Opening the black box of environmental innovation

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Governmental policy and learning in the Dutch paper and board industry

Het openen van de zwarte doos van milieu-innovatie
Overheidsbeleid en leren in de Nederlandse papier- en kartonindustrie

(met een samenvatting in het Nederlands)

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1 Introduction

1.1 Background

Although climate change has always taken place, it has become clear that the recent changes in our climate are the result of human activity (IPCC, 2007). Changes in the climate that have taken place since the industrialisation of our economy (around 1850) cannot completely be explained by natural fluctuations. One important cause is the emission of greenhouse gases and in particular the emission of CO_2. The emission of CO_2 is mainly due to the use of fossil fuels. When fossil fuels are burned, CO_2 is released. The increased concentrations of greenhouse gases lead to radiative forcing, which results in an increase in temperature of the earth's surface and oceans, sea level rise, and the melting of ice and snow. To reduce the risks of negative effects due to climate change, it is important to reduce the emissions of greenhouse gases, as is acknowledged globally. In 1997, agreement was reached on the Kyoto protocol, which was enforced in 2005. The goal of this protocol is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The aim for Europe was to reduce greenhouse gases by 8% as compared to the level of 1990, in the period 2008-2012. The Netherlands agreed to a reduction of 6% (UNFCCC, 2007). Very recently, the goals have been adjusted to a 30% reduction by 2020 (VROM, 2007). In order to achieve these goals, one effective strategy is to reduce the energy demand of the industry, especially energy-intensive industry since these industries represent a big chunk of global energy use.

In the past, studies have been carried out to identify potentials for energy savings in industry (c.f. (Worrell, 1994; De Beer et al., 1998; Patel, 1999)). There appeared to be a considerable potential to save energy in the production processes of basic materials such as steel and paper. It turned out to be possible to halve the specific energy use over the coming decades (Blok, 2000). This resulted in significant investments by industry to reduce carbon emissions. Recent statistics show that this trend continues to today, as the share of firms' investments in environmental-friendly processes increased again in the Netherlands in 2006, compared to the year before (CBS, 2007). However, despite the success of measures to reduce the environmental impact, we still face considerable environmental problems (European Environmental Agency, 2003; Elzen et al., 2005). In order to achieve a sustainable[1] society, more fundamental changes in industrial processes are necessary (Hall et al., 2003; Geels et al., 2004). A significant strategy to achieve this is environmental innovation. Environmental innovation is a special form of innovation and "consists of new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harm" (Beise et al., 2005) (p.6). There is a need to better understand these environmental innovation processes (Foster et al., 2000; Rennings, 2000; Hall, 2003); a need to open the black box of environmental innovation.

What makes these environmental innovation processes special? As with innovation in general, environmental innovation concerns something new for the innovating firm. Innovation either entails doing the same thing in a different way, or it entails doing new things. This means that learning needs to take place. But what does such a learning process look like? That is initially unclear. With regard to primary processes this seems obvious, but is this also the case for environmental innovation? The challenging aspect of environmental innovation is that these innovations are not part of the primary process of innovating firms. This at least suggests that other parties/actors need to be involved in this learning process. But who becomes involved and why? There is a need to empirically analyse these learning processes to understand how and why these learning processes proceed as they do.

The issue at stake is even more complex, because the environment is a public good. A public good can be characterised as non-rival and non-excludable[2]. As a consequence, the cost-benefit ratio of environmental innovation is somewhat "awkward". While the benefits are for society as a whole, costs are mainly carried by the innovating firm and it is often difficult to appropriate the profits. This is referred to as the *double-externality* problem. This problem reduces the incentive for firms to invest in environmental innovation (Beise et al., 2005), suggesting that this type of innovation (environmental innovation) will not be an autonomous development. This is often referred to as market failure. Therefore, governments are an important actor influencing environmental innovation. This makes it interesting to study the influence of governmental environmental policy on environmental innovation processes (Hardin, 1968; Foster et al., 2000; Rennings, 2000; Beise et al., 2005; Vollebergh, 2007).

This thesis focuses on the Dutch paper and board industry because of its energy intensive process of paper and board production. For this reason, the Dutch paper and board industry has a long history in energy-saving efforts. After the oil crisis of 1973, when energy prices increased enormously, energy became one of the most important topics for the paper and board industry (VNP, 2003), remaining on their innovation agenda ever since. Moreover, this industry has two other environmental topics to deal with. In addition to energy, waste and waste water are important areas of concern in the production process of the Dutch paper and board industry. These two issues have also been on their innovation agenda for quite some time.[3]

In sum, causes of climate change and potential means of saving energy are known, but insight into the underlying organisational and behavioural processes affecting (both positively and negatively) the application of these innovative potentials is lagging. The challenge is to open the black box of environmental innovation. Therefore, the aim of this thesis is twofold. We aim to achieve a better understanding, on the one hand of the structuring and the interactions taking place within these learning processes, and on the other hand of the interaction with the government. The next paragraph will explain these concepts in more detail, and research questions will be formulated.

1.2 Theoretical background

1.2.1 Environmental innovation

Following Freeman et al. (2000) we define innovation as putting new ideas to use. These new ideas are inventions, which Freeman et al. (2000) (p.6) define as "an idea, a sketch, or model for a new or improved device, product, process or system." Inventions become innovation, once they are put to use. In line with this idea is the definition of Rogers (2003) (p.11), who defines innovation as "an idea, a practice or an object that is perceived as new by an individual or other unit of adoption". Innovation processes are said to be complex, non-linear, and uncertain (Van de Ven et al., 1992; Rogers, 1995; Van de Ven et al., 1999). This complexity is the main reason for firms to avoid innovation on their own (Edquist, 1997). Innovations are developed in interaction with many institutions surrounding the innovating firm, known as the innovation system (Hekkert et al., 2007) Innovation systems can be defined as "the network of institutions in the public and private sectors, whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987) (p.1). Consequently, different aspects of innovations can be studied on different levels, such as the level of a nation, the level of firms or the level of a set of firms, or the interactions between firms. In this thesis we study several levels, namely the level of the industry, the individual firm and the interactions within the innovation system.

Innovating firms can follow different strategies. On the one hand, firms can develop the innovation, which is called generation of innovation. On the other hand, firms can decide to buy an innovative object or device. This is called adoption. After adopting an innovation, it needs to be implemented in the organisation. This thesis analyses all three processes, that is to say the generation, the adoption, and implementation of innovation.

As indicated above, our focus is specifically on environmental innovation. This is a type of innovation with potential environmental benefits (Hall et al., 2003). "Environmental innovation consists of new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harm" (Beise et al., 2005) (p.6). A very broad definition of environmental innovation or eco-innovation is: "All measures of relevant actors (firms, politicians, unions, associations, churches, private households), which develop new ideas, behavior, products and processes, apply or introduce them and which contribute to the reduction of environmental burdens or ecologically specified sustainability targets" (Klemmer et al. 1999 in Rennings 2000). In this thesis the focus is on firms, more specifically Dutch paper and board mills. In order to reduce their environmental impact, firms can choose between curative and preventive approaches (Rennings, 2000). A curative approach aims to control and cure environmental problems (ex-post), whereas a preventive approach aims to prevent environmental problems (ex-ante) (De Blécourt-Maas et al., 1997; Keijzers, 2000). Over time, there has been a shift from a curative to a preventive approach (De Blécourt-Maas et al., 1997; De Bruijn et al., 2000; Hofman et al., 2003). By the mid-eighties, an awareness had grown that curative measures were insufficient to solve massive environmental problems, and that they were too expensive besides. The money could better be used for preventive measures (Cramer, 1991). Environmental technology is used to achieve this prevention or cure of environmental problems. Environmental technology can broadly be defined as every technique, process or product that conserves environmental qualities. Different types of technologies can be distinguished, such as pollution control technologies, off-site waste recycling and treatment, process-integrated changes in production technology, input material changes and good housekeeping, and finally environmentally beneficial products (Kemp, 1995; Brezet et al., 1997; De Blécourt-Maas et al., 1997; Tukker et al., 2001). While pollution control technologies and off-site waste recycling and treatment are more related to a curative approach, process-integrated changes and environmentally beneficial products are more related to a preventive approach.

