on environmental technology, competitiveness of companies and the value chain of printed paper in the context of the environmental issues. In the literature, the impact of technology on the competitiveness of companies and the value chain is clearly understood (Porter, 1985). In this study, a term *environmental value creation* was defined as '*performing activities by managing environmental aspects so that the value of* *goods and services to consumers or to customers increases'*. 'Environmental aspect' refers to an element of an organisation's activities or products and services that interact with the environment (SFS-EN 14001, 2004). Environmental value creation produces value for companies by managing environmental aspects. Environmental value creation of environmentally sound technologies was indirectly explored in this study by measuring competitiveness impacts by cost factors and differentiation factors. *Eco-efficiency* is a related term that means joint value creation for society and company. It links the goals of business excellence and environmental excellence (World Business Council for Sustainable Development, 1996). The relationship between environmental technology and competitiveness of companies has not so far been extensively studied. The impact of environmental regulation on the economic results of companies has been a popular topic (Barbera and McConnell, 1990; Gray and Shadbegian, 1993; Brännlund and Grosskopf, 1995; EC, 1998), as has the Porter Hypothesis, which is a part of this topic (Oates, 1993; Palmer et al., 1995; Boyd and McClelland, 1999; Marklund, 1999; Xepapadeas and de Zeeuw, 1999; Mohr, 2000; Roedeger-Schluga, 2003; Murty and Kumar, 2003; Hillard, 2004). The research approaches vary a lot, as do the results of studies concerning the Porter Hypothesis. The role of environmentally sound technology and related factors inside companies are not widely explored in these studies. Even the Porter Hypothesis has not been studied in detail inside the companies before. This study provides detailed information about value-creating properties of environmentally sound technologies inside the companies, and along the value chain as well. It helps to understand the progress happening in the value chain of printed paper at the moment and future. It comments on a very important topic of the role of environmental regulation inducing value creation in companies. This study provides information about environmental technology that is useful for researchers, technology developers, company managers and policymakers.

10.1.1 Environmentally Sound Technologies with the Most Important for Environmental Impacts

Technological Categories of Environmentally Sound Technologies

The respondents were asked to identify the environmentally sound technologies that were the most important for environmental impact. This was the first research question. Automation, measurement and information technology was found the most frequently mentioned in responses of technological categories; energy technology the second frequently mentioned and closing-up technology the third frequently mentioned. The result of automation, measurement and information technology supports Helmut Kaiser Consultancy's (1991) view that technologies of measurement and process control analysis were the fastest-growing environmental technology. The other categories of environmentally sound technologies mentioned are wood and recycled fibre technology, operation, chemical-elimination technology, emission-control technology, wastewater technology and solid-waste technology. Automation, measurement and information technology, closing-up technology, and energy technology were assessed to be the most important technologies on environmental impacts as well.

Environmental Aspects Controlled by Environmentally Sound Technologies

It was asked what environmental aspect the environmentally sound technology affected. The use of raw materials and natural resources was the most frequently mentioned environmental aspect controlled by the environmentally sound technologies of the value chain of printed paper. This progress is found to strengthen among the technologies of the time period 2000-2019. As such, this aspect is not commonly considered as an environmental aspect in the literature, but is mentioned as paper choices, non-renewable resources and use of chemicals (Kellomäki, 1998; Gullichsen and Fogelholm, 2000; Göttsching and Pakarinen, 2000; Minnesota Environmental Initiative, 2006, 28.3.2006). As a conclusion, the value chain of printed paper concentrates on implementing the technologies resulting in 'more value from fewer resources'. The emissions to air were the second most frequent mentioned; the third were releases to water and the use of energy. The other controlled environmental aspects are biodiversity, use of fresh water, waste management, landscape and contamination of land. In this study, the used categories of environmental aspects did not specify emissions and environmental impacts. These aspects included control of erosion in the forests, forest absorption of air impurities, noise abatement, heavy-metal and chloro-organic content of recovered paper, composition and reduction of volatile organic compounds (Kellomäki, 1998; Gullichsen and Fogelholm, 2000; Göttsching and Pakarinen, 2000; Minnesota Environmental Initiative, 2006, 28.3.2006).

The technological categories vary significantly in controlling environmental aspects. The automation, process control and information technologies were found to be the most important driver for managing raw materials and natural resources, but also wood and recycled-fibre technologies, energy technologies and operations were. Closing-up technologies control releases to water and use of fresh water. Operations control biodiversity. Chemical-elimination technologies control emissions to air and releases to water. Emission-control technologies control emissions to air.

Legal Incentive and Other-than-Legal Incentives Related to Environmentally Sound Technologies

In this study, legal incentive is any kind of environmentally regulative stimulation focused on technology and other-than-legal incentive is any kind of incentive except environmentally regulative stimulation. Environmental-saving technological change should be viewed in a similar manner as a normal technological change. An important difference compared with other technologies is that environmental technological change depends to a large extent on government regulation (Kemp, 1993). The most important driving factors of the environmental technology market are legislation and cost (Helmut

Kaiser Consulting, 1991; Kemp, 1993). Responses concerning legal incentives related to environmentally sound technology were categorised as having legal incentive. In the 40% of mentioned technology responses (26 responses), it was found to have legal incentive impacted on them. Technological categories were found to differ in having legal incentive. The category of operation is the most frequently mentioned to be impacted by legal incentives. The automation, measurement and information technologies are the most frequently mentioned to not be impacted by legal incentives. Evidence was found for differences among environmental aspects controlled by environmentally sound technologies in having legal incentive or not. Environmentally sound technologies controlling raw materials and natural resources have the most frequently not legal incentives impacted on, but that aspect also have the legal incentives most frequently impacted on. It had responses the most frequently mentioned. The technologies controlling releases to water are the second most frequently mentioned to be impacted by legal incentives. The technologies controlling use of energy have the second most frequently not legal incentives impacted on. Pollution-abatement technologies were found more frequently mentioned to be impacted by legal incentives than pollution-prevention technologies.

The most frequently mentioned categories of the other-than-legal incentives were cost, public image and market pressure. The technological categories were found to differ in categorised other-than-legal incentives. Cost is the most frequently mentioned other-than-legal incentive for automation, measurement and information technology and energy technology; and public image for closing-up technology was also frequently mentioned.

Pollution-Prevention Technology and Pollution-Abatement Technology

Pollution-prevention technology is defined as an action aiming to prevent pollution beforehand (Tekniikan sanastokeskus, 1998) and has been an idea of controlling pollutants from the beginning of 90s (U.S. Environmental Protection Agency, 1990). Environmentally sound technologies were categorised as pollution-prevention technology and pollution-abatement technology. Most, 90%, of the technologies represented pollution-prevention technology in this study. The function mechanisms of pollution prevention and pollution abatement differ significantly in technological categories. Automation, measurement and information technologies, energy technologies, closing-up technologies, wood and recycled-fibre technologies and operations, solid-waste technologies are all categorised as pollution-prevention technologies. Wastewater technologies, emission-control technologies and chemical-elimination technologies were categorised by the researcher as pollution-abatement technologies. Function mechanisms of pollution prevention and pollution abatement varied according to time period 1980-1999 and 2000-2019, breakthrough time period, and environmental aspect. Almost all the responses for the pollution-abatement technologies were from the time period 1980-1999. The function mechanism of environmentally sound technology, pollution-prevention technology, sets aside the pollution abatement approach in the time period 2000-2019. It was found that the most frequently mentioned breakthrough time period of pollution abatement was the time period 1980-1990 and that of pollution-prevention technology were the time periods 1990-1999 and 2000-2009. The pollution-prevention technologies control the most frequently mentioned the use of materials and natural resources of environmental aspects, but control also all the other studied categories of environmental aspects. The pollution-abatement technologies control emissions to air, releases to water and waste management.

10.1.2 Impacts of Environmentally Sound Technologies on Competitiveness of Companies in Terms of Cost and Differentiation Factors

In this study, the respondents were asked to assess the competitiveness impacts of environmentally sound technologies they had identified. It was investigated through the cost competitiveness variables, such as raw material, energy, staff, capital and other cost and through differentiation competitiveness variables, such as product characteristics, product image, company image and other differentiation factors. This was the second research question. Technology affects competitive advantage if it has a significant role in determining relative cost position or differentiation (Porter, 1985). As these factors were related to environmentally sound technologies in this study, they measured indirectly environmental value creation of the studied technologies. The competitive advantages of integrating environmental technology into strategic management will result in, for example, cost reduction and quality, competitive edge and public image improvement (Shrivastava, 1995). Environmental performance of a company and good records of profitability have a positive association according to many studies (Bragdon and Marlin, 1972; Russo and Fouts, 1997; Cohen et al., 1997; Ytterhus, 1997). There are also studies in which has been found a negative association between them (Jaggi and Freedman, 1992) or no negative association (Freedman and Jaggi, 1992) or positive and negative association (Lankoski, 2000).

Means of variables values of competitiveness assessment were found to be in between ‘No impact’ and ‘A little increasing or decreasing impact’. Figure 10.1 presents the means of variable values gained as a result of competitiveness assessment of environmentally sound technologies in this study.

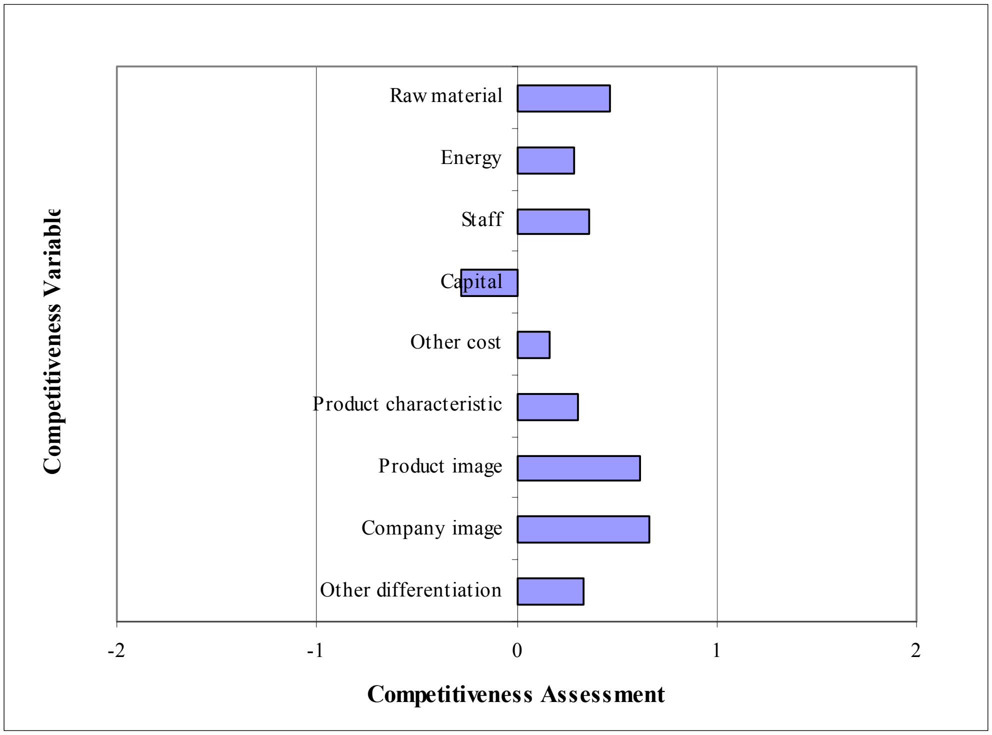

Figure 10.1 Means of variable values gained as a result of competitiveness assessment of environmentally sound technologies. Scale of competitiveness assessment is significantly decreasing (-2), a little decreasing (-1), no effect (0), a little increasing (1) and significantly increasing (2).

In the study, the cost-competitiveness impacts of environmentally sound technologies through cost factors of raw material, energy, staff, capital and other cost were assessed. Among environmentally sound technologies, the cost factors of raw material and staff most increase competitiveness of companies and the cost factor of capital most decrease it. According to Bragdon and Marlin (1972), pollution control investment can reduce operating costs through lower costs of raw material, labour, taxes and legal costs, or costs for plant and equipment purchase and maintenance. Florida (1996) found that pollution prevention expenditures are a component of overall capital expenditures. These results support the arguments of Bragdon and Marlin (1972) and Florida (1996). Kemp (1993) argued that the purchase price of cleaner technology is not often the most important factor in decision-making. In this study, environmentally sound technologies were found to most decrease competitiveness through capital.

In this study, the differentiation-competitiveness impacts of environmentally sound technologies through product characteristics, product image, company image and other differentiation factors were assessed. These factors related to environmentally sound technologies were found to most increase the competitiveness of companies, mostly through the image of product and company. Environmental actions are considered to have a great positive influence on the product image (Ytterhus, 1997). Reputation advantage is enhanced by environmental performance (Kemp, 1993). According to Shrivastava (1995), technological change can lead to sustainable competitive advantage when it itself enhances differentiation. Cleaner technology is supposed to improve the public image of the company because it can create not only unique and inimitable strategies, but also consumer satisfaction. It can result in an advantage for public relations and corporate image (Shrivastava, 1995). The results of this study support the studies of Ytterhus (1997), Kemp (1993) and Shrivastava (1995).