Besides this environmental technology grouping, it is also possible to distinguish between different types of environmental innovations based on generic innovation characteristics. We can distinguish process and product innovations, and different levels of innovative complexity. The typology of environmental technologies clarifies that innovation relates to production processes as well as to its products. This distinction is referred to as product versus process innovation. In the case of product innovation, the composition, design, operation, quality or function(s) of products (including services) is changed (Moors, 2000). Process innovation concerns changes in the way inputs in a production process are transformed into outputs, i.e. the actual products. Process innovation may entail an improvement of or a complete new production process of a product. Such innovations can for instance lead to cost reductions, material savings, or energy savings. This thesis concentrates on process innovations.

These changes in products and processes can be more or less far-reaching for the innovating firm. This is referred to as the level of innovation and is the final distinction we will discuss. The level of innovation is also called the perceived complexity of an innovation (Tidd et al., 2001). Complexity has been defined in many different ways. Traditionally, there is a distinction between incremental innovation (relatively minor changes) and radical innovation (based on a different set of engineering and scientific principles) (Freeman, 1982; Henderson et al., 1990). Nooteboom (2000) refers to this as exploitation and exploration, respectively. It is often recognised that, in the case of environmental innovation, radical innovation is necessary to truly achieve a sustainable world (Hall et al., 2003; Geels et al., 2004). Incremental innovation is important but insufficient to overcome the environmental problems we face.

Having discussed some general aspects of environmental innovation, we now can take a closer look at environmental policy.

1.2.2 Environmental policy

As discussed at the start of this chapter, government and governmental environmental policy will generally be important to environmental innovation (Rennings, 2000; Beise et al., 2005; Vollebergh, 2007). Environmental policy can be defined as all goal-directed and planned efforts of government in the pursuit of specific aims regarding the physical environment, with the help of specific means in a certain time sequence (Hoogerwerf, 1985).[4] Different classifications of instruments can be found in the literature. In this thesis we use the distinction between top-down regulation (command and control), interactive regulation, and positive and negative economics instruments (subsidies and taxes, respectively). During the last decades, the approach of the Dutch government has shifted from mainly top-down regulation towards more interactive regulation (Gunningham et al., 1998; Keijzers, 2000; Keijzers, 2002; Vermeulen, 2002; Zito et al., 2003). As a result of these different policy strategies, the relationship between government and industry is changing. It is argued that, in the policy-making process concerning environmental issues, cooperation between government and firms is a means to create more efficient solutions to environmental problems (Rennings, 2000; Marcus et al., 2002). The industry association can function as an intermediary between government and individual firms in their formulation (and realisation) of objectives. However, not much is known about the role of stakeholders in these policy-making processes, in particular the role of the industry association. We therefore formulate the following research question:

RQ 1: To what extent is the industry association of the Dutch paper and board industry involved in the policy-making processes of distinct types of instruments?

Furthermore, the effect of specific policy instruments on environmental innovation is much disputed. Different and sometimes even conflicting theoretical and empirical findings on the relation between environmental policy and environmental innovation are found in literature (Sanchez, 1997). The effects of environmental policy on innovation are ambiguous; environmental policy can either stimulate or constrain environmental innovation. In addition, the literature offers different explanations. Unsurprisingly, the relation is said to be complex (Millstone, 1994; Firth et al., 1999; Rennings, 2000).

The literature reports three types of negative effects of environmental regulation on environmental innovation: extra costs, uncertainty about regulators and regulations, and a restriction of innovation options. First, the application of regulations adds to the firm's costs (Rothwell et al., 1981; Rothwell, 1992; Braun et al., 1994; Hitchens et al., 1998; Marcus et al., 2002). This results in a reduction of money available for innovation (Braun et al., 1994) and in a reallocation of technical and management resources (Rothwell et al., 1981). Consequently, less environmental innovation is said to take place.

Second, it is argued that firm managers are uncertain about the regulations (Marcus, 1981; Hall, 2003), due to a lack of clarity (Marcus, 1981). Moreover, managers are uncertain about the behaviour of the regulators (Marcus, 1981; Rothwell et al., 1981; Gunningham et al., 1998). There are concerns about the regulators' competence to set the right policy, to implement it correctly, and their ability to determine the impact of the policy on the industry (Rothwell et al., 1981). This difficulty of policy development is due to the fact that regulators must draw on very detailed sectoral and technical knowledge of the workings and capacity of industry. On account of this complexity, enforcing the law is an intricate affair (Gunningham et al., 1998). As a consequence, managers develop risk-avoiding behaviour, resulting in less environmental innovation.

The third negative effect of environmental regulation reported in the literature is that it limits the innovation options. Three reasons are given for this effect. First of all, the time spans available for implementation are too short to identify optimal solutions (Rothwell et al., 1981). Besides this time pressure, innovative options are limited by the regulatory goals. As innovative options are selected out, firms cannot innovate in whatever way they like. Regulations or a change to regulations disturbs the context in which firms operate. As a consequence of this regulation, the set of options for the innovating firms changes, as well as the value of these innovations. Regulation influences what is learned (Firth et al., 1999). Finally, the bureaucracy necessary to comply with the regulation also limits the innovative options (Braun et al., 1994).

The opposite statement is that environmental regulation can stimulate innovation (Rothwell et al., 1981; Norberg-Bohm, 1999). The positive effects can be subdivided in three categories: saving money, creating markets, and a jolting effect. Environmental regulation can stimulate environmental innovation, first, because innovations can save money. Wiener (2004) distinguishes two different types of savings: strong savings and weak savings. The strong form refers to an environmental innovation that reduces the firm's variable or fixed costs. This is for instance the case if an improvement of the process results in less consumption of material. Programmes on clean production and pollution prevention have demonstrated that firms can and do actually reduce costs by applying preventive strategies (Huisingh et al., 1982; Huisingh et al., 1986; Tibbs, 1993; Cagno et al., 2005).

The weaker form emerges when one firm takes the lead and other countries need to follow. The innovating firm thereby gains a first-mover advantage (Hitchens et al., 1998; Wiener, 2004). Porter (1991a; 1995) has written several articles on this so-called weak effect. He argues that tough standards trigger innovation and that these strict environmental codes may actually improve the competitiveness. This effect occurs because it may result in lower costs or improve quality. He is aware of the fact that the short-term costs increase and that there is a need to re-design products and processes. This results in a competitive advantage, however (Porter, 1991a; Porter et al., 1995).

Second, environmental regulation can stimulate environmental innovation, because it can create the necessary market for environmental innovation. The idea behind this argument is that market forces operate too slowly (Braun et al., 1994). Regulation can provide directions for technical change and product attributes (Ashford, 2002), thereby opening new market niches and creating new demands and opportunities (Braun et al., 1994). According to Sunnevag (2000), environmental regulation enhances the climate for innovation. Environmental regulation can add an exterior threat, necessary to draw attention to a problem. In the absence of environmental regulation and without such a threat, behaviour will not change (Van de Ven, 1986; Van de Ven et al., 1992; Van de Ven et al., 1999) and environmental innovation will not take place. Hence, (environmental) policy may stimulate (environmental) innovation. Policy is then seen as an external jolt, that is, a sudden and unprecedented event (Meyer, 1982).

The reported research shows that more insight into the relation between environmental policy and environmental innovation is required. Although governmental policy is considered the most influential or at least a critical driver for environmental innovation (Rothwell et al., 1981; Foster et al., 2000; Vollebergh, 2007), innovation is influenced by many factors. Two factors often neglected are *policy accumulation* (Schuddeboom, 1990; Rennings, 2000; Vermeulen, 2002; Dieperink et al., 2004; Vollebergh, 2007) and *intra-organisational factors* (Rennings, 2000; Beise et al., 2005; Vollebergh, 2007).

Policy accumulation refers to how, quite often, several sets of policy instruments are at work simultaneously and additional new policies are implemented. This implies that there is an accumulation of policy instruments over time. In earlier literature, it is acknowledged that little attention is paid to this accumulation of policy instruments (Schuddeboom, 1990; Rennings, 2000; Vermeulen, 2002; Dieperink et al., 2004; Vollebergh, 2007). We define policy accumulation as the implementation of a number of policy instruments focusing on a specific target group or on several target groups, and aiming at the achievement of related policy goals in relatively short time periods. This policy accumulation often implies a mixture of policy instruments with a variety of underlying mechanisms that enable the achievement of policy goals. Policy accumulation entails major complications in terms of the efficacy of implemented policy measures. The time span in which related policy instruments are implemented determines the policy pressure for target groups, as they are confronted with new instruments to comply with. If implemented in too short a time span, policies will create pressure that may trigger behavioural resistance among the target group. If the set of policy instruments is based on related mechanisms that contribute to target achievement in distinct ways, policies not only accumulate but also reinforce each other. An example is the implementation of a financial stimulus in addition to already existing top-down regulation, interactive regulation, or subsidies. However, another possibility is that the mechanisms of the instruments are related yet inconsistent, thus leading to compliance based on contradictory mechanisms. Policy makers must take such flaws into account, as well as the fact that these are more likely to occur as the variety of policy measures grows, especially in a short time span.

With regard to intra-organisational factors, several groups of factors can be found in literature (Frambach et al., 1998; Waarts et al., 2002; Wejnert, 2002; Rogers, 2003; Dieperink et al., 2004). Generally, they can be summarised in the following groups: innovation characteristics (e.g. technological complexity), characteristics of innovators (e.g. firm size), and context characteristics (e.g. public concerns or demand conditions). In order to explain the relative role of environmental policy on environmental innovation, there is a need to take these other factors into account as well (Vermeulen, 1992; Dieperink et al., 2004).

RQ2: What is the relative role of distinct environmental policy instruments in the case of environmental innovation in the Dutch paper and board industry with regard to energy, waste water, and waste?

1.2.3 Learning and its explanatory factors

The third and final central concept in this thesis is learning. As already mentioned, due to the newness of innovation, we conceive the process of innovation as a learning process. Either innovation entails something completely new for the innovating firm, or the innovation means doing something in a new way. In both cases learning needs to take place. In the literature on learning, the learning process is divided in different phases (Cyert et al., 1963; Kolb, 1976; Hedberg, 1981; Huber, 1991; Pawlowsky, 2000). The ideas of these different authors do not differ very much. Therefore, based on their ideas, the following phases can be identified:

- Access to knowledge and/or information[5]
- The diffusion of this knowledge and/or information
- The interpretation of it
- The recombination into something new.

These different phases do not necessarily take place in a fixed sequence over time, and feedback loops are very common. Nonaka (1994) argues that organisational learning is not possible without individuals. Organisational learning is the aggregate of the individual learning of members of the organisation and only takes place if the insights and skills of the individual are embedded in the routines, practices and beliefs of the organisation, which last even after the originating individual has left the organisation (Attewell, 1992).

In studies on innovation processes, adaptive processes of organisational learning are addressed, or so-called trial-and-error learning. In short, trial-and-error learning entails the following phases (Cyert et al., 1963; Levitt et al., 1988; Van de Ven et al., 1999):

- People undertake some course of action
- There is an outcome response from the environment
- People interpret and evaluate the response
- The course of action is adapted to increase the propensity of the desired response.

The core idea behind trial-and-error learning is a loop between action and outcomes. An action course can result in negative and positive perceived outcomes. If the perceived outcome is

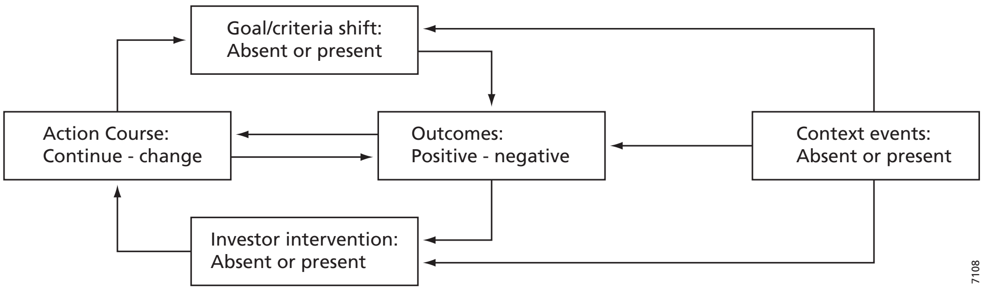

Figure 1.1 Adaptive model of trial-and-error learning during the development of an innovation (Van de Ven et al, 1992)

negative, it is learned which action course should not be taken and the action course is changed accordingly. If the outcome is positive, it is learned that this course is likely to be successful. Therefore, the action course is continued. If there is a continuation of a course of action, organisations will learn to increase the performance. If there is a change in the action course, the learning process starts anew. Van de Ven and colleagues (1992, 1999) analysed this trial-and-error learning model in a very detailed manner using a process model. Figure 1.1 presents their conceptual model.

Interaction

Innovating firms should not be treated as isolated, decision-making units, since innovation processes seldom pertain to one actor (Edquist, 1997). As explained earlier in this introduction, innovations are developed in interaction with the innovation system. In the learning process, some form of interaction almost always takes place (Lundvall, 1992). The growth of knowledge requires a sequence of exchanges of information and knowledge between departments of firms, and/or between firms and other stakeholders in society, and should thus be seen as an interactive process (Jovanovic et al., 1989; Johnson, 1992). Following this argument, learning is considered to be an interactive process. The definition used is based on the definition given by ((Meeus et al., 2001a) (p.148)): "the (in-)formal exchange and sharing of knowledge resources with other actors that is conducive to the innovation of the firm." The notion of interactive learning was introduced in the late eighties by Lundvall (1988). It took several years before these interactive learning processes were empirically explored and tested. Meeus and colleagues conducted several studies in which they focused on the level of interactive learning between the innovating firm and its suppliers, customers, or the knowledge infrastructure (Meeus et al., 2001a; Meeus et al., 2001b; Meeus et al., 2004).

The existing literature on interactive learning processes focuses on dyadic relations (i.e., a relation between two actors). However, it is likely that more than two actors are involved during these processes (Fleck, 1997). The relations that a firm has as a consequence of its business and innovative activities result in networks (Edquist, 1997). A network consists of nodes (actors) and links (relationships). So far, little research has been performed as to the design of learning processes in the case of environmental innovation. The focus on environmental innovation has a number of implications for the learning process. Environmental innovation is not the primary process for industries such as the paper and board industry. This non-core element of environmental innovation suggests that, more often than in the case of core innovation, competences will be missing and new knowledge and routines will need to be acquired (Ehrenfeld, 1999; Marcus et al., 1999). Furthermore, in the case of environmental innovation, actors outside the 'normal' network (being the value chain) of the firm will be engaged (Ehrenfeld, 1999). In sum, innovation is a learning process in which interaction is more frequent and more diverse in the case of environmental innovation than of 'normal innovation'.