Competitiveness Impacts and Technological Categories

The differences among technological categories in competitiveness factors were analysed. The technological categories differed when the competitiveness impacts of raw material, staff, product characteristics and product image were assessed, but did not differ when the competitiveness impacts of capital, other cost, company image and other differentiation were assessed. As a conclusion, it can be said that competitiveness impacts of environmentally sound technologies vary depending technological category and the competitiveness factors of raw material, staff, product characteristics and product image they impacted through. The found variation in competitiveness impacts among technological categories explains also why the results of the studies of the connections between environmental technology or investment and economic success of companies have varied a lot (Shrivastava, 1995; Freedman and Jaggi, 1992; Chung et al., 1997; Kemp, 1993; Anonymous, 1998; Klassen and Whybark, 1999a; Hart et al., 2000; Nehrt, 1996). In this study, it was found that the automation, measurement and information technologies increase competitiveness most frequently through raw material, staff and product characteristics, but increase competitiveness also through the other assessed competitiveness factors, such as energy, other cost, product image and company image. This technological category does not decrease competitiveness through capital as the other investigated categories do. The other studied technological categories both increase and decrease competitiveness through cost-competitiveness factors. Wood and recycled-fibre technologies were assessed to increase competitiveness through factors of raw material and staff and decrease competitiveness through product characteristics. Operations were assessed to increase competitiveness through staff, but decrease competitiveness through raw material. Closing-up technologies were assessed to increase competitiveness through factors of raw material and product image and decrease competitiveness through factors of staff and product characteristics.

Competitiveness Impacts and Environmental Aspects

It was asked which environmental aspects the investigated technologies control and their differences among competitiveness factors were analysed. The study showed that environmental aspects controlled by environmentally sound technologies differed when the competitiveness impacts of raw material, energy, staff, other costs and product image were assessed, but there is no evidence that they differed when the competitiveness impacts of capital, other costs, product characteristics, company image and other differentiation were assessed. The technologies that control use of raw material and natural resources, use of energy, biodiversity and releases to water increase competitiveness through raw material, while those controlling contamination of land and use of fresh water decrease competitiveness through raw material. The technologies that control use of energy, waste management and raw material and natural resources increase competitiveness through energy, while those controlling contamination of land, emissions to air, biodiversity and releases to water decrease competitiveness through energy. The technologies controlling landscape, contamination of land, use of raw material and natural resources, use of energy and biodiversity increase competitiveness through staff, while those controlling waste management, releases to water and emissions to air decrease competitiveness through staff.

Competitiveness Impacts in Time Periods 1980-1999 and 2000-2019

The respondents were asked to identify environmentally sound technologies of time periods 1980-1999 and 2000-2019. Evidence was found that the time periods 1980-1999 and 2000-2019 of environmentally sound technologies differed when the competitiveness impact of product image was assessed, but there was no evidence of this when the other competitiveness impacts were assessed. It was clearly found that environmentally sound technologies of the time period of 2000-2019 were assessed to increase competitiveness more through product image than through the technologies of the time period of 1980-1999. This result supports the product image benefits that are pointed to in many studies (Kemp, 1993; Ytterhus, 1997, Bansal and Roth, 2000).

Competitiveness Impacts and Legal Incentives

Marklund's (1999) major conclusion is that there seems to be no obvious and clear relationship between environmental regulation and efficiency in the Swedish pulp and paper industry. As a result of this study, it was found that, among the environmentally sound technologies, there is no difference between having legal incentive and not having them on impacts of studied competitiveness factors of companies in the value chain of printed paper. According to literature, the impacts of environmental regulation on company performance can be positive or negative (Barbera and McConnell, 1990), negative (Gray and Shadbegian, 1993; Brännlund and Grosskopf, 1995), not negative (European Commission, 1998) in the form of costs or loss of profit or productivity. Smith and Walsh (2000) reported the result of their study, which supports the statements that environmental regulation does not ruin the competitiveness of companies, but nor does it strengthen it either. The heavily regulated EU chemical industry, for example, has not suffered from environmental regulation (European Commission, 1998). Chistainsen and

Haveman (1981) argued that environmental regulations push organisations to investments that increase the ratio of labour to conventional capital. The result is lower productivity. Since pollution control equipment requires manpower to operate it, employment levels rise with no addition to marketable output. Complying with these regulations requires information-gathering, administrative, and legal activities, which also require inputs yielding no sellable output. (Christainsen and Haveman, 1981). This relationship between legal incentives and competitiveness impacts of staff was not confirmed in this study. As a conclusion of this study, it is possible to say that even the value chain of printed paper does not suffer heavily from environmental regulation, and that legal incentives do not impact positively or negatively on the competitiveness of companies in the value chain of printed paper.

Competitiveness Impacts and Function Mechanisms of Pollution Prevention and Pollution Abatement

According to Klassen and Whybark (1999), pollution-abatement technology decreases manufacturing performance, while pollution prevention investments lead to better manufacturing performance. On the basis of this study, it may be said that, among environmentally sound technologies, there is a difference between function mechanisms in impact of staff on competitiveness, but there is not that difference in the impact of the other competitiveness factors. Pollution-prevention technologies increase the competitiveness of companies through staff, but pollution-abatement technologies decrease the competitiveness of companies through staff. This study supports the argument of Klassen and Whybark (1999) when manufacturing performance is measured by the staff factor. According to Boyd and McClelland (1999), pollution abatement allocates capital to lower productivity investments, but also lowers costs for plant and equipment purchase. This study underlines that capital costs of environmentally sound technology decrease the competitiveness of companies, but it was not found difference in pollution-prevention technologies and pollution-abatement technologies.

Associations Between Competitiveness Factors and Importance of Environmental Impact

The association between competitiveness factors of environmentally sound technologies and their importance on environmental impact was analysed. According to Kemp (1993), the benefit of cleaner technology may involve improvement of consumer satisfaction. Nehrt (1996) found that some customers of pulp manufacturers may prefer products made from less polluting-intensive manufacturing processes, or products that are themselves less pollute when consumed or disposed of. Firms that can offer such products may find sales higher as a result. The product image factor was found to have a correlation with the importance on environmental impact, which means that the more important for environmental impact the technology is, the more competitiveness increasing it is through product image. The result supports the arguments and findings of Kemp (1993) and Nehrt (1996). The other competitiveness factors do not correlate with the importance on environmental impact.

Associations Among Competitiveness Factors Related to Environmentally Sound Technologies

The correlations among competitiveness factors were analysed. The measured competitiveness factors related to environmentally sound technologies are not independent, while they are correlated to each other. The strongest positive correlation was found between factors of capital and staff, and raw material and staff. With respect to technical change, it is known that this can have an effect on the ratio of labour to capital (Anonymous, 1998); the results of this study indicate this, too. In this study, cost-competitiveness factors and differentiation-competitiveness factors are positively and negatively correlated to each other. It was found that differentiation factor of product characteristics had a positive correlation with the cost factors of staff, capital and other costs, while the differentiation factor of company image has a positive correlation with the cost-competitiveness factor of staff. Differentiation factor of product image has a negative correlation with the cost factor of raw material, while the company image has a negative correlation with the cost factor of energy. Company image and product image factors have positive correlation between each other in competitiveness impacts.

Gray and Shadbegian (2003) found that plants with higher pollution abatement costs have significantly lower productivity levels. This relationship differs greatly, based on a plant's technology, with productivity at integrated mills being greatly affected by abatement costs, while the impact at non-integrated mills is negligible. As a conclusion of this study, it can be assumed that increasing competitiveness through the cost factor of capital creates cost advantage by staff, raw material, energy and product characteristics and other costs. This does not support Gray and Shadbegian (2003)'s results of high pollution abatement costs and lower productivity levels. The data of this study concludes not only pollution abatement but also pollution-prevention technologies, which might explain the difference when comparing it with Gray and Shadbegian (2003) findings.

Significantly Competitiveness-Increasing and Significantly Competitiveness-Decreasing Technologies

In the study, 60% of technology responses (40 technology responses) mentioned that competitiveness increased significantly through any of the measured competitiveness factors. The most frequently mentioned these technologies were automation, measurement and information technologies, closing-up technologies and wood and recycled-fibre technologies. The evidence was found that significantly competitiveness-increasing technologies were more important for environmental impact than the other investigated technologies. The majority of significantly competitiveness-increasing technologies are implemented in paper mills and printing houses. The significantly competitiveness-increasing technologies increase competitiveness mostly through cost factors by raw material and staff. They did not decrease competitiveness through the factor of capital at all, unlike other investigated technologies. Significantly competitiveness-increasing technologies created more competitiveness through product image and company image than the other investigated technologies when competitiveness impacts were measured by means of variable values of competitiveness assessment.

Porter (1985) argued that, when the technological change improves overall industry structure, sustainable competitive advantage can be achieved by technological change. According to this study, it can be clearly assumed that the significantly competitiveness-increasing environmentally sound technologies may change the value chain of printed paper in the paper mills and printing houses through the cost factors of raw material and staff related to them that change may happen without negative competitiveness impacts of capital.

There was 16% of technology responses (11 technology responses) included in this study that indicated significantly decreased competitiveness. Significantly competitiveness-decreasing technologies differ from other investigated technologies in breakthrough time, legal incentive and value chain. The most frequently mentioned breakthrough time periods of significantly competitiveness-decreasing technologies are the time periods 1980-1990 and 1990-1999. Almost half of the significantly competitiveness-decreasing technologies are found in printing houses. There is no significantly competitiveness-decreasing technology in paper mills. Half of significantly competitiveness-decreasing technologies control emissions to air, and one-fourth releases to water, and half of them have legal incentives impacted on, but only one-third of the other investigated technologies have legal incentives.

The significantly competitiveness-decreasing technologies decrease competitiveness mostly through the cost factors of capital and energy, but also decrease competitiveness through the other cost factors of raw material, staff and other costs. Significantly competitiveness-decreasing technologies did not differ from the other investigated technologies in measured differentiation competitiveness factors of product characteristics, product image, company image and other differentiation factor. Evidence was found that the significantly competitiveness-decreasing technologies have more frequently mentioned legal incentives impacted on than the other investigated technologies. This result indicates that there is a category of environmentally sound technologies that causes disadvantage for companies by legal incentives impacted on. It can be concluded that those technologies are already available and the coming technologies are less competitiveness decreasing.

10.1.3 Comparison of Environmentally Sound Technologies in Different Parts of the Value Chain

The term *value chain* refers to the idea that a company is a chain of activities transforming inputs into outputs that customer's value (Hill and Jones, 1999). The data of environmentally sound technologies was collected from following four parts of value chain: forest harvesting, pulp mill, paper mill and printing house. It was analysed the differences among those parts of value chain of printed paper in competitiveness impacts and other related factors. That was the third research question. The value chain includes activities from raw materials to customers. In this study, the major raw material is timber and the final customer is the consumer of printed paper.

The parts of value chain were found to differ in technological categories, in function mechanisms of pollution prevention and pollution abatement, in categorised other-than-legal incentives and in environmental aspects. Among environmentally sound technologies, a technological category of automation, measurement and information technology and as well as an environmental aspect of raw material and natural resources were the most frequently mentioned categories in forest harvesting and printing houses. Closing-up technology and emission-control technology and an environmental aspect of releases to water were the most frequently mentioned categories in pulp mills, as well as energy technology and wood and recycled fibre technology and an environmental aspect of use of energy in paper mills are the most frequently mentioned categories. The function mechanism of pollution prevention is favoured in forest harvesting, but also in the other parts of value chain. Pollution-abatement technologies are most frequently mentioned to use in pulp mills. Cost is the most frequently mentioned the categorised other-than-legal incentives in all studied parts of the value chain, except for pulp mills where the most frequently mentioned incentive is public image. Table 10.1 summarises the differences among the parts of the value chain in terms of (the variables of) technological category, function mechanism, other-than-legal incentives, and environmental aspect. In this study the environmentally sound technologies in the different parts of the value chain were found to not to differ in having legal incentive.

Table 10.1 Most Frequently Mentioned Responses of Technological Category, Function Mechanism, Categorised Other-than-Legal Incentive and Environmental Aspect in the Different Parts of the Value Chain

		The Part of Value Chain of Printed Paper		
Variable	**Forest Harvesting**	**Pulp Mill**	**Paper Mill**	**Printing House**
Technological category	Automation, measurement and information technology (seven responses)	Closing-up technology (four responses) and emission-control technology (four responses)	Energy technology (four responses) and wood and recycled fibre technology (four responses)	Automation, measurement and information technology (seven responses)
Function mechanism	Pollution prevention (18 responses)	Pollution prevention (14 responses) and pollution abatement (four responses)	Pollution prevention (16 responses) and pollution abatement (two responses)	Pollution prevention (14 responses) and pollution abatement (one response)
Categorised other-than-legal incentive	Cost (six responses)	Public image (three responses)	Cost (six responses)	Cost (five responses)
Environmental aspect	Use of raw materials and natural resources (Nine responses)	Releases to water (Eight responses)	Use of energy (Eight responses)	Use of raw material and natural resources (Nine responses)

The differences among parts of value chain in competitiveness impacts were analysed. Table 10.2 summarises the differences between the parts of the value chain in the measured competitiveness factors of energy, staff, and other costs and product characteristics, product image and company image. Cost-competitiveness impacts of the capital factor did not differ in the parts of the value chain, but the cost factors of energy, staff and other costs differed. The differentiation competitiveness factors of product characteristics, product image and company image differed by sector. The competitiveness of companies increases mostly by environmentally sound technologies through the factors of company image, product image, product characteristic and staff in printing houses and through the factors of energy and product image in paper mills. Competitiveness of companies decreases mostly by environmentally sound technologies through factors of staff, other costs and product characteristics in pulp mills. Since investigated technologies having legal incentive and not having it did not differ in parts of value chain the conclusion is that differences in competitiveness impacts must be dependent with other factors than legal incentive impacted on. The results of this study do not support that more-regulated plants had significantly lower productivity levels than less-regulated plants (Gray and Shadbegian, 1993). Spengler (1998) argued that with respect to the regulated sectors competitiveness effects will differ by industry according to significance of environmental costs, non-environmental factors, such as labour, capital and product differentiation. The difference among parts of value chain was found in cost factors of raw material, energy, labour, and differentiation factors of product characteristic, product image and company image but not in capital, but these differences are not caused by legal incentives impacted on.

Table 10.2 Differences Between the Parts of the Value Chain in the Measured Competitiveness Factors of Energy, Staff and Other Costs and Product Characteristics, Product Image and Company Image of Environmentally Sound Technologies

Competitiveness Factor/Part of Value Chain	**Part of Value Chain**			
	Forest Harvesting	**Pulp Mill**	**Paper Mill**	**Printing Houses**
Energy	No effect	Increasing impact	Mostly increasing impact	Mostly decreasing impact
Staff	Increasing impact	Mostly decreasing impact	Increasing impact	Mostly increasing impact
Other costs	Decreasing impact	Mostly decreasing impact	Mostly increasing impact	Increasing impact
Product characteristics	Increasing impact	Mostly decreasing impact	Increasing impact	Mostly increasing impact
Product image	Increasing impact	Increasing impact	Mostly increasing impact	Mostly increasing impact
Company image	Increasing impact	Increasing impact	Increasing impact	Mostly increasing impact

Environmentally sound technologies were assessed to increase competitiveness mostly in printing houses through factors of staff, product characteristic, product image and company image and decreased competitiveness mostly in pulp mills through factors of staff, product characteristics and other costs.

10.1.4 Impact of Environmentally Sound Technology on the Competitiveness of Companies in the Other Part of the Value Chain

Whether the environmentally sound technology has an impact on the competitiveness of companies in the part of the value chain other than where the technology was positioned, was investigated. This was the fourth research question. According to Porter (1985), a technology is important for competition if it significantly affects a firm's competitive advantage or industry structure. Supplier relations and supply-chain management (Florida, 1996) can affect industrial and environmental performance in different ways.

Half of the investigated technologies had an impact on competitiveness of company in the competitiveness of company in the other part of the value chain. The environmentally sound technologies of forest harvesting and printing houses had the most frequent responses mentioned to have an impact on the other part of the value chain and environmentally sound technologies of pulp mills have the least frequently responses mentioned. The technological categories that had the most frequently responses mentioned to have impact on the competitiveness of companies in the other part of the value chain were automation, measurement and information technology, wood and recycled-fibre technology and energy technology. Emission-control technology, wastewater technology and solid-waste technology did not have impacts on the competitiveness of companies in the other part of the value chain. Pollution-prevention technologies had that impact more frequently responses mentioned than pollution-abatement technologies. The technologies that will breakthrough in the time period 2000-2009 were assessed to have the most frequently responses mentioned to have impact on the competitiveness of companies in the other part of the value chain.

The environmentally sound technologies having an impact on the competitiveness of companies in the other part of the value chain increase the competitiveness of companies implemented the technology more through factors of raw material, product image and other differentiation than the technologies that do not have that impact. The technologies not having an impact on the competitiveness of companies in the other part of the value chain decrease the competitiveness of companies implemented the technology more through the factor of capital, but increase competitiveness through the factor of energy. When respondents were asked about the how does technology impacted on competitiveness of company in other parts of the value chain, the raw material at the following phase was given as the main impact, but the paper market was also mentioned category.

The results indicate that some environmentally sound technologies have an effect across the value chain of printed paper relating to raw material at the next part of the value chain or paper market. These technologies increase competitiveness of companies through raw material and product image in host companies, too, more than the other technologies, but do not decrease competitiveness through capital. The results of this study may indicate that some investigated environmentally sound technologies will change the structure of the value chain of printed paper.

10.1.5 Relationships Among Legal Incentive, Function Mechanisms and Competitiveness Impacts—Applying of the Porter Hypothesis

Whether pollution-prevention technologies and pollution-abatement technologies differ in competitiveness impacts, when they have legal incentive impacted on or not have it. This is a part of Porter Hypothesis and its acceptance is studied as the fifth research question in this thesis. Porter (1991 a, b) has claimed the following: 'turning environmental concern into competitive advantage demands that we establish the right kind of regulation. They must stress pollution prevention rather than merely abatement or clean-up'. In this study the Porter Hypothesis was operationalised by the variables of legal incentive, function mechanisms and competitiveness impacts of environmentally sound technologies.

The environmentally sound technologies were classified into four categories: pollution-prevention technology with legal incentive and without legal incentive and pollution-abatement technology with legal incentive and without legal incentive. These four categories were found to differ when competitiveness impacts of the staff factor were tested, but did not differ when the other competitiveness factors were tested. The staff factor decreases competitiveness mostly in pollution-abatement technologies with legal incentives and increases competitiveness mostly in pollution-prevention technologies without legal incentives. Pollution-prevention technologies without legal incentive increase competitiveness of companies clearly more through staff than pollution-prevention technologies with legal incentive. This supports Mohr (2000)'s model showing that environmental regulations can simultaneously alleviate pollution and increase productivity and endogenous technical change that makes Porter's hypothesis feasible, but not necessarily optimal. The Porter Hypothesis is explored from various points of view and approaches at the level of companies. Oates et al. (1993) presented a simple economic model in which the Porter Hypothesis in shown to be false. The results in Xepapadeas and de Zeeuw (1999) indicate that, despite a stricter environmental policy, increased productivity of the capital stock may be expected. Murty and Kumar (2003) concluded that endogenous technical change makes the Porter Hypothesis feasible.

According to this study, the Porter Hypothesis (1991 a,b) can be reformulated as follows

'Turning environmental concern into competitive advantage through staff demands that it is established the right kind of regulations. They must stress pollution prevention rather than merely abatement or clean-up. They must not constrain the technology used to achieve them, or else innovation will be stifled. And standards must be sensitive to the staff costs involved'.

Hillard (2004) argues that the failure of both neoclassical environmental economics and Porter's theory to provide a convincing analysis of how regulation can promote competitiveness-enhancing technical change is because of their failure to look inside the phenomenon. There seems to be a lack of understanding through which mechanisms inside companies create advantages from the pressure of environmental regulation (Hillard, 2004). In this study, the relationships among factors related to pollution prevention and pollution abatement were analysed in detail. As a result of this study, the Porter Hypothesis concerning the function mechanisms of technologies is confirmed only when the competitiveness of companies is measured by the factor of staff. The Porter Hypothesis is rejected concerning the other studied competitiveness factors, such as cost factors of raw material, energy, capital other costs and differentiation factors of product characteristic, product image, company image and other differentiation factors. A part of the Porter Hypothesis relating to function mechanisms and legal incentive is valid when competitiveness of companies is assessed by staff factor in pulp mills and in printing houses in the time period of 1980-1999 and when environmentally sound technologies controlled environmental aspects of releases-to-water and waste management. The breakthrough time period in such technologies was 1980-1989.

As a result of this study, it may be said that pollution-abatement technologies without legal incentives increase competitiveness most of all factors through energy and company image. Pollution-abatement technologies with legal incentives decreased competitiveness most of all through factors of capital and energy. This means that pollution-abatement technologies can create value for companies when there is no legal incentive impacted on technology and so the function mechanism of pollution-prevention technology is not the key to competitive advantage in managing environmental aspects of companies. There is no need to implement pollution-prevention technology to achieve maximum benefits for the companies.

As a conclusion it can be said that the Porter Hypothesis of an importance of the function mechanism of pollution prevention or pollution-abatement technology in fulfilling environmental requirements confirmed only when the competitiveness of companies is measured by the factor of staff. Another conclusion is that, pollution-prevention technologies are not one and only key for competitive advantage in companies, but also pollution-abatement technologies can create value for companies. For the regulative point of view this means that there in no need to tailor the environmental regulation for pollution-prevention technologies. Environmental regulation should focus on controlling of environmental impacts, not on ideas of win-win situations, which might not be capitalised ever.

10.2 Validity and Reliability of the Study

Validity is concerned with the question of whether one is measuring what one thinks one is measuring (Nahmias and Nahmias, 1981). The three basic types of validity are content validity, empirical validity and construct validity.

The content validity of a scale involves a systematic but subjective assessment of the scale's ability to measure what it is supposed to measure (Nahmias and Nahmias, 1981). In this study, the most important words that have to be understood in the same way are 'environmentally sound technology' and 'competitiveness'. The responses might include technologies that impact partly harmfully on the environment, not environmentally sound technologies. Competitiveness can be understood at the level of a nation, therefore it was called *competitiveness of company*. The value chain of printed paper is divided into forest harvesting, pulp mill, paper mill and printing houses. In reality, there are often integrated mills consisting both of pulping and paper manufacturing, so it is not easy to separate the units for assessment of competitiveness. This may have affected the competitiveness assessment of environmentally sound technologies in paper mills.

The scale of competitiveness assessment in questionnaires was designed to use a conception of positive (increasing) and negative (decreasing) impacts. The scale was ordinal and is supposed to have worked well in that sense. The competitiveness data were measured by the tool of the ordinal, not interval, scale. The variable of 'other costs' was added to cost competitiveness and 'other differentiation' to the differentiation competitiveness for factors, which were not otherwise included in the metrics. Since competitiveness impacts of the other costs and the other differentiation were assessed to be minor, it can be concluded that no significant competitiveness factor is missing from metrics of competitiveness assessment.

The following are potential sources of error in the survey data that are not related to the interviewer (Fowler and Mangione, 1990; Fowler, 1993): question wording can affect answers, as can respondent characteristics unrelated to what is being measured, the setting in which an interview occurs, the position of a question in an interview schedule, and even the presence of an interviewer, as compared with having the respondent fill out a form, can affect answers.

Most of the questions were structured as closed-ended questions. The closed-ended type of question categorises the responses beforehand. There is a risk that for some responses there is no category describing them (pigeon holed). The advantages of closed-ended questions are that they are easy to process, they make group comparisons easy, and they are useful for testing specific hypothesis. The weaknesses of the closed, fixed response, interview are that respondents must fit their experiences and feelings into the researcher's categories, and that they may be perceived as impersonal, irrelevant, and mechanistic. The method can distort what respondents really mean or experienced by so completely limiting their response choices (Patton, 1990). The disadvantages of closed-ended questions are the loss of spontaneous responses, bias in answer categories, and their sometimes seeming too crude and possibly irritating respondents (Oppenheim, 1997).

Outliers are atypical (by definition), infrequent observations (Statsoft, 2006). They should be eliminated because they can impact the validity of the researcher's findings and therefore must be identified and dealt with as well. The competitiveness impacts of environmentally sound technology technologies were assessed in five fixed stages and therefore no distinctly different values exist.

Construct validity (Nahmias and Nahmias, 1981) involves relating a measuring instrument to an overall theoretical framework in order to determine whether the instrument is tied to the concepts and theoretical assumptions that are employed. The measured concept of competitiveness is based on a theoretical frame of competitive advantage (Porter, 1985) divided into cost advantage and differentiation advantage. The metrics were collected from the literature. The Porter Hypothesis was operationalised at the company level. The results of this study can be compared with a part of the statement of the Porter Hypothesis, but no other study implemented in an identical way was found.

In research, the term reliability means "repeatability" or "consistency". A measure is considered reliable if it would give the same result over and over again (Trochim, 2006). The respondents were asked to identify the five most important environmentally sound technologies in the time periods 1980-1999 and 2000-2019. The selection of investigated technologies was dependent of opinions of the respondents what they found to be the most important technologies for environmental impact. Among respondents these opinions can change according to time and knowledge about environmental impacts. Non-probability sampling was used. There are no statistical methods for measuring the sampling error for a non-probability sample. Thus, the researcher cannot generalise the findings to the target population with any measured degree of confidence, as is possible with probability samples (Hair et al., 2003). In order to strengthen the reliability, there were two respondents for each part of the value chain. The interviewees were all well-known experts in their own field. The interviewees represented wide expertise of technologies, independence on technology businesses and future orientated knowledge as reasons for selection. The responses were based on knowledge and attitude.