RQ3: To what extent does the Dutch paper and board industry involve external actors in their learning processes in the case of environmental innovation?

The level of interactive learning is said to be influenced by resource-based variables and activity-based variables. In short, when the innovating firm has sufficient resources, the incentive to search for external partners is low. However, it is also possible that the resources of the innovating firm are insufficient. In that case resource deficits emerge, which will probably result in the acquisition of external knowledge and/or other resources (Teece, 1986; Meeus et al., 2000; Nooteboom, 2000). This means that the level of interactive learning increases if innovating firms lack resources. However, the level of interactive learning also depends on the complexity of the innovation. A higher complexity occasions interaction and interactive learning (Lundvall, 1988), because a high complexity requires skills, capabilities, and/or knowledge which most innovating firms do not have internally (Zahra et al., 2002).

Studies on innovation and learning processes also need to focus more on temporal aspects (an analysis on a longitudinal base). So far, this has been neglected in most studies, in the sense that context and conditions are often implicitly assumed to be stable over time. Yet we know that the situation within an industry changes over time (see e.g. (Waarts et al., 2002) for empirical evidence). Poole (2004) also advocates taking time into account in studies on innovation and change, because the social, economic or other functional impacts of innovation only become clear over time.

Not only conditions within an industry will change. Innovation projects often take several years. In the meantime members will leave and new members will join. Moreover, the commitment of members will fluctuate over time. Hence, the availability and quality of human resources within innovations projects is volatile over time. While such factors will influence learning processes, this has not been explicitly researched. This yields the fourth and final research question:

RQ4: To what extent can (the development of) these learning processes be explained from a resource based view of the innovating firm(s)?

1.3 Outline and methodological approach

In this thesis, three concepts are central: environmental innovation, environmental policy, and interactive learning. These concepts and the relations between these concepts can be studied on different levels, for example the level of the firm or the industry as a whole. In this thesis we will study three different levels: the level of the industry, projects of individual firms and the development of a multi-actor project (intra-project level). Thus, the most aggregated level in this thesis is the industry level. The thesis is constructed in such a way that we start by studying this most aggregated level, to then continue studying environmental innovation in more detail. However, before we start opening the black box by discussing our empirical results, Chapter 2 first offers a brief description of the industry.

In Chapter 3, the focus is on the policy-making process. The central aim is to develop more insight into the policy-making processes of different types of policy instruments (top-down regulation, interactive regulation, positive and negative economic instruments). This chapter furthermore aims to identify the relative role of the industry association in these policy-making processes. We shall examine the development of governmental policy aimed at the Dutch paper and board industry regarding the issues of waste water, waste and energy efficiency, over the period 1980-2003.

This insight into the development process of policy instruments is the first step to a better understanding of the relation between policy and innovation. In Chapter 4, we try to identify temporal patterns in the implementation of the environmental policy instruments described in Chapter 3 and the number of collective research projects of the industry and eco-efficiency indicators. In this chapter, the focus is also on the issues of waste water, waste and energy efficiency over the period 1980-2003.

Introduction in general *(Chapter 1)*

Introduction in paper and board industry *(Chapter 2)*

	Environmental policy →	**Environmental innovation**	**Learning**
Industry	Role of industry association in *policy-making processes* waste water, waste and energy *(Chapter 3, RQ 1)*	Relation between *environmental policy* and *environmental innovation* outcomes (research activities and eco-efficiency) waste water, waste, and energy *(Chapter 4, RQ 2)*	
Project		Relative influence environmental policy in *adoption* CHP *(Chapter 5, RQ 2)*	Learning structures and influence of strength internal resource base and technological complexity on *adoption* and *implementation* CHP *(Chapter 6, RQ 3+ 4)*
Intra-project			*Knowledge generation:* trial-and-error learning. Influence of volatile inputs *(Chapter 7, RQ 3+ 4)*

Conclusion and discussion (Chapter 8)

Figure 1.2 Thesis outline

We subsequently turn to the second level, namely projects of individual firms. The use of cogeneration of heat and power (CHP) technology is an interesting option for firms producing paper and board. The adoption and implementation of CHP-installations is the central topic of Chapters 5 and 6. Instead of focusing on policy instruments (see Chapter 3 and 4), our starting point in Chapter 5 is the innovation process, whereby we adopt an actor perspective to explain the innovation. We analyse the adoption and implementation of CHP installations in the Dutch paper and board industry, explicitly taking into account the accumulation of different policy instruments as well as intra-organisational factors. This enables us to identify the relative role of different types of policy instruments on the one hand, and the impact of intra-organisational factors on the other in the adoption and implementation processes.

The final two empirical chapters (Chapter 6 and Chapter 7) aim to deepen our understanding of the underlying learning processes. Chapter 6 focuses on the learning structures (operationalised as varying network configurations) in the adoption and implementation of the CHP installations. We focus on the innovating firms and the relations with their innovation partners (suppliers, consumers, competitors, consultancies and research institutes) for the adoption. To explain the choice for a specific learning structure, we analyse the influence of technological complexity and the strength of the internal resource base.

In the final empirical chapter (Chapter 7), we shift to the final level: the intra-project level. The focus is on how a 4-year multi-actor project concerning knowledge generation developed. We use the trial-and-error learning model of Van de Ven and colleagues as a starting point to try to

Table 1.1 Overview of empirical chapters

Chapter	Part of theoretical framework	Cases	Data	Unit of analysis
Three	Insight into the policy- making processes	Waste water, Waste, Energy	Archival data	Dutch paper and board industry
Four	Insight into environmental policy and environmental innovation (collective research projects and reduction of environmental impact)	Waste water, Waste, Energy	Archival data	Dutch paper and board industry
Five	Insight into relative role of environmental policy and other factors in environmental innovation (CHP-adoption)	Cogeneration heat and power (CHP)	Interviews	Adoption and implementation projects of firms
Six	Insight into influence of technological complexity and internal resource base strength on learning structure (CHP-adoption and implementation)	Cogeneration heat and power (CHP)	Interviews	Adoption and implementation projects of firms
Seven	Insight into (interactive) learning processes and the influence of human resources, functioning of partners and network dynamics	Fibre raw material technology for sustainable production of paper and board	Archival data and interviews	Collective knowledge generation project of KCPK

explain the influence of changes in inputs (such as human resources, functioning of partners or stability of the network) on the learning process by means of a process approach.

Finally, Chapter 8 presents an overall discussion of the results, and conclusions are drawn. Moreover, some policy recommendations will be made.

The outline of this thesis is visualised in Figure 1.2. The central concepts, different levels and the different chapters are pictured. Figure 1.2 also shows the research question(s) (RQ) that is/are studied in the chapters.

Thus, the first two empirical chapters (Chapters 3 and 4) focus on the level of the industry and three environmental domains (Waste water, Waste, Energy). In Chapter 5 we shift to the project level and study the adoption and implementation of CHP installations. This is also the focus in Chapter 6, although then we are specifically interested in the learning structures in these adoption and implementation processes. In the final empirical chapter we study one innovation project and analyse the development of the learning processes. For all five empirical chapters we use longitudinal data. Data were collected in two ways. Desktop research was done to collect archival data and grey literature, and additionally we carried out semi-structured interviews. Table 1.1 shows the theoretical focus, the cases, type of data, and the unit of analysis of the empirical chapters. The methodological aim of this thesis is to study the concept of environmental innovation at different levels and from different perspectives, using a longitudinal approach as much as possible.