The type of question was open-ended. Advantages of open questions are freedom and spontaneity of the answers, opportunity to probe and their usefulness in testing hypotheses about ideas or awareness (Oppenheim, 1997).

In the data, there were not identical technology responses, which could have been analysed as parallel samples.

The interviews and questionnaires given to the Finns were carried out in Finnish, and the others in English. This might have caused some differences in understanding questions and answers. All the respondents were asked the same questions to ensure that differences in answers could be attributed to differences in parts of the value chain and respondents.

In three technologies mentioned, the interviewees did not assess competitiveness factors. All these will be implemented in the future; the reason for the missing data lies in the difficulties of competitiveness-impact assessment. These technologies were two technologies of forest harvesting such as use of automation in general and multipurpose use of forest or a part of it and a technology of pulp mill such as regeneration of inorganic salts. These technologies are not taken as a response in the competitiveness analysis. There are no missing data in the following variables: technological category, the value chain, the time period, and function mechanism.

10.3 Limitations of this Study

There are some limits for generalisation of the result of the study. The data were collected from the value chain of printed paper. The value chain is dominated by raw material of fibre. The results of environmental aspect are value-chain specific as well as the importance of raw material across the chain. The companies of pulp mill and paper mill are large and capital intensive, while the companies of forest harvesting and printing houses can be small. One limitation is also the sampling. The used non-probable and purposeful sampling does not make statistical generalisation possible.

The results are valid in European countries, where there are equal environmental regulations and cost structures of companies, and a common environmental public consciousness. The data were collected from Finland, Sweden and

Germany. This study does not provide the final answer to the question of competitiveness impacts, as not all the possible aspects of competitiveness of companies were explored. The variables chosen for the measurement model set limits, too. The competitive impact of price was not specified in the measurement model. The price impacts can be seen included in the factor of product characteristics.

10.4 Recommendations for Researchers, Company Managers, Technology Developers and Policymakers

For Researchers

The value chain approach to the environmentally sound technologies is a new idea that could be applied also less raw material intensive industries and the other value chains. Further research is needed to investigate the impacts of environmental technologies on the competitiveness of small- and medium-sized companies. The industrial companies in the value chain of printed paper are large, so environmental investments do not affect so dramatically the economy of these companies. Further research is needed to investigate the market dynamics of environmentally sound technologies. The impacts of environmentally sound technologies on competitiveness through product prices were not specifically studied here. It can be found a tip for the other researchers, too. The results of the study are valid in countries where the cost structure of companies is similar to Finland, German and Sweden, but may not be valid in countries where the cost of labour is cheaper and where there is a lack of capital in industry. In these circumstances, the competitiveness impacts of environmentally sound technologies could be greater. The results of competitiveness assessments may differ from European companies if the data would have been collected from U.S. companies.

For Company Managers

The respondents of this study found the image of product and company valuable for companies. It is possible to achieve joint benefits of importance from environmental impact and product image, as was concluded in this study. From the point of view of company managers, environmental investment should be worth the money. The decision-makers of companies should try to find solutions that not only solve the environmental problem but also create other value for their companies. It was found in the study that the most important technologies for environmental impact also increase competitiveness the most. Companies can use environmental investments in product marketing and company image, too. Company managers should take care of how to create value for the company through environmental investments and how to avoid the use of capital and further staff.

For Technology Developers

An ideal property of environmentally sound technologies can be suggested with help of this study. It is possible to provide some tips for technology development based on the results of the study. Besides the control of environmental impacts, an ideal environmentally sound technology also creates other benefits for companies. The studied technologies created benefits the mostly through raw material, staff, and images of product and company. It is also important to focus on the capital intensity of technology. As a recommendation, these factors should take into account beneficial environmental technology development. It is recommended that automation, measurement and information technologies should be developed to solve the problems of environmental impacts and that the focus of doing so should be on the use of raw material and natural resources across the value chain. U.S. Environmental Protection Agency (2006) has started to implement the environmental technology verification system and similar verification system is in progress in European Union (EC, 2006). The aims of these systems are to accelerate the entrance of new environmental technologies into the markets. The results of this study may help in defining criterion for ideal environmental technologies.

For Environmental Policymakers

The efficiency of legal instruments in controlling environmental impacts is an important challenge for the governments. From the point of view of regulated companies, there is no evidence that legal incentives impact generally on the competitiveness of companies through environmentally sound technologies, either positively or negatively. The clear conclusion of this study is that legal incentives do not create competitive advantage for the regulated companies, but, when there is legal pressure on environmental investment, it is better for companies to solve it by adopting the pollution prevention approach and optimising staff factor. It was found evidence that in the worst cases, legal incentives cause a loss in the competitiveness of companies. Pollution-prevention technologies are not one and only key for competitive advantage in companies, but also pollution-abatement technologies can create value for companies. This means for regulators that there in no need to tailor the environmental regulation for pollution-prevention technologies. As a recommendation of this study, it is suggested that the focus of environmental policy should simply be on controlling harmful environmental impacts, rather than on the complicated benefits of competitiveness of companies. This recommendation is actual and relevant because new pieces of environmental regulation in the European Union, such as chemical legislation, are based on the idea that tightening regulative control increases innovations and the competitiveness of companies. European Commission (EC, 2006) has started the actions for simplifying environmental regulation as a target on reducing administrative burdens on industry from the field of that. This study encourages the Commission to continue.

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APPENDIX I
Parts of Value Chain, Respondents and Codes

This appendix contains the respondents who identified the environmentally sound technologies and assessed their competitiveness impacts.

The Respondents

The interviewed respondents divided the parts of the value chain as presented in Table I-1.

Table I-1 Respondents, Codes and Parts of Value Chain

Part of the Value Chain	Code	Respondent
Forest Harvesting	R1	Professor Esko Mikkonen Forestry Faculty Helsinki University, http://honeubee.helsinki.fi/users/ESMIKKON/cv.html, 23.6.2003 Helsinki, Finland
	R2	Professor Iwan Wästerlund Sveriges landbruksuniversitet http://www.slu.se, 23.6.2003 Uppsala, Sweden
Pulp Mills	R3	Director Peter Axegård Swedish Pulp & Paper Institute Stockholm, Sweden http://www.stfi.se, 23.6.2003
	R4	Professor Johan Gullichsen Laboratory of Pulp Technology Helsinki University of Technology Espoo, Finland
Paper Mills	R5	Professor Hannu Paulapuro Laboratory of Paper Technology Helsinki University of Technology, http://www.hut.fi/units/paper/personnel.html, 23.6.2003 Espoo, Finland
	R6	Professor Lothar Göttsching Papierenfabraktion und Mechanische Verfahrenstechnik Technische Universität Darmstadt http://pix.ifp.machinenbau.tu-darmstadt.de, 23.6.2003 Darmstadt, Germany
Printing Houses	R7	Professor Arwid-Carl Huebler Institute fuer Print- and Medientechnik der Universität Chemnitz http://www.tu-chemnitz.de, 23.6.2003 Chemnitz, Germany
	R8	Professor Pirkko Oittinen Laboratory of Median Technology Helsinki University of Technology, http://www.media.hut.fi/henkilokunta, 23.6.2003 Espoo, Finland

Appendix II contains Questionnaire No. 1.

QUESTIONNAIRE NO. 1

Sanna Perkiö **29.3.1999**

Topic of the study: ENVIRONMENTALLY SOUND TECHNOLOGY IN THE VALUE CHAIN OF PAPER PRODUCTION AS A FACTOR OF COMPETITIVENESS OF FOREST CLUSTER COMPANIES

Topic of the interview: **The environmentally sound technology changes in forest management and wood harvesting (raw material from forest to pulp mill)/pulp mills/ paper mills/printing housees and their impacts on the competitiveness of the value chain of forest cluster companies—Questionnaire No. 1**

Identification of Environmentally Sound Technology Changes

Interviewee ____________________

Date of Interview____________________

1 Technology changes in forest management and harvesting (raw material from forest to pulp mill)/pulp mill/paper manufacture/printing house since 1980

Identify the environmentally sound technology changes implemented in forest management and harvesting/pulp mills/paper mills/printing housees since 1980 that have the most significant positive impacts on the environment (e.g. energy, raw materials, emissions, impacts on ecosystem). Assess the importance of environmental impacts (1 = the most important, 2 = the second important, 3 = the third important).

1.1 Technological Change____________________

____

(Name; what has been changed to which)

Importance of Environmental Impacts____________________(1.1.1)

1.2 Technological Change____________________

____

(Name; what has been changed to which)

Importance of Environmental Impacts____________________(1.2.1)

1.3 Technological Change____________________

____

(Name; what has been changed to which)

Importance of Environmental Impacts____________________(1.3.1)

1.4 Technological Change____________________

____

(Name; what has been changed to which)

Importance of Environmental Impacts____________________(1.4.1)

1.5 Technological Change____

____ _________________
(Name; what has been changed to which)
Importance of Environmental Impacts_____________________________(1.5.1)

2 Technology Changes in Forest Management and Harvesting/Pulp Mills/Paper Mills/Printing Houses Before 2020

Identify the environmentally sound technology changes in forest management and harvesting/pulp mills/paper mills/printing houses that will be implemented before year 2020 and that will have the most significant positive impacts on the environment (e.g. energy, raw materials, emissions, impacts on ecosystem). Assess the importance of environmental impacts (1 = the most important, 2=the second important, 3=the third important).

2.1 Technological Change____

____
(Name; what will be changed to which)

Importance of Environmental Impacts_____________________________(2.1.1)

2.2 Technological Change____

________________________ ___________________________________
(Name; what will be changed to which)

Importance of Environmental Impacts_____________________________(2.2.1)

2.3 Technological Change____

____
(Name; what will be changed to which)

Importance of Environmental Impacts_____________________________(2.3.1)

2.4 Technological Change____

____
(Name; what will be changed to which)

Importance of Environmental Impacts_____________________________(2.4.1)

2.5 Technological Change____

____
_
(Name; what will be changed to which)

Importance of Environmental Impacts_____________________________(2.5.1)

Thank you very much for your attention!

APPENDIX III
Helsinki University of Technology **QUESTIONNAIRE NO. 2**

Department of Industrial Management
Sanna Perkiö 29.3.1999
Tel.: 050 5636651
Fax: 09 43542200

Topic of the Study:
ENVIRONMENTALLY SOUND TECHNOLOGY IN THE VALUE CHAIN OF PAPER PRODUCTION AS A FACTOR OF THE COMPETITIVENESS OF FOREST CLUSTER COMPANIES

Topic of the Interview:
The environmentally sound technology changes in forest management and harvesting (raw material from forest to pulping)/pulp mills/paper mills/printing houses and their effects on the competitiveness of the value chain of forest cluster companies—Questionnaire No. 2

Impacts of Technology Change on Competitiveness

Interviewee ________________________________
Date of Interview________________________________

This part of the questionnaire focuses on the technology changes mentioned in Questionnaire No. 1 and their impacts on factors of competitiveness (cost effectiveness and differentiation) in forest management and harvesting (raw material from forest to pulping)/pulp mills/paper mills/printing houses) and how technology changes that have been implemented (or will be implemented) are impacting on the competitiveness of other parts of the value chain of paper production.

A questionnaire should be filled in about every technology change mentioned in Questionnaire No. 1.
(The researcher will fill this in.)

Technology change (name, number from Questionnaire 1)______________________________________

3 Background of the technology change

3.1 What paper grades are produced by the technology?
____

3.2 What environmental aspects of forest management and harvesting has that technology change affected? (Describe the mechanism influencing forest management and harvesting.)

____

____

3.3 New technology
- time of the first industrial or commercial implementation (3.3.1), year___________________
- company/site/country (3.3.2)____
- time of breakthrough (general use), year (3.3.3)____________________________________

3.4 What kind of legal incentives have there been to implement the new technology, and in which countries?____

____

3.5 What other kind of incentives have there been to implement the new technology? Where?

Helsinki University of Technology
QUESTIONNAIRE NO. 2

Department of Industrial Management
Sanna Perkiö
Tel.: 050 5636651
Fax: 09 43542200
29.3.1999

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4 What factors of cost has this technology change impacted on? How? Consider significance of competitiveness.

Scale of assessment
-2= has decreased competitiveness significantly
-1= has decreased competitiveness a little
0= no effect on competitiveness
1= has increased competitiveness a little
2= has increased competitiveness significantly

By

4.1 Raw materials. Which? How?

Assessment of direction and significance of competitiveness

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

4.2 Energy. What? How?

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

4.3 Staff. What? How?

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

4.4 Other factors of cost competitiveness (solid waste, etc.) What? How?

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

4.5 Capital costs. What? How?

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

____________________ -2 -1 0 1 2

Helsinki University of Technology **QUESTIONNAIRE NO. 2**
Department of Industrial Management
Sanna Perkiö 29.3.1999
Tel.: 050 5636651
Fax: 09 43542200

5 What <u>factors of differentiation</u> has this technology change impacted on? How? Consider significance of competitiveness.