2 The Dutch paper and board industry: the empirical focus

2.1 The production process and environmental topics

The basic raw material used for the production of paper and board is pulp. Two main fibrous materials that can be used to produce this pulp are recovered paper and wood (Koninklijke VNP, 2007). If one uses recovered paper, it should be cleaned before one can use the fibres of the recovered paper. The recovered paper is dissolved in water and some chemicals. Non-fibre impurities, such as plastic and staples, are being removed. In some cases fibres are also deinked. This latter process is necessary if paper requires whiteness and purity (Paperonline, 2007b). The process by which ink is removed is flotation. Air is blown into the solution. The ink adheres to air bubbles and these bubbles (including the ink) rise to the surface (VNP, 2003; Paperonline, 2007b).

Wood consists mainly of cellulose and lignin. For high grade paper just the cellulose is used after it is separated from the lignin (wood free paper). For low grade paper this separation step does not take place. Preparing the wood for papermaking is done during the pulping process. One can discern between chemical pulping and mechanical pulping. The two mills in the Netherlands that pulp wood make use of mechanical pulping (VNP, 2003). Mills that use wood but do not pulp themselves, buy large thick sheets of pulp.

The wood fibres are mixed with other materials like dyes, broke and fillers (chalk, clay and starch) in large vessels with rotor bleeds, so-called pulpers, in which they are blended with large quantities of water (Paperonline, 2007a). In this process step, the fibres are separated and they absorb water. Subsequently, the pulp is put in the refiner. By means of cone or plate refiners the pulp will be made finer. Due to beating, bruising and crushing, the pulp will be made smoother. This process influences the paper characteristics (e.g. strength or printability) (Favini, 2007). The pulp is then distributed onto a moving wire, where the fibres link together and form a web (Koninklijke VNP, 2007). During this process water is draining away by means of gravitational forces. In the wet end section drying continues. By means of gravity and suction water is removed. At the end of the wire the paper web contains still 70% water, but can be labelled "paper" (Favini, 2007). The next drying step is the press section, in which the paper is squeezed between a series of presses. At the end of this section the paper still contains 50-55% water. The paper then passes around several extremely hot cylinders that are heated by high pressure steam. The water content is lowered to 5-8% (Paperonline, 2007a). The paper then can undergo some finishing operations, such as calendring (smoothing the surface of the paper) or extra coating. The paper is wound into jumbo reels, which can be slitted to meet requirements of customers (Favini, 2007; Koninklijke VNP, 2007; Paperonline, 2007a).

Several important environmental topics are related to this production process. First, the production of paper and board is energy intensive. The dry section requires most energy. The cost of energy in the total production costs is about 15% (VNP, 2003). So, energy efficiency is very important to lower production costs and stay competitive. Second, a large part of the fibrous raw material input in The Netherlands, namely 74%, is covered by the use of recovered paper. In addition to recovered paper, imported wood pulp is used as fibrous raw material in The Netherlands (22%). This turnkey pulp is imported from Europe (74%), the USA and Canada (16%), and Latin America (10%) (Koninklijke VNP, 2007). The production of the two mills that produce their own pulp, is about 4% of total the fibrous raw material usage. The use of recovered paper has some consequences. Recovered paper contains of 4-5% contamination. This is solid waste, like plastic and metal, which is found in the paper. When separated from the waste paper this is labelled as rejects. Besides, some mills need to de-ink the recovered paper to acquire high paper quality. This results in de-inking sludge, which also needs to be handled. Hence, waste is an important topic in the production of paper and board, especially in the Netherlands due to high recovered paper input. A final and third topic is waste water. As explained in the technical description, the process of paper making inherently requires large amounts of water. Due to strict regulation in the seventies regarding the emission of harmful substances to surface water (WVO = Wet verontreiniging oppervlaktewater) many waste water treatment installations were adopted and implemented within the Dutch paper and board industry. Therefore, waste water and discharges are important topics for this industry. Overall, the Dutch paper and board industry has to cope with three environmental topics, namely energy efficiency, waste, and waste water.

2.2 The industry: some facts and figures

Today, the Dutch paper and board industry consists of 24 paper and board mills. These 24 different paper mills are owned by 17 multinational paper production companies. In 2006 the turnover of the Dutch paper and board industry was almost 2 billion euros by a production of 3.368 kiloton of paper and board products (Koninklijke VNP, 2007). The paper and board industry can be divided into three product groups: graphic papers, packaging and board, and household and sanitary papers. About 70% of the Dutch production is exported, of which 80% within Europe (Koninklijke VNP, 2007).

In the period 1980-2006, the number of paper mills decreased from 38 to 25 and the number of paper machines decreased from 92 to 48. As a consequence the number of employees also decreased, from more then 9000 in 1980 to 5100 full-time equivalent in 2006 (VNP, 1981; Koninklijke VNP, 2007). However, during the same period both sales and turnover have roughly doubled. Figure 2.1 gives a graphical representation of these trends. These trends are made possible by an impressive improvement of the efficiency by which paper and board is produced; more paper is produced and sold with less employees, machines and mills.

Even though these dramatic improvements in efficiency, the industry is under pressure. In 2006 two mills were closed in the Netherlands and last year (2007) a third mill has been shut down. The reason for this is that the paper and board industry has to cope with rising costs of energy and raw materials (Koninklijke VNP, 2007) while the growing global competition is increasing. Large paper and board mills have been built at a high rate in low-wage countries, such as China.

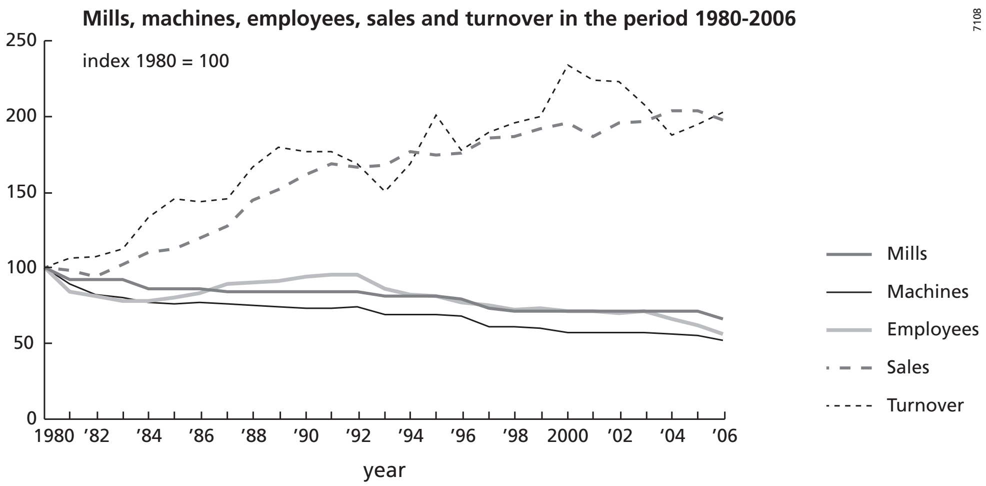

Figure 2.1 The development of mills, machines, employees, sales and turnover for the period 1980-2006 in the Dutch paper and board industry (based on annual reports of the Koninklijke VNP)

The interests of the Dutch paper mills are represented by the Royal Netherlands' Paper and Board Association (de Koninklijke Vereniging van Nederlandse Papier- en Kartonfabrieken, Koninklijke VNP, in Dutch). This industry association was established in 1904 and one of its goals is to have an environmental friendly, innovative and attractive industry (Koninklijke VNP, 2007). All 25 mills are a member of the industry association.

Over time, the Dutch paper and board industry has been supported with regard to knowledge development. In the period 1980-1990 the Research Unit of the Dutch paper industry (RNP in Dutch) has taken care of the knowledge support (VNP, 1981). In 1990 a research unit was integrated in the industry association: the Research, Technology and Environment Group of the VNP (RTM in Dutch). Nowadays knowledge development is supported by the Centre of Competence Paper and Board (KCPK). This is a separate organisation and has been set up at the initiative of the Royal VNP in 1998. The mission of the Centre of Competence Paper and Board is to improve the knowledge infrastructure of the (inter)national paper and board industry. Its long term goal is to create a better competitiveness of the Dutch paper and board industry (Kenniscentrum Papier en Karton, 2007). The KCPK has four main activities: knowledge generation, knowledge collection, knowledge diffusion and knowledge implementation.

Some other players in this field of knowledge development concerning paper and board are the Wageningen University and Research Centre (Wageningen UR) and TNO, which used to have a special department for paper research. Furthermore, in 1987 the industry associations of the Dutch paper and board industry and of the Dutch corrugated board industry have established a special training centre: VAPA. This training centre takes care of education of and training programmes for employees with regard to technological aspects of the production process (VAPA, 2007).

2.3 The Dutch paper and board industry, a perfect object of study?

We have two main reasons why we focus on the Dutch paper and board industry: the empirical richness and challenge and the data availability. As we explained above this industry has to cope with different environmental topics. Moreover, in the past it undertook several activities to reduce the environmental impact on these topics, which makes it interesting and possible to research environmental innovation activities over a longer time period. Furthermore, the industry was confronted with a multitude of policy instruments concerning these three environmental topics. This makes it possible to study the relation environmental policy and environmental innovation. Hence, the environmental problems and activities on the one hand and the governmental policy instruments on the other hand, make it a suitable industry for this thesis.

The second reason is the data availability and the willingness to cooperate. Because the number of mills is relative low a more or less complete picture can be drawn in the different chapters. Furthermore, the Koninklijke VNP and KCPK have very well organised archives, which is required if one studies longer time periods. Last but not least, we experienced a large willingness to cooperate. All these factors make it interesting to focus on this industry.

3 The intermediary role of an industry association in policy-making processes[6]

Based on: Chappin, M. M. H., M. P. Hekkert, M. T. H. Meeus and W. J. V. Vermeulen "The intermediary role of an industry association in policy-making processes: the case of the Dutch paper and board industry." Journal of Cleaner Production In press, Corrected Proof.

3.1 Introduction

Despite attempts to reduce the environmental impact, we are still faced with environmental problems (Elzen et al., 2005). It is recognised that fundamental changes in industrial processes will be necessary for a transition towards a sustainable society (Geels et al., 2004). However, it remains difficult for the government to set the "correct" policy that can bring about these changes. Specific knowledge is required to understand the innovative opportunities; whereas the industry does possess this knowledge, the government often does not (VROM, 2000). It is argued that, in the policy-making process concerning environmental topics, cooperation between government and firms is a means to create more efficient solutions to environmental problems (Marcus et al., 2002). An intermediary organisation can play an important role in this policy-making process. The roles of intermediaries in transition processes towards sustainable development have been discussed earlier (Van Lente et al., 2003). The authors state that an intermediary organisation can function as a broker between various parties. An obvious example of an intermediary organisation in the process of policy development is the industry association. The industry association can bridge the government and individual firms in their formulation (and reaching) of objectives. As a consequence, it is interesting to learn more about the role of the industry association as an intermediary organisation in the process of environmental policy-making.

During the last decades, a shift has occurred in the approach of the Dutch government (Gunningham et al., 1998; Keijzers, 2000; Keijzers, 2002; Vermeulen, 2002; Zito et al., 2003). Vermeulen (2002) distinguishes between three different strategies: 1) central management by means of coercion and incentives, 2) interactive management and internalisation, 3) self-management (Vermeulen, 2002). Where the government used to apply strategy 1, the second strategy was developed in the 1980s. In addition, the third strategy has been used for the last decade. Due to the nature of these different policy strategies (from top-down towards more interactive policy-making), the relationship between government and industry is changing. Moreover, one would also expect to observe a difference in the role of the industry association. However, little is known about the (relative) role of the industry association in these policy processes. Therefore, the question of this research is the following: *What is the role of the industry* *association in the policy-making process, and to what extent is the relative role of the industry association different for various policy instruments?*

The approach in this chapter is to map the activities of the industry association and the government in the development of environmental policy in the period 1980-2003. The Dutch paper and board industry is taken as the object of study since different environmental policy instruments are aimed at this sector and various environmental topics are important for this industry. The interests of the Dutch paper and board industry are represented by the Royal Netherlands' Paper and Board Association (Koninklijke VNP in Dutch). This industry association was willing to participate, thus giving us the opportunity to obtain detailed information about its actions, which was necessary to find answers to our questions. In this research, we focus on three environmental topics, related to the production processes of this industry: waste water, waste, and energy. For each topic, several mixtures of policy instruments were formulated. The development processes of these instruments are analysed in this chapter.

3.2 Theoretical background

3.2.1 Intermediary organisations

An intermediary organisation is defined by Van der Meulen et al (2005) as any organisation that mediates the relationship(s) between two or more social actors. The two (or more) actors are not the same. Therefore, the term mediation implies that some kind of translation of meaning, results, and/or interests of activities or of the actors will be necessary (Van der Meulen et al., 2005). This mediation is an added value to the relationship of the actors, justifying the existence of intermediaries (Doorewaard, 1990).

Intermediary organisations have different roles and functions. Howells (2006) provides a review of studies examining intermediaries and the intermediation process in innovations. An overview of intermediary roles and functions of consultants is provided by Bessant and Howard (Bessant et al., 1995). They focus on the role of consultants as builders of bridges in the innovation process. Consultancy firms can perform different bridging activities, such as articulation and specification of needs, selection of options, training and development, education and communication, localising knowledge (sources), and building knowledge linkages (Bessant et al., 1995).

Based on the roles that intermediary organisations perform, a typology of intermediary organisations is given by Van Lente et al (2003). They distinguish: 1 Knowledge Intensive Business Services, 2 Research and Technology Organisations, 3a Industry Associations, 3b Chambers of Commerce, 3c Innovation Centres, 3d University-liaison Offices. In addition, they distinguish between vertical and horizontal intermediaries (Van Lente et al., 2003). Whereas vertical intermediaries operate between state and private firms, horizontal intermediaries operate between research institutes and private firms. In this chapter, we focus on public policy-making and the role of the industry association in bridging between the government and the industry. Therefore, we are dealing with vertical intermediaries. Industry associations have the following characteristics: they are independent organisations controlled and funded by their members, supporting the entire industry (non-profit) with various services (Van Lente et al., 2003).

The studies mentioned above implicitly assume that the role of intermediary organisations remains the same under different circumstances. We will contribute to this literature by adding the dimension of time; we will identify the role of intermediaries over time. Moreover, we assume that (and test if indeed) the role of the industry association, as intermediary organisation, is different for different types of instruments. Therefore, we will now further discuss the various roles of an industry association in the policy-making process.

3.2.2 Intermediary organisations and environmental policy

In the case of environmental policy, which aims at identifying and controlling environmental problems, differences in interest between firms and government are clear. On the one hand, firms aim at minimal environmental costs. The government's aim, on the other hand, is to reduce environmental problems despite high investments. In the policy-making process, the intermediary organisation can play a role in "bridging" these differences. However, as a consequence of these differences, firms and government have different expectations of the role of the intermediary organisation. Whereas firms expect the intermediary organisation to defend their individual interests, the government expects the intermediary organisation to defend the interests of the group as a whole and it expects it to be willing to make concessions, if necessary (Doorewaard, 1990). Doorewaard (1990) refers to the paradoxical role of the intermediary organisation. In the mediating process between firms and government, the intermediary organisation can perform the following activities (Doorewaard, 1990): collection and distribution of information about problems of the target group and the government; proposition of solutions in the policy process, informing the target group and, finally, the participation of the intermediary organisation may result in additional legitimacy for the policy instrument.