Assessment of direction and significance of competitiveness

By

5.1 Characters of product. What? How?

____ -2 -1 0 1 2

____ -2 -1 0 1 2

5.2 Image of product. What? How?

____ -2 -1 0 1 2

____ -2 -1 0 1 2

5.3 Image of producing company. What? How?

____ -2 -1 0 1 2

____ -2 -1 0 1 2

5.4 Other factors of differentiation. Quality. What? How?

____ -2 -1 0 1 2

____ -2 -1 0 1 2

6 How has the technology change affected the competitiveness of other parts of the value chain in paper production? What parts and processes? How has it affected factors of cost and differentiation?

____

Appendix IV contains the variables, definitions of categories used and author or reference of categorisation or information.

Table IV-1 contains the definitions of parts of the value chain.
Table IV-2 contains the definitions of time period.
Table IV-3 contains the definitions of technological categories.
Table IV-4 contains the definitions of environmental aspects.
Table IV-5 contains the definitions of the function mechanism.
Table IV-6 contains the definitions of breakthrough time period.
Table IV-7 contains definition of legal incentive.
Table IV-8 contains the definitions of other-than-legal incentives.
Table IV-9 contains the definitions of categorized other-than-legal incentive and
Table IV-10 contains the definitions of the impact on the other parts of value chain.
Table IV-11 contains the definitions of categorized impact on competitiveness of companies in the other part of value chain.
Table IV-12 contains the definitions of categories of significantly competitiveness-increasing technology.
Table IV-13 contains the definitions of categories of significantly competitiveness-decreasing technology.
Table IV-14 contains the definitions of categories of joint variable of function mechanism and legal incentive(
Table IV-15 contains the definitions of categories of competitiveness factors.

Table IV-1 Definitions of Categories of Value Chain

Part of the Value Chain Category	**Definition**	**Author/Reference**
Forest harvesting	Forest management and forest harvesting includes forest inventorying, planning, management of forest ecosystem, timber procurement, timber measurement and storing.	Kellomäki, 1998
Pulp mills	Pulp mills include chemical pulping of wood handling, cooking, and pulp washing, bleaching and drying.	Gullichsen and Fogelholm, 2000
Paper mills	Paper mills include pulp handling, pigment handling and paper machine operations. Mechanical pulping is included here, because it is often integrated to paper manufacturing.	Britt, 1970, Paulapuro, 2000
Printing houses	Printing housees include producing printed products such as newsprints, magazines, promotion materials etc. Operations of gravure printing, flexography, offset, lithography, screen-printing and digital printing.	www.swan.ac.uk/pprinting/education, 16.5.2005

Table IV-2 Definitions of Categories of Time Period

Time Period Category	**Definition**	**Author/Reference**
1980-1999	Time period when the technology was identified to be effective.	From respondents
2000-2019	Time period when the technology was identified to be effective.	From respondents

Table IV-3 Definitions of Technological Categories

Technological Category	**Definition**	**Author/Reference**
Automation, measurement and information technology	Techniques or procedures based on highly automatic machinery or measurement and information technology	Helmut Kaiser Consultancy, 1991
Energy technology	Techniques or procedures that affect the production or use of energy	Higgins, 1996 a
Wood- or recycled-fibre technology	Techniques or procedures that affect the process of using wood or recycled fibre as a raw material	From the data
Closing-up technology	Techniques or procedures that close up the liquid loops in a process	From the data
Operation	Operation procedure that controls environmental aspects	From the data
Chemical-elimination technology	Techniques or procedures that eliminate environmentally harmful substances.	From the data
Emission-control technology	Techniques or procedures that control emissions to air	Higgins, 1996 a
Wastewater technology	Techniques or procedures that control releases to waterways	Higgins, 1996 a
Solid-waste technology	Techniques or procedures that prevent production of solid waste or manages waste material	Helmut Kaiser Consultancy, 1991
Other	Other environmentally sound techniques or procedures	From the data

Table IV-4 Definitions of Categories of Environmental Aspects

Environmental Aspect Category	Definition of Category	Author/Reference
Emissions to air	The release of unwanted waste into the air	Finnish Standards Association, 1996
Releases to water	The release of unwanted waste into the waterways	Finnish Standards Association, 1996
Waste management	Management of the collection, recovery and disposal of wastes, including options of waste reduction.	Finnish Standards Association, 1996
Use of energy	Use, production and recovery of energy	Defined from data
Use of fresh water	Use, reuse and saving of fresh water	Defined from data
Use of raw material and natural resources	Use, reuse and recycling of raw material and natural resources	Finnish Standards Association, 1996
Biodiversity	The diversity of plant and animal life in a particular habitat	The Free Dictionary by Farlex, www.thefreedictionary.com, 28.3.2006
Contamination of land	The release of unwanted waste into the soil or groundwater	Finnish Standards Association, 1996

Table IV-5 Definitions of Categories of Function Mechanism

Function Mechanism Category	Definition	Author/Reference
Pollution prevention	Action aiming to prevent pollution beforehand	Tekniikan sanastokeskus, 1998
Pollution abatement	Designed to treat pollutants or reduce pollutants after they have been physically created	Department of Agricultural Economics and Rural Sociology, 2006

Table IV-6 Definitions of Categories of Breakthrough Time

Breakthrough Time Category	Definition	Author/Reference
1980-1989	Time period in which technology is assessed to have broken through to general use	From the data
1990-1999	Time period in which technology is assessed to have broken through to general use	From the data
2000-2009	Time period in which technology is assessed to have broken through to general use	From the data
2010-2019	Time period in which technology is assessed to have broken through to general use	From the data
After 2020	Time period in which technology is assessed to have broken through to general use	From the data

Table IV-7 Definitions of Categories of Legal Incentive

Legal incentive Category	Definition	Author/Reference
Yes	Any kind of environmental regulative stimulation focused on technology	From the data
No	No kind of environmental regulative stimulation focused on technology	From the data

Table IV-8 Definitions of Categories of Other-than-Legal Incentive

Other-than-Legal Incentive Category	Definition	Author/Reference
Yes	Any kind of incentive, except environmental regulative stimulation focused on technology	From the data
No	No kind of incentive, except environmental regulative stimulation focused on	From the data

Table IV-9 Definitions of Categories of Categorized Other-than-Legal Incentive

Categorized Other-than-Legal Incentive Category	**Definition**	**Author/Reference**
Cost	Cost as a pressure or constraint of other than environmental regulation or other environmental legal requirement	Bragdon and Marlin, 1972
Public image	Public image as a pressure or constraint, of other than environmental regulation or other environmental legal requirement	Kemp, 1993; Srivastava, 1995
Ability to operate	Ability to operate as a pressure or constraint, of other than environmental regulation or other environmental legal requirement	Bansal and Roth, 2000
Financial or other subvention	Financial or other subvention as a pressure or constraint of other than environmental regulation or other environmental legal requirement	From the data
Market pressure	Market pressure as a pressure or constraint of other than environmental regulation or other environmental legal requirement	Srivastava, 1995 b
Energy supply	Energy supply as a pressure or constraint of other than environmental regulation or other environmental legal requirement	Turner, 1993
Development of technology	Development of technology as a pressure or constraint of other than environmental regulation or other environmental legal requirement	From the data
Other	Other pressure or constraint of other than environmental regulation or other environmental legal requirement	From the data

Table IV-10 Definitions of Impact on Competitiveness of Company in the Other Part of the Value Chain

Impact on Competitiveness of Company in the Other Part of the Value Chain Category	**Definition**	**Author/Reference**
Yes	Technology has impact on competitiveness of company in the other part of value chain	From the data
No	Technology has no impact on competitiveness of company in the other part of value chain	From the data

Table IV-11 Definitions of Categorized Impact on Competitiveness of Company in the Other Part of the Value Chain

Categorized Impact on Competitiveness of Company in the Other Part of Value Chain Category	**Definition**	**Author/Reference**
Raw material in the following phase	Operation related to raw material, which is impacted by technology in the other part of value chain	
Environmental image	Operation related to environmental image, which is impacted by technology in the other part of value chain.	Kemp, 1993; Srivastava, 1995
Ability to operate	Operation-related ability to operate, which is impacted by technology in the other part of value chain	Bansal and Roth, 2000
Cost	Cost driver, which is impacted by technology in the other part of value chain	Bragdon and Marlin, 1972
Paper market	Operation related to paper market, which is impacted by technology in the other part of value chain	Nehrt, 1996; Kemp, 1993
Logistic	Operation related to logistics, which is impacted by technology in the other part of value chain	From the data
Other	Operation related to any other issue, which is impacted by technology in the other part of value chain	From the data

Table IV-12 Definitions of Categories of Significantly Competitiveness-Increasing Technology

Significantly Competitiveness-Increasing Technology Category	**Definition**	**Author/Reference**
Significantly competitiveness increasing technology	Technology has been assessed to increase competitiveness significantly in this study	From the data
Other investigated technology	Technology has not been assessed to increase competitiveness significantly in this study	From the data

Table IV-13 Definitions of Categories of Significantly Competitiveness-Decreasing Technology

Significantly Competitiveness-Decreasing Technology Category	Definition	Author/Reference
Significantly competitiveness decreasing technology	Technology has been assessed to decrease competitiveness significantly in this study	From the data
Other investigated technology	Technology has not been assessed to decrease competitiveness significantly in this study	From the data

Table IV-14 Definitions of Categories of a Joint Variable of Function Mechanism and Legal Incentive (Porter Hypothesis; Porter, 1991 a, b)

Function Mechanism and Legal Incentive Category	Definition	Author/Reference
Pollution prevention technology with legal incentive	Action aiming to prevent pollution beforehand, when there is legal incentive impacted on technology	Tekniikan sanastokeskus, 1998
Pollution prevention without legal incentive	Action aiming to prevent pollution beforehand, when there is no legal incentive impacted on technology	Tekniikan sanastokeskus, 1998
Pollution abatement with legal incentive	Designed to treat pollutants or reduce pollutants after they have been physically created, when there is legal incentive impacted on technology	Department of Agricultural Economics and Rural Sociology, 2006
Pollution abatement without legal incentive	Designed to treat pollutants or reduce pollutants after they have been physically created, when there is no legal incentive impacted on technology	Department of Agricultural Economics and Rural Sociology, 2006

Table IV-15 Definitions of Categories of Competitiveness Factors

Competitiveness Factor Category	Definition	Author/Reference
Raw material	Raw material factor, which is connected to environmentally sound technology and competitiveness of company	Peattie, 1995; Bragdon and Marlin, 1972, Porter, 1985: Porter and van der Linde, 1995) Turner, 1993
Material consumption	Material consumption as a raw material factor, which is connected to environmentally sound technology and competitiveness of company	Turner, 1993
Waste production	Waste production as a raw material factor , which is connected to environmentally sound technology and competitiveness of company	Day, 1998
Material management	Material management as a raw material factor , which is connected to environmentally sound technology and competitiveness of company	From the data
Energy	Energy factor, which is connected to environmentally sound technology and competitiveness of company.	Peattie, 1995
Energy consumption	Energy consumption as an energy factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Energy production	Energy production as an energy factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Energy management	Energy management as an energy factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Staff	Staff factor, which is connected to environmentally sound technology and competitiveness of company	Bragdon and Marlin, 1972
A number of staff	A number of staff as a staff factor, which is connected to environmentally sound technology and competitiveness of company.	From the data
Education and skills	Education and skills as a staff factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Capital	Capital factor, which is connected to environmentally sound technology and competitiveness of company	Kemp 1993; Bragdon and Marlin, 1972
Intensified use of capital	Intensified use as a capital factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Released capital	Released capital as a capital factor, which is connected to environmentally sound technology and competitiveness of company.	From the data
Machine and equipment	Capital used for machine and equipment as a capital factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Data control	Capital used for data control as a capital factor, which is connected to environmentally sound technology and competitiveness of company	From the data

Table IV-15 Definitions of categories of competitiveness factors, continues

Competitiveness Factor Category	**Definition**	**Author/Reference**
Other costs	Other-than-previously mentioned cost factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Operation cost	Other operation as an other cost factor, which is connected to environmentally sound technology and competitiveness of company	Bragdon and Marlin 1972
Transportation	Transportation as an other cost factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Product characteristics	Product characteristics factor, which is connected to environmentally sound technology and competitiveness of company	Peattie, 1995; Hill & Jones, 1999, Spengler, 1998, Srivastava, 1995 b)
Quality characteristics	Product quality as a product characteristics factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Use characteristics	Product use as a product characteristics factor, which is connected to environmentally sound technology and competitiveness of company.	From the data
Product image	Product image factor, which is connected to environmentally sound technology and competitiveness of company	Peattie 1995; Hill & Jones, 1999; Spengler, 1998; Bansal and Roth, 2000; Ytterhus, 1997
Environmental image	Environmental image as a product image factor, which is connected to environmentally sound technology and competitiveness of company	Ytterhus, 1997
High-tech image	High-tech image as a product image Factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Company image	Company image factor, which is connected to environmentally sound technology and competitiveness of company	Peattie 1995; Hill & Jones, 1999; Spengler, 1998; Bansal and Roth, 2000; WBCD 1996, Kemp, 1993
Good citizenship	Good citizenship as a company image factor, which is connected to environmentally sound technology and competitiveness of company	Graves and Waddock, 1994
Environmental image	Environmental image as a company image factor, which is connected to environmentally sound technology and competitiveness of company	Kemp, 1993; Srivastava, 1995
High-tech image	High-tech image as a company image factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Other differentiation factor	Other-than-previously mentioned differentiation factor, which is connected to environmentally sound technology and competitiveness of company.	From the data
Transportation	Transportation as an other-than-previously mentioned differentiation factor, which is connected to environmentally sound technology and competitiveness of company	From the data
Ability to operate	Ability to operate as an other-tan-previously mentioned differentiation factor , which is connected to environmentally sound technology and competitiveness of company	Bansal and Roth, 2000

Variables, Measurement, a Number of Response Categories and Type of Measurement Scale, Variables Tested with and Statistical Test

Appendix V contains the variables of the study and information about measurement, a number of response categories, a type of scale, variables tested with and the statistical test.

Table V-1 contains the nominal variables tested.
Table V-2 contains the variable of importance on environmental impact in ordinal scale,
Table V-3 contains the variables of competitiveness assessment in ordinal scale.
Table V-4 contains the variables categorized from data of competitiveness assessment.
Table V-5 contains variable of cost competitiveness factor of staff, measurement, a number of response categories and type of measurement scale, variables tested with and statistical test.

Variables, Measurement, a Number of Response Categories and Type of Measurement Scale, Variables Tested with and Statistical Test

Table V-1 Variables, Description of Measurement, a Number of Response Categories and a Type of Measurement Scale, Variables Tested with and Statistical

Variable	Measurement	Response Categories	Scale	Variables Tested With	Statistical Test
Value chain	A part of value chain of printing paper	1…4	Nominal	All the nominal variables variables measured by ordinal scale	Likelihood ratio G2 Kruskall Wallis H
Time period	Time period conserning the identified technology, 1980-1999 or 2000-2019	1…2	Nominal	Binominal variables All the other nominal variables All the competitiveness variables measured by ordinal scale	Fisher's exact test Likelihood ratio G2 Mann-Whitney U
Technological category	Type of technology	1…10	Nominal	All the nominal variables All the ordinal competitiveness variables	Likelihood ratio G2 Kruskall Wallis H
Environmental aspect	Causer of environmental impact	1…8	Nominal	All the nominal variables All the competitiveness variables measured by ordinal scale	Likelihood ratio G2 Kruskall Wallis H
Function mechanism	Pollution prevention or pollution abatement	1…2	Nominal	Binominal variables All the ordinal competitiveness variables	Fisher's exact test Mann-Whitney U
Breakthrough time period	Breakthrough time periods of technology	1…5	Nominal	All the nominal variables variables measured by ordinal scale	Likelihood ratio G2 Kruskall Wallis H
Legal incentive	Existence of legal incentive, yes or no	1…2	Nominal	Binominal variables All the other nominal variables variables measured by ordinal scale	Fisher's exact test Likelihood ratio G2 Mann-Whitney U
Other-than-legal incentive	Existence of other-than-legal incentive, yes or no	1…2	Nominal	All the nominal variables All the ordinal competitiveness variables	Likelihood ratio G2 Mann-Whitney U
Quality of other than legal incentive	Type of other-than-legal incentive	1…8	Nominal	All the nominal variables All the competitiveness variables measured by ordinal scale	Likelihood ratio G2 Kruskall Wallis H
Impact to other part of value chain	Existence of impact to other part of value chain, yes or no	1…2	Nominal	Binominal variables All the other nominal variables All the competitiveness variables measured by ordinal scale	Fisher's exact test Likelihood ratio Mann-Whitney U
Quality of impact	Type of the impact	1…7	Nominal	All the nominal variables	Likelihood ratio G2
Joint variable of function mechanism and legal incentive (Porter hypothesis)	Joint variable: pollution abatement (PA) without legal incentive , PA with legal incentives, pollution prevention (PP) without legal incentive, PP with legal incentive	1…4	Nominal	Binominal variables All the other nominal variables All the competitiveness variables measured by ordinal scale	Fisher's exact test Likelihood ratio G2 Kruskall Wallis H
Compmax	Significantly competitiveness increasing technology, yes or no	0…1	Nominal	Binominal variables All the other nominal variables All the competitiveness variables measured by ordinal scale	Fisher's exact test Likelihood ratio Mann-Whitney U

Variables, Measurement, a Number of Response Categories and Type of Measurement Scale, Variables Tested with and Statistical Test

Table V-2 Variable of Importance on Environmental Impact, Measurement, a Number of Response Categories and a Type of Measurement Scale, Variables Tested with and Statistical Test

Variable	Measurement	Response Categories	Scale	Variables Tested With	Statistical Test
Importance on environmental impact	Order of importance on environmental impact	1…5	Ordinal	All binominal variables	Mann-Whitney U
				All multinominal variables	Kruskall Wallis H

Table V-3 Variables of Competitiveness Assessment, Measurement, a Number of Response Categories and a Type of Measurement Scale, Variables Tested with and Statistical Test

Variable	Measurement	Response Categories	Scale	Variables Tested With	Statistical Test
Raw material	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance on environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)
Energy	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance on environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)
Staff	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance on environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)
Capital	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance on environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)
Other costs	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance for environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)
Product characteristics	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance on environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)
Product image	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance on environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)
Company image	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance on environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)
Other differentiation	Assessment of competitiveness impact	1….5 (-2…2)	Ordinal	All binominal variables All multinominal variables Importance on environmental impact	Mann-Whitney U Kruskall Wallis H Spearman's correlation coefficient (rho)

Table V-4 Variables Categorized from Data of Factors of Competitiveness Assessment, Measurement, a Number of Response Categories and a Type of Measurement Scale and Statistical Test

Variable	**Measurement**	**Response Categories**	**Scale**	**Statistical Test**
Raw material				
Material consumption	A technology impacts on cost of material consumption (yes, no)	0...1	Nominal	No tests
Waste production	A technology impacts on cost of waste production (yes, no)	0...1	Nominal	No tests
Material management	A technology impacts on cost of material management (yes, no)	0...1	Nominal	No tests
Energy				
Energy consumption	A technology impacts on cost of energy consumption (yes, no)	0...1	Nominal	No tests
Energy production	A technology impacts on cost of energy production (yes, no)	0...1	Nominal	No tests
Energy management	A technology impacts on energy management (yes, no)	0...1	Nominal	No tests
Staff				
Amount of staff	A technology impacts on cost of amount of staff (yes, no)	0...1	Nominal	No tests
Education and skills	A technology impacts on cost of education and skills (yes, no)	0...1	Nominal	No tests
Capital				
Intensified use of capital	A technology impacts on intensifying use of capital (yes, no)	0...1	Nominal	No tests
Released capital	A technology impacts on releasing capital (yes, no)	0...1	Nominal	No tests
Machine and equipment	A technology impacts on capital of machine and equipment (yes, no)	0...1	Nominal	No tests
Data control	A technology impacts on capital of data control systems (yes, no)	0...1	Nominal	No tests
Other costs				
Operation costs	A technology impacts on other operation costs (yes, no)	0...1	Nominal	No tests
Transportation	A technology impacts on cost of transportation (yes, no)	0...1	Nominal	No tests
Product characteristics				
Quality characteristics	A technology impacts on quality characteristic of product (yes, no)	0...1	Nominal	No tests
Use characteristics	A technology impacts on use characteristic of product (yes, no)	0...1	Nominal	No tests
Product image				
Environmental image	A technology impacts on environmental image of product (yes, no)	0...1	Nominal	No tests
High-tech image	A technology impacts on high tech image of product (yes, no)	0...1	Nominal	No tests
Company image				
Good citizenship	A technology impacts on good citizenship image of company (yes, no)	0...1	Nominal	No tests
Environmental image	A technology impacts on environmental image of company (yes, no)	0...1	Nominal	No tests
High-tech image	A technology impacts on high tech image of company (yes, no)	0...1	Nominal	No tests
Other differentiation				
Transportation	A technology impacts on transportation operations (yes, no)	0...1	Nominal	No tests
Ability to operate	A technology impacts on company’s ability to operate (yes, no)	0...1	Nominal	No tests

Table V-5 Variable of Cost-Competitiveness Factor of Staff, Measurement, a Number of Response Categories and Type of Measurement Scale, Variables Tested with and Statistical Test

Variable	Measurement	Response Categories	Scale	Variables Tested With (Two-Way Contingency Table)	Variables Tested With (Three-Way Contingency Table)	Statistical Test
Cost-competitiveness factor of staff	Assessment of competitiveness impact	1…3	Ordinal	Joint variable of function mechanism and legl incentive (Porter hypothesis)	All nominal variables	Likelihood ratio G2

Identified Environmentally Sound Technological Changes, Their Importance on Environmental Impact, Time Period and Technological Categories

This appendix contains the identified environmentally sound technologies. TableVI-1 contains the technologies of forest harvesting, the respondents, technologies' importance for environmental impacts, technological categories, time period of technology. Table VI-2 contains the same data from pulp mill, Table VI-3 from paper manufacturing, and Table VI-4 from the printing houses.

Environmentally Sound Technologies of Forest Harvesting

In the study, there are nine environmentally sound technologies of forest harvesting concerning the time period 1980-1999 and there are ten technologies of forest harvesting relating to the time period 2000-2019. In Table VI-1, the respondents, environmentally sound technologies, importance for environmental impact, time period and technological category are presented.

Table VI-1 Environmentally Sound Technologies, Importance for Environmental Impact and Technological Categories of Forest Harvesting in the Time Period 1980-1999 and the Time Period 2000-2019

Environmentally Sound Technology	Importance for Environmental Impact	Time Period	Technological Category
Single grip harvester, R2	1.	1980-1999	Automation, measurement and information technology
Intensified use of raw material, R1	1.	1980-1999	Wood or recycled-fibre technology
Better adaptation of cutting to different nature conditions, R2	2.	1980-1999	Operation
Integrated harvesting for wood-based energy production, R1	2.	1980-1999	Energy technology
Reduced negative impacts of harvesting machines, R2	3.	1980-1999	Energy technology
Mechanisation of harvesting, R1	3.	1980-1999	Automation, measurement and information technology
Changes in work organisation, R2	4.	1980-1999	Operation
Bioenergy, R2	5.	1980-1999	Energy technology
Changes in silviculture systems, R2	1.	2000-2019	Operation
Increasing amount of thinning, R1	1.	2000-2019	Operation
Landscape planning in forest management, R2	2.	2000-2019	Automation, measurement and information technology
Intensifying consideration of biodiversity in harvesting, R1	2.	2000-2019	Operation
Multipurpose vehicles, R2	3.	2000-2019	Automation, measurement and information technology
Differentiation of machinery, automation and measurement, R1	3.	2000-2019	Automation, measurement and information technology
Use of automation in general, R2	4.	2000-2019	Automation, measurement and information technology
Change in information technology, R1	4.	2000-2019	Automation, measurement and information technology
Multipurpose use of forest or a part of it, R2	5.	2000-2019	Operation
Increasing energy use of wood, R1	5.	2000-2019	Energy technology

Environmentally Sound Technologies of Pulp Mills

In the study, there are ten environmentally sound technologies of pulp mills relating to the time period 1980-1999. Furthermore, there are nine environmentally sound technologies of pulp mills relating to the time period 2000-2019. Environmental technologies, importance for environmental impact, time period and technological category in pulp mill are presented in Table VI-2

Table VI-2. Environmentally Sound Technologies of Pulp Mill, Importance on Environmental Impact, Time Period and Technological Categories

Environmentally Sound Technologies	**Importance for Environmental Impact**	**Time Period**	**Technological Category**
Elimination of molecular chlorine gas in bleaching for oxygen, peroxide and chlorine dioxide, R3	1.	1980-1999	Chemical-elimination technology
Closing up liquid loops, R4	1.	1980-1999	Closing-up technology
Extended delignification in cooking and oxygen bleaching, which has resulted in less demand for bleaching, R3	2.	1980-1999	Chemical-elimination technology
Wastewater treatment in active sludge plants, R4	2.	1980-1999	Wastewater technology
Closing up the “brown” part of the mill, R3	3.	1980-1999	Closing-up technology
Odour prevention systems, R4	3.	1980-1999	Emission control technology
Introduction of different techniques for lowering the release of TRS, R3	4.	1980-1999	Emission control technology
Evaporation of spent liquor to high dry content, R4	4.	1980-1999	Emission control technology
More efficient recovery boilers, R3	5.	1980-1999	Energy technology
Bleaching by chlorine dioxide gas, R4	5.	1980-1999	Chemical elimination technology
Replacing fossil fuels by bioenergy, R3	1.	2000-2019	Energy technology
Closing up of liquid loops, R4	1.	2000-2019	Closing-up technology
Virtually no liquid effluent achieved by advanced systems closure , R3	2.	2000-2019	Closing-up technology
Gasification of black liquor and wood waste, R4	2.	2000-2019	Energy technology
No solid waste produced, R3	3.	2000-2019	Solid waste technology
Selective processes, R4	3.	2000-2019	Wood and recycled-fibre technology
Total odour prevention, R4	4.	2000-2019	Emission control technology
Regeneration of inorganic salts, R4	5.	2000-2019	Solid waste technology

Environmentally Sound Technologies of Paper Manufacturing

In the study, there are ten technologies of paper manufacturing relating to the time period 1980-1999. Furthermore, there are nine technologies of paper mills relating to the time period 2000-2019. Environmental technologies, importance for environmental impact, time period and technological category in paper mill are presented in TableVI-3.