The development of a policy instrument can be described as a process. This process consists of several sub-processes or steps (Neilson, 2001) and its application can be seen as a policy cycle. The following division into steps of the policy cycle will be used in this research: 1. Policy formulation, 2. Decision, 3. Implementation, and 4. Evaluation. See also Figure 3.1. In practice, the different steps of the policy-making process do not need to be strictly divided. Sub-processes can take place at the same time, in a different order, or sub-processes can be skipped. The decision about the instrument, the second step, is defined in this research as the *moment* the instrument becomes valid, whereas the other three steps describe *time periods*. In these periods, stages, or phases, several activities will take place, some of which can be performed by the intermediary organisation.

The Dutch government applied a variety of policy instruments to influence the behaviour of firms (Rothwell, 1992; Skea, 1994; Keijzers, 2000b; Keijzers, 2002; Vermeulen, 2002; Zito et al., 2003). Different classifications of instruments can be found in literature. However, in this

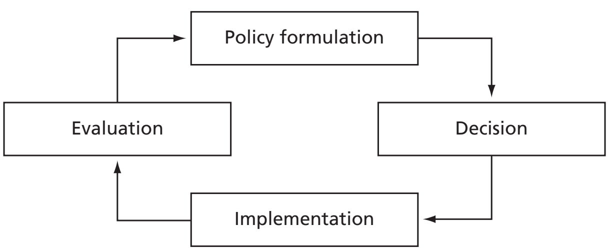

Figure 3.1 The policy-making process

thesis we use the distinction between top-down regulation (command and control), interactive regulation, and positive and negative economics instruments (subsidies and taxes, respectively). Below, the different types of policy instruments and the relative role of an industry association in the policy process are explained in more detail. As little is known in literature about this relation, the description is largely based on our expectations of this relation.

Top-down Regulation

The first category, top-down regulation, is described by Rothwell (1992) (p.449) as "a standard imposed by the government, legally and administratively enforceable, that must be met, or as an absolute threshold of performance that must not be exceeded" (Rothwell, 1992). In general, in the case of top-down regulation, it is to be expected that the role of an industry association will be limited. The role of the industry association is mainly to represent interests and to protect members against excessive regulation (Vermeulen et al., 1995). Therefore, we assume the role of the industry association to be largest in the first phase of the policy process, when the policy is formulated and the industry association tries to minimise the negative effects of the regulation on the industry. The government plays the leading role in the policy-making process. The expected behaviour of the industry association can be characterised as reactive, defending the stakes of the industry.

Interactive Regulation

Target group policy, covenants, or voluntary agreements are examples of interactive regulation. Covenants or voluntary agreements are defined by Glasbergen (1998) (p.694) as "a more or less formal agreement between a governmental organisation and a representative of the private sector with the intent of achieving national environmental policy aims on a voluntary basis". The relationship tends to be more cooperative when interactive regulation is used compared to top-down regulation (Sunnevag, 2000). With this type of regulation, the expected role of the industry association is also to elaborate on the objectives which were set in the negotiations (Vermeulen et al., 1995). In view of the fact that the industry association is involved in this first phase of the policy process, in contrast to reactive behaviour of the industry association in the case of top-down regulation, we assume that the willingness of the industry to make an effort during the implementation and evaluation will also be greater. Therefore, supportive and evaluative activities are expected of the government as well as the industry association. Moreover, in the case of interactive regulation, the industry association is also involved in the second step (the decision). It is a joint agreement.

Economic Instruments

Economic instruments are an attempt to promote allocative efficiency through monetary incentives (Rothwell, 1992). With regard to the economic instruments, one can distinguish instruments that result in a higher cost price, such as levies and taxes, and instruments that result in a lower cost price or investment, such as subsidies (Vermeulen, 1989). To make this distinction obvious, the former group will be called *negative economic instruments* in this research, whereas the latter is called *positive economic instruments*.

If *negative economic instruments* are used, we assume the role of an industry association to be mainly reactive. As mentioned in the description of top-down regulation, the industry association will protect its members against excessive regulation (Vermeulen et al., 1995) and will never

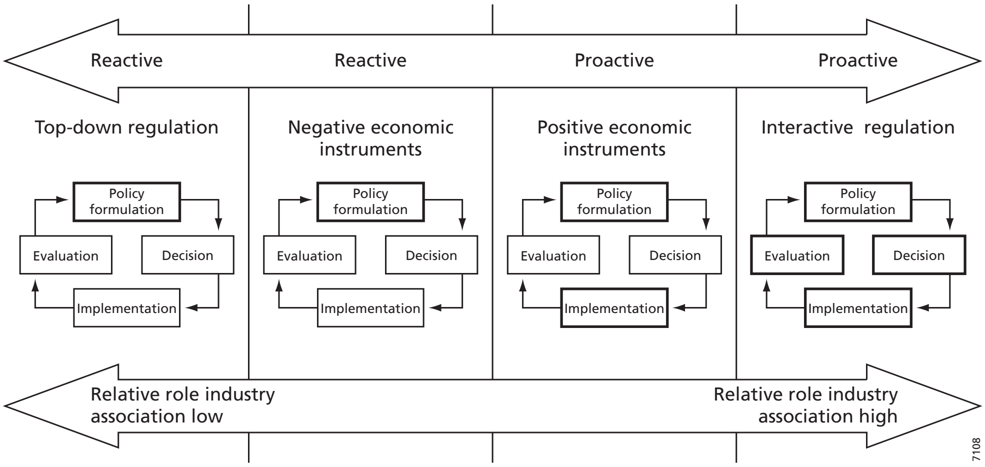

Figure 3.2 Visualisation of hypotheses. The steps of the policy process in which the relative role of the industry association is expected to be largest are highlighted

initiate this type of instrument. In other words, if the economic situation of the industry changes or may change, an industry association will try to reduce the negative economic consequences to a minimum. It is to be expected that an industry association reacts to actions of the government. The possible "negative" effects of negative economic instruments are more visible than the possible effects of top-down regulation. This will provoke a more immediate reaction. Therefore, we expect the relative role of the industry association to be larger than in the case of top-down regulation, yet also to be mainly present in the first step.

With regard to *positive economic instruments*, we expect an industry association to try maximise the benefits of the instruments. Therefore, it is possible that the industry association participates in the policy formulation. Besides, the association can be active during the implementation phase in order to stimulate the industry to make use of it. As a consequence of the instrument's positive aspect, one can imagine that the industry association to be more inclined to be proactively involved than in the case of negative economic instruments, where mainly reactive behaviour is expected (see above).

The above is also visualised in Figure 3.2, in which one can observe that we expect the relative role of the industry association to increase from top-down towards interactive regulation. Moreover, Figure 3.2 shows that we expect the behaviour of the industry association to be reactive for top-down regulation and negative economic instruments, and proactive for positive economic instruments and interactive regulation.

Finally, Figure 3.2 shows for each instrument the steps in which the role of the industry association is expected to be largest.

3.3 Research design

As mentioned in the introduction, the Dutch paper and board industry is object of study. To create insight into the (relative) role of the industry association, several policy areas will be analysed for the Dutch paper and board industry: waste water, waste, and energy. For each area, the development of environmental policy for the paper and board industry will be identified. Aim is create insight into the policy-making process. Therefore, we map events to shed light onto the process. We analyse the time period 1980-2003.

The events are distilled from archival data (see data collection below). For each event, the contribution of the government and the industry organisation are determined, as well as the step of the policy-making process it concerns. The content of these events provides insight into the role played by the industry association. This content of events enables us to determine whether the behaviour of the industry association is proactive or reactive. Proactive behaviour of the industry association is its initiation of activities and its active participation in the policy-making process. This is contrary to reactive behaviour, in which the activities of the industry association are focused on avoiding further regulation; its actions are reactions to the behaviour of the government.