Table I-4 Environmentally Sound Technologies of Paper Manufacturing, Importance on Environmental Impact, Time Period and Technology Categories

Environmentally Sound Technologies	**Importance on Environmental Impact**	**Time Period**	**Technological Category**
Development of process control, diagnostic and management systems, R5	1.	1980-1999	Automation, measurement and information technology
Intensified closure of process water loops in papermaking, R6	1.	1980-1999	Closing-up technology
Wastewater treatment in active sludge plant, R5	2.	1980-1999	Wastewater technology
Extended use of recovered paper in papermaking substituting virgin fibres, R6	2.	1980-1999	Wood or recycled-fibre technology
Intensified closure of process water loops in papermaking, R5	3.	1980-1999	Closing-up technology
Increase of dry content of the paper web by wet pressing, R6	3.	1980-1999	Energy technology
Energy producing by mechanical pulp production and using it in drying of paper, R5	4.	1980-1999	Energy technology
Anaerobic biological treatment of effluent additionally to aerobic biological treatment, R6	4.	1980-1999	Wastewater technology
Development of wet press, R5	5.	1980-1999	Energy technology
Totally closed water loops without emissions of effluent, R6	1.	2000-2019	Closing-up technology
Development of process control, diagnostic and management systems, R5	1.	2000-2019	Automation, measurement and information technology
Improved technologies of wet pressing and drying in paper machines (e.g. impulse drying, Condebelt drying) , R6	2.	2000-2019	Energy technology
Multilayer formulation of paper web, R5	2.	2000-2019	Wood and recycled-fibre technology
Further upgrading of recycled fibre pulp by recovered paper processing, R6	3.	2000-2019	Wood and recycled-fibre technology
Further reduction of the basis weight of paper (Paulapuro, H, 1999), R5	3.	2000-2019	Wood and recycled-fibre technology
Further reduction of the basis weight of paper, R6	4.	2000-2019	Wood and recycled-fibre technology
Totally closed water loops without emissions of effluent, R5	4.	2000-2019	Closing-up technology
Condebelt – pressing and drying system , R5	5.	2000-2019	Energy technology

Environmentally Sound Technologies of Printing Houses

In the study, there are seven technologies of printing houses relating to the time period 1980-1999 and the time period 2000-2019. Furthermore, there are eight technologies of printing houses relating to the time period 2000-2019. Environmentally sound technologies, their importance, the time period and technology category are presented in Table VI-4.

Table VI-4 Environmentally Sound Technologies of Printing Houses, Importance for Environmental Impact, Time Period and Technological Categories

Environmentally Sound Technologies	Importance for Environmental Impact	Time Period	Technological Category
Digitalisation, R8	1.	1980-1999	Automation, measurement and information technology
Diffusion of printing to smaller units, R8	2.	1980-1999	Operation
Recycling, decreased use and changes of solvents, R8	3.	1980-1999	Chemical-elimination technology
Use of recycled fibre paper, R7	No importance assessed	1980-1999	Wood or recycled-fibre technology
Digital production of prepress, R7	No importance assessed	1980-1999	Automation, measurement and information technology
Drying technology in offset printing, R7	No importance assessed	1980-1999	Energy technology
Recycling solvents in gravure printing, R7	No importance assessed	1980-1999	Closing-up technology
"On-demand" printing, R8	1.	2000-2019	Operation
Water-based inks, R8	2.	2000-2019	Chemical-elimination technology
Advertisement produced in net, R8	3.	2000-2019	Automation, measurement and information technology
Water-based inks, R7	No importance assessed	2000-2019	Chemical-elimination technology
New printing technologies from computer to press, R7	No importance assessed	2000-2019	Automation, measurement and information technology
Digital distribution of documents, local printing, R7	No importance assessed	2000-2019	Automation, measurement and information technology
Changes in printing machines, R7	No importance assessed	2000-2019	Automation, measurement and information technology
Reusable paper, "electronic paper", R7	No importance assessed	2000-2019	Automation, measurement and information technology

Appendix VII contains contingency tables of response frequencies between various variables.

Table VII-1 contains the response frequencies of environmental aspects controlled by the technological categories. Table VII-2 contains the response frequencies of categorised other-than-legal incentive divided into technological categories.

Table VII-3 contains the response frequencies of function mechanisms of pollution prevention and pollution abatement divided into the breakthrough time periods.

Table VII-4 contains the response frequencies of significantly competitiveness-increasing and the other investigated technologies divided into the technological categories.

Table VII-5 contains the response frequencies of significantly competitiveness-increasing technologies and the other investigated technologies divided into the parts of the value chain.

Table VII-6 contains the response frequencies of significantly competitiveness-decreasing and the other investigated technologies divided into the breakthrough time periods.

Table VII-7 contains the response frequencies of significantly competitiveness-decreasing and the other investigated technologies divided into the environmental aspects.

Table VII-8 contains the response frequencies of significantly competitiveness-decreasing and the other investigated technologies divided into having legal incentive and not having legal incentive.

Table VII-9 contains the response frequencies of significantly competitiveness-decreasing and the other investigated technologies divided into the parts of the value chain.

Table VII-10 contains the response frequencies of technological categories divided into the parts of the value chain of printed paper.

Table VII-11 contains the response frequencies of environmental aspects controlled by environmentally sound technologies divided into the parts of the value chain of printed paper.

Table VII-12 contains the response frequency of the categorised quality of the competitiveness impact in the other part of the value chain by environmentally sound technology of other part of the value chain divided into the parts of the value chain, where technology is implemented.

Table VII-13 contains the response frequencies of the categorised other-than-legal incentive divided into the parts of the value chain.

Table VII-14 contains the response frequencies of technological categories divided into categories of joint variable of function mechanism and legal incentive.

Table VII-15 contains the response frequencies of the value chain divided into categories of joint variable of function mechanism and legal incentive.

Table VII-16 contains the response frequencies of environmental aspect divided into categories of joint variable of function mechanism and legal incentive.

Table VII-17 contains the response frequencies of the impact on the other part of the value chain divided into categories of joint variable of function mechanism and legal incentive.

Table VII-18 contains the response frequencies of the competitiveness factor of staff in pulp mills and printing houses divided into categories of joint variable of function mechanism and legal incentive.

Table VII-19 contains the response frequencies of the competitiveness factor of staff in time period 1980-1999 divided into categories of joint variable of function mechanism and legal incentive

Table VII-20 contains the response frequencies of the competitiveness factor of staff in breakthrough time period 1980-1989 divided into categories of joint variable of function mechanism and legal incentive.

Table VII-21 contains the response frequencies of the competitiveness factor of staff having no impact on competitiveness of company in other part of the value chain divided into categories of joint variable of function mechanism and legal incentive.

Table VII-22 contains the response frequencies of the competitiveness factor of staff in categorised impact on competitiveness of company in other part of the value chain divided into categories of joint variable of function mechanism and legal incentive.

Table VII-1 Response Frequencies of Environmental Aspects Controlled by the Technological Categories

Environmental Aspect/Technological Category	**Emissions to Air**	**Releases to Water**	**Waste Management**	**Use of Energy**	**Use of Raw Materials and Natural Resources**	**Use of Fresh Water**	**Biodiversity**	**Landscape**	**Contamination of Land**	**Total**
Automation, measurement and information technology	0	0	0	2	11	0	2	1	0	16
Energy technology	1	0	0	6	5	0	0	0	1	13
Wood or recycled-fibre technology	0	0	0	1	6	0	1	0	0	8
Closing-up technology	1	4	0	0	0	4	0	0	0	9
Operations	1	0	0	0	3	0	4	0	1	9
Chemical-elimination technology	3	3	0	0	0	0	0	0	0	6
Emission-control technology	4	0	0	0	0	0	0	0	0	4
Wastewater technology	0	2	1	0	0	0	0	0	0	3
Solid-waste technology	0	0	2	0	0	0	0	0	0	2
Total	10	9	3	9	25	4	7	1	1	69

Table VII-2 Response Frequencies of the Categorised Other-than-Legal Incentive Divided into Technological Categories

Other-than-Legal Incentive/Technological Category/	Ability to Operate	Financial or Other Subvention	Cost	Public Image	Energy Supply	Market Pressure	Development of Technology	Total
Automation, measurement and information technology	0	0	11	2	0	2	0	15
Energy technology	0	2	5	0	1	0	0	8
Wood or recycled-fibre technology	1	0	1	0	0	1	0	3
Closing-up technology	1	0	0	4	0	0	0	5
Operation	0	2	1	3	0	0	1	7
Chemical-elimination technology	0	0	0	1	0	2	1	4
Emission-control technology	0	0	0	1	0	0	0	1
Wastewater technology	1	0	0	1	0	0	0	2
Solid-waste technology	0	0	1	0	0	0	0	1
Total	3	4	19	12	1	5	2	46

Table VII-3 Response Frequencies of Function Mechanisms of Pollution Prevention and Pollution Abatement Divided into the Breakthrough Time Periods

Function Mechanism/ Breakthrough Time Period	Pollution Abatement	Pollution Prevention	Total
1980-1989	3	8	11
1990-1999	0	16	16
2000-2009	0	15	15
2010-2019	1	9	10
After 2020	0	2	2
Total	4	50	54

Table VII-4 Response Frequencies of Significantly Competitiveness-Increasing and the Other Investigated Technologies Divided into the Technological Categories

Significantly Competitiveness-Increasing Technologies/Technological Category	**Significantly Competitiveness-Increasing Technology**	**Not Significantly Competitiveness-Increasing Technology**	**Total**
Automation, measurement and information technology	14	2	16
Energy technology	3	10	13
Wood or recycled-fibre technology	6	2	8
Closing-up technology	7	2	9
Operation	4	4	8
Chemical-elimination technology	2	4	6
Emission-control technology	1	3	4
Wastewater technology	3	0	3
Solid-waste technology	0	2	2
Total	40	29	69

Table VII-5 Response Frequencies of Significantly Competitiveness-Increasing Technologies and the Other Investigated Technologies Divided into the Parts of the Value Chain

Significantly Competitiveness-Increasing Technologies/A Part of the Value Chain	**Significantly Competitiveness-Increasing Technology**	**Not Significantly Competitiveness Increasing Technology**	**Total**
Forest harvesting	9	9	18
Pulp mills	7	11	18
Paper mills	12	6	18
Printing houses	12	3	15
Total	40	29	69

Table VII-6 Response Frequencies of Significantly Competitiveness-Decreasing and the Other Investigated Technologies Divided into the Breakthrough Time Periods

Significantly Competitiveness-Decreasing Technologies/Breakthrough Time Period	**Significantly Competitiveness-Decreasing Technology**	**Not Significantly Competitiveness-Decreasing Technology**	**Total**
1980-1989	3	8	11
1990-1999	3	13	16
2000-2009	1	14	15
2010-2019	2	8	10
After 2020	2	0	2
Total	11	43	54

Table VII-7 Response Frequencies of Significantly Competitiveness-Decreasing and the Other Investigated Technologies Divided into the Environmental Aspects

Significantly Competitiveness-Decreasing Technologies/Environmental Aspect	**Significantly Competitiveness-Decreasing Technology**	**Not Significantly Competitiveness-Decreasing Technology**	**Total**
Emissions to air	4	6	10
Releases to water	3	6	9
Waste management	0	3	3
Use of energy	1	8	9
Use of raw materials and natural resources	1	24	25
Use of fresh water	0	4	4
Biodiversity	1	6	7
Landscape	0	1	1
Contamination of land	1	0	1
Total	11	58	69

Table VII-8 Response Frequencies of Significantly Competitiveness-Decreasing and the Other Investigated Technologies Divided into Having Legal Incentive and Not Having Legal Incentive

Significantly Competitiveness-Decreasing Technologies/Having Legal Incentive	**Significantly Competitiveness-Decreasing Technology**	**Not Significantly Competitiveness-Decreasing Technology**	**Total**
Having legal incentive	7	19	26
Not having legal incentive	4	37	41
Total	11	56	67

Table VII-9 Response Frequencies of Significantly Competitiveness-Decreasing and the other Investigated Technologies Divided into the Parts of the Value Chain

Significantly Competitiveness-Decreasing Technologies/A Part of the Value Chain	Significantly Competitiveness-Decreasing Technology	Not Significantly Competitiveness-Decreasing Technology	Total
Forest harvesting	2	16	18
Pulp mill	4	14	18
Paper mill	0	18	18
Printing houses	5	10	15
Total	11	58	69

Table VII-10 Response Frequencies of Technological Categories Divided into the Parts of the Value Chain of Printed Paper

A Part of the Value Chain/Technological Category	Forest Harvesting	Pulp Mills	Paper Mills	Printing Houses	Total
Automation, measurement and information technology	7	0	2	7	16
Energy technology	4	3	5	1	13
Wood- and recycled-fibre technology	1	1	5	1	8
Closing-up technology	0	4	4	1	9
Operation	6	0	0	2	8
Chemical-elimination technology	0	3	0	3	6
Emission-control technology	0	4	0	0	4
Wastewater technology	0	1	2	0	3
Solid-waste technology	0	2	0	0	2
Total	18	18	18	15	69

Table VII-11 Response Frequencies of Environmental Aspects Controlled by Environmentally Sound Technologies Divided into the Parts of the Value Chain of Printed Paper

A Part of the Value Chain/ Environmental Aspect	Forest Harvesting	Pulp Mills	Paper Mills	Printing Houses	Total
Emissions to air	0	5	0	5	10
Releases to water	0	8	1	0	9
Waste management	0	2	1	0	3
Use of energy	0	0	8	1	9
Use of raw materials and natural resources	9	3	4	9	25
Use of fresh water	0	0	4	0	4
Biodiversity	7	0	0	0	7
Landscape	1	0	0	0	1
Contamination of land	1	0	0	0	1
Total	18	18	18	15	68

Table VII-12 Response Frequency of the Categorised Quality of the Competitiveness Impact in the Other Part of the Value Chain by Environmentally Sound Technology of Other Part of the Value Chain Divided into the Parts of theValue Chain, Where Technology is Implemented.

Quality of the Competitiveness Impact in the Other Part of the Value Chain/A Part of the Value Chain	Raw Material at Following Phase	Environmental Image	Ability to Operate	Cost	Paper Market	Logistics	Other	Total
Forest harvesting	8	2	1	0	0	0	0	11
Pulp mills	4	0	0	1	0	0	0	5
Paper mills	5	0	0	1	0	0	1	7
Printing houses	0	0	0	0	7	1	1	9
Total	17	2	1	2	7	1	2	32

Table VII-13 Response Frequencies of the Categorised Other-than-Legal Incentive Divided into the Parts of the Value Chain

Other-than-Legal Incentive/A Part of the Value Chain/	Ability to Operate	Financial or Other Subvention	Cost	Public Image	Energy Supply	Market Pressure	Development of Technology	Other	Total
Forest harvesting	1	4	6	4	1	0	0	1	18
Pulp mills	2	0	2	3	0	2	0	0	9
Paper mills	0	0	6	3	0	0	0	1	10
Printing houses	0	0	5	2	0	3	2	1	13
Total	3	4	19	12	1	5	2	3	49

Table VII-14 Response Frequencies of Technological Categories Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Joint Variable (Porter Hypothesis)/Technological Category	**Pollution Abatement without Legal Incentive**	**Pollution Abatement with Legal Incentive**	**Pollution Prevention without Legal Incentive**	**Pollution Prevention with Legal Incentive**	**Total**
Automation, measurement and information technology	0	0	15	1	16
Energy technology	0	0	9	4	13
Wood- and recycled-fibre technology	0	0	4	3	7
Closing-up technology	0	0	6	3	9
Operation	0	0	2	6	8
Chemical-elimination technology	0	1	2	3	6
Emission-control technology	1	2	1	0	4
Wastewater technology	1	2	0	0	3
Solid-waste technology	0	1	0	0	1
Total	2	6	39	20	67

Table VII-15 Response Frequencies of the Value Chain Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Joint Variable (Porter Hypothesis)/Value Chain	**Pollution Abatement without Legal Incentive**	**Pollution Abatement with Legal Incentive**	**Pollution Prevention without Legal Incentive**	**Pollution Prevention with Legal Incentive**	**Total**
Forest harvesting	0	0	9	9	18
Pulp mills	1	4	7	5	17
Paper mills	1	1	12	3	17
Printing houses	0	1	11	3	20
Total	2	6	39	20	67

Table VII-16 Response Frequencies of Environmental Aspect Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Joint Variable (Porter Hypothesis)/Environmental Aspect	**Pollution Abatement without Legal Incentive**	**Pollution Abatement with Legal Incentive**	**Pollution Prevention without Legal Incentive**	**Pollution Prevention with Legal Incentive**	**Total**
Emissions to air	1	3	4	2	10
Releases to water	0	2	3	4	9
Waste management	1	1	0	0	2
Use of energy	0	0	7	2	9
Use of raw materials and natural resources	0	0	18	7	24
Use of fresh water	0	0	4	0	4
Biodiversity	0	0	3	4	7
Landscape	0	0	1	0	1
Contamination of land	0	0	0	1	1
Total	2	6	39	20	67

Table VII-17 Response Frequencies of Impact on the other Part of the Value Chain Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Joint Variable (Porter Hypothesis)/Impact on Other Part of the Value Chain	**Pollution Abatement without Legal Incentive**	**Pollution Abatement with Legal Incentive**	**Pollution Prevention without Legal Incentive**	**Pollution Prevention with Legal Incentive**	**Total**
Impact on other part of the value chain, yes	0	1	21	11	33
No impact on other part of the value chain	2	5	17	8	32
Total	2	6	38	19	65

Table VII-18 Response Frequencies of the Competitiveness Factor of Staff in Pulp Mills and Printing Houses Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Competitiveness Factor of Staff/ Value Chain	**Joint Variables of Function Mechanism and Legal Incentive**	**Competitiveness Assessment of Staff**			**Total**
		Decreasing Competitiveness	**No Impact**	**Increasing Competitiveness**	
Pulp mills	Pollution abatement without legal incentive	0	1		1
	Pollution abatement with legal incentive	3	1		4
	Pollution prevention without legal incentive	2	5		7
	Pollution prevention with legal incentive	0	5		5
Total		5	12		
Printing houses	Pollution abatement without legal incentive				
	Pollution abatement with legal incentive		1	0	1
	Pollution prevention without legal incentive		3	8	12
	Pollution prevention with legal incentive		3	0	3
	Total		7	8	16

Table VII-19 Response Frequencies of the Competitiveness Factor of Staff in Time Period 1980-1999 Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Competitiveness Factor of Staff/ Time Period	**Joint Variables of Function Mechanism and Legal Incentive**	**Competitiveness Assessment of Staff**			**Total**
		Decreasing Competitiveness	**No Impact**	**Increasing Competitiveness**	
1980-1999	Pollution abatement without legal incentive	0	2	0	2
	Pollution abatement with legal incentive	2	2	0	4
	Pollution prevention without legal incentive	1	10	6	17
	Pollution prevention with legal incentive	0	6	5	11
Total		3	20	11	34

Table VII-18 Response Frequencies of the Competitiveness Factor of Staff in Releases to Water and Waste Management of Environmental Aspect Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Competitiveness Factor of Staff/ Environmental Aspect	Joint Variables of Function Mechanism and Legal Incentive	Competitiveness Assessment of Staff			Total
		Decreasing Competitiveness	No Impact	Increasing Competitiveness	
Releases to water	Pollution abatement without legal incentive				
	Pollution abatement with legal incentive	1	1		2
	Pollution prevention without legal incentive	2	1		3
	Pollution prevention with legal incentive	0	4		4
Total		3	5		8
Waste management	Pollution abatement without legal incentive	0	1		1
	Pollution abatement with legal incentive	1	0		1
	Pollution prevention without legal incentive				
	Pollution prevention with legal incentive				
	Total	1	1		2

Table VII-20 Response Frequencies of the Competitiveness Factor of Staff in Breakthrough Time Period 1980-1989 Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Competitiveness Factor of Staff/ Breakthrough Time Period	Joint Variables of Function Mechanism and Legal Incentive	Competitiveness Assessment of Staff			Total
		Decreasing Competitiveness	No Impact	Increasing Competitiveness	
1980-1989	Pollution abatement without legal incentive				
	Pollution abatement with legal incentive	2	1		3
	Pollution prevention without legal incentive	0	4		4
	Pollution prevention with legal incentive	0	2		2
Total		2	7		9

Table VII-21 Response Frequencies of the Competitiveness Factor of Staff Having No Impact on Competitiveness of Company in the Other Part of the Value Chain Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Competitiveness Factor of Staff/ Impact on Competitiveness of Company in Other Part of Value	**Joint Variables of Function Mechanism and Legal Incentive**	**Competitiveness Assessment of Staff**			**Total**
		Decreasing Competitiveness	**No Impact**	**Increasing Competitiveness**	
Impact on competitiveness of company in other part of value, no	Pollution abatement without legal incentive	0	2	0	2
	Pollution abatement with legal incentive	3	2	0	5
	Pollution prevention without legal incentive	1	9	7	17
	Pollution prevention with legal incentive	1	5	2	8
Total		5	18	9	32

Table VII-22 Response Frequencies of the Competitiveness Factor of Staff in Categorised Impact on Competitiveness of Company in Other Part of the Value Chain Divided into Categories of Joint Variable of Function Mechanism and Legal Incentive

Competitiveness Factor of Staff/ Categorised Impact on Competitiveness of Company in the Other Part of the Value Chain	**Joint Variables of Function Mechanism and Legal Incentive**	**Competitiveness Assessment of Staff**			**Total**
		Decreasing Competitiveness	**No Impact**	**Increasing Competitiveness**	
Raw material at the following phase	Pollution abatement without legal incentive				
	Pollution abatement with legal incentive				
	Pollution prevention without legal incentive	2	6	2	10
	Pollution prevention with legal incentive	0	2	4	6
Total		2	8	6	16
Paper market	Pollution abatement without legal incentive				
	Pollution abatement with legal incentive		1	0	1
	Pollution prevention without legal incentive		1	5	6
	Pollution prevention with legal incentive				
	Total		2	5	

Legal Incentives Impacting on Environmentally Sound Technologies in the Value Chain of Printed Paper

Table VIII-1 contains the mentioned legal incentives impacting on environmentally sound technologies in the various parts of the value chain of printed paper.

Table VIII-1 Mentioned Legal Incentives Impacting in the Value Chain of Printed Paper

A Part of Value Chain/	**Forest Harvesting**	**Pulp Mills**	**Paper Mills**	**Printing Houses**
Specified legal incentive	Forest legislation considering environmental issues; Forest Act in Sweden Pest legislation Shore protection legislation; Carbon dioxide and sulfur dioxide taxes; Legal limitations of working hours; Waste rules; Environmental legislation generally (future)	Adsorpable organic halogens (AOX); Biological oxygen demand (BOD); Chemical oxygen demand (COD) limitations; Toxicity limitations in Canada Odour rules in Japan; Greenhouse gas trading; Solid waste taxes; Permits for discharge of effluent into waterways; Permits for airborne emissions	Waterway legislation; Recycled fibre regulations	Pollution legislation in Germany, Regulation for emissions, recovery and use of solvents (EU and other states)

Appendix IX contains the means of competitiveness factors in technological categories.

Table IX-1 Means of competitiveness factors in technological categories

Technological category/Competitiveness factor	**Raw material** Mean	**Energy** Mean	**Staff** Mean	**Capital** Mean	**Other cost** Mean	**Product characteristic** Mean	**Product image** Mean	**Company image** Mean	**Other differentiation** Mean
Automation, measurement and information technology	1,2	0,47	1,07	0	0,43	1,27	0,6	1	0,46
Energy technology	0,08	0,85	0,23	-0,31	-0,22	0,23	0,23	0,46	0,08
Wood and recycled-fibre technology	1,25	0,63	0,75	0,38	0,29	-0,25	0,63	0,5	0,71
Closing-up technology	0,11	-0,22	-0,11	-0,71	-0,11	-0,33	1,33	0,78	0
Operation	-0,14	-0,33	0,57	0,14	0,43	0,71	0,71	0,33	0,67
Chemical-elimination technology	0	-0,17	-0,17	-0,83	0	-0,4	0,67	0,67	0,4
Emission-control technology	0,5	0,25	-0,25	-1,25	0	0	0	0,75	0
Wastewater technology	0	0	-0,33	-0,67	-0,33	0	0,67	0,33	0,67
Solid-waste technology	0	0	-1	-1	1	0	1	1	0
Total	0,47	0,29	0,36	-0,28	0,15	0,31	0,62	0,66	0,33

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