The relative roles of the government and the industry association will be determined by a strict coding of the events (see operationalisation below). To analyse the relative role of government and industry association, the following formulae (1a and 1b) will be used:

(1a) Relative role industry association = RR IA =
$$[(\Sigma \text{ events IA} + ½ * \Sigma \text{ events J})/\Sigma \text{ events}_{\text{total}}] * 100\%$$

(1b) Relative role government = RR G = $[(\Sigma \text{ events G} + ½ * \Sigma \text{ events J})/\Sigma \text{ events}_{\text{total}}] * 100\%$

IA = industry association; G = government; J = joint

The idea of Formulae 1a and 1b is simple and logical: the relative roles of the industry association or the government depend on their contribution to the policy-making process. The joint activities are performed by the industry association as well as the government and are split among these two actors. However, one can also determine the relative roles of the industry association and the government in one step of the policy-making process. This can be determined in the following way:

(2a)
$$\text{RR IA}_{\text{policy formulation}} = [(\Sigma \text{ events IA}_{\text{policy formulation}} + ½ * \Sigma \text{ events J}_{\text{policy formulation}}) / (\Sigma \text{ events}_{\text{policy formulation}})] * 100\%$$

(2b)
$$\text{RR G}_{\text{policy formulation}} = [(\Sigma \text{ events G}_{\text{policy formulation}} + ½ * \Sigma \text{ events J}_{\text{policy formulation}}) / (\Sigma \text{ events}_{\text{policy formulation}})] * 100\%$$

IA = industry association; G = government; J = Joint

Table 3.1 Operationalisation environmental policy process

Category	Indicators
Policy formulation with regard to policy instrument q for topic waste water, waste, or energy Definition: The activities of government and industry with the aim to formulate the policy	Written communication of government, industry, or both Meetings initiated by government, industry, or both
Decision on policy instrument q for topic waste water, waste, or energy Definition: The moment the policy instrument becomes effective	Agreement in the Parliament Signing of policy instrument
Implementation policy instrument q for topic waste water, waste, or energy Definition: The period after the execution until the instrument is replaced or expired	Reports concerning implementation of government, industry, or both White papers concerning implementation of government, industry, or both Meetings concerning implementation of government, industry, or both Monitoring reports government of government, industry, or both
Evaluation policy instrument q for topic waste water, waste, or energy Definition: Insight into the extent to which and/or the manner in which the goals of policy instrument are realised	Evaluation report on the extent of realisation of goals by the government, industry, or both Evaluation report on the manner, of the realisation of goals by government, industry or both

Instrument q refers to top-down regulation, interactive regulation, negative economic instrument, or positive economic instrument

Logically, Formulae 1a and 1b can be calculated for all different types of policy instruments (top-down regulation, interactive regulation, negative economic instruments, positive economic instruments); Formulae 2a and 2b can be calculated for all different steps in the policy-making process (policy formulation, decision, implementation, and evaluation).

3.3.1 Operationalisation

Table 3.1 presents the operationalisation we used. All events are coded with the nominal categories 0-1, for it is quite difficult to weigh events (Poole et al., 2000). In this study, each event that validly represents a concept, is counted as 1.

3.3.2 Data collection

For the data collection we used documentation of the Royal Netherlands' Paper and Board Association (Koninklijke VNP)[7] and the Centre of Competence Paper and Board Industry (KCPK). The focus merely on the data of the paper and board industry should not be a problem, since we are interested in the role of the association and we are looking at the *relative* role of this industry association for different types of instruments.

3.4 Results

Before we show and discuss the results of the (relative) role of the industry association in the policy-making processes, we will provide a short overview of the policy development for the different environmental topics in the period 1980-2004.

Figure 3.3 shows which policy instruments were implemented by the Dutch government over time per topic. It becomes clear that this a genuine mixture of policy instruments. However, per topic some instruments are more dominant than others. With regard to waste water, levies (negative economic instrument) for dischargers are important, whereas in the case of waste, the top-down regulation (limitation landfill) is dominant. In the case of energy, interactive regulation is important (Long Term Agreements, Convenant Benchmarking).

3.4.1 Top-down Regulation

Top-down regulation has been observed for all three topics. The activities and the observed behaviour will briefly be discussed below. Appendix 3-I provides detailed information on these activities.

Waste water: Top-down Regulation

In 1991, communication took place between government and industry association about the discharge of nitrogen and phosphorus. More specifically, the industry association responded to the government. More implementation activities took place between 1995 and 1997, when small adaptations of the licenses were being discussed. In addition, the government conducted an evaluation study in 1997, in which the bottlenecks were identified with regard to the WVO license procedure (De Bruin et al., 1997).

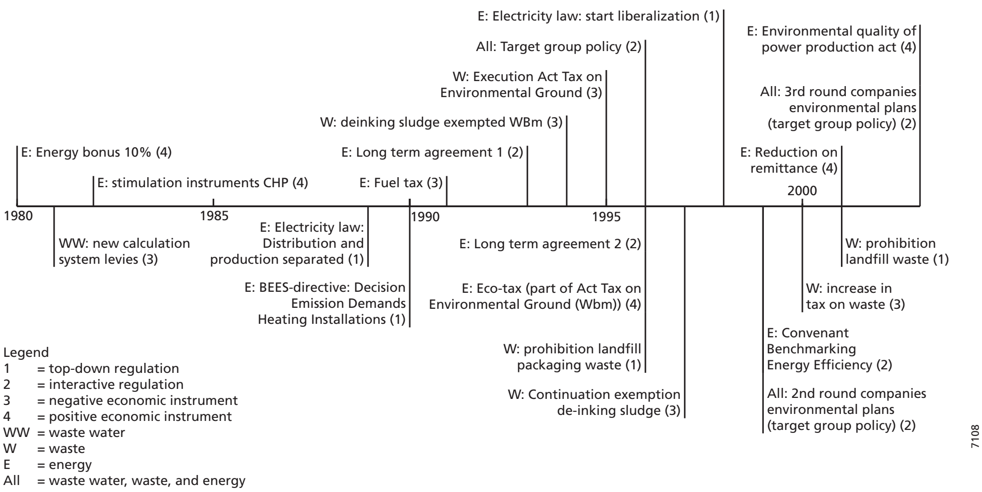

Figure 3.3 An overview of the policy instruments in the period 1980-2003

Waste: Top-down Regulation

For the topic of waste, two important instruments were the limitation of waste landfill in 1996 (VROM, 1996) and, eventually, the prohibition to landfill waste in 2001 (VNP, 1998). The relative role of the industry association was small, only two events were observed. As a consequence of a limitation of the possibilities to landfill in 1983, the rejects in the recovered paper became a problem. This was mentioned by the board association (VNP, 1983), which can be identified as reactive behaviour.

In addition to the decisions of the government concerning instruments (second phase of the policy cycle), two governmental events were observed. A report was written on the collection, prevention, and reuse of waste in 1989. The second event was the proposition of the Waste Consultation Organ to have an accelerated introduction of the prohibition to landfill and to close the boarders with regard to waste, in order to prevent an overcapacity of waste incineration installations.

Energy: Top-down Regulation

Top-down regulation was used for the topic of energy as well. In 1989, the Electricity Law was executed and in 1998 this act was renewed. Among other things, this act dealt with electricity rates and permits. In addition, some directives were executed. In 1990, the Bees-directive (Decision Emission Demands Heating Installations = Besluit emissie-eisen stookinstallaties) came into force. The decisions about these instruments were attributed to the government. All other events we observed were initiated by the government as well. Before the introduction of the new Electricity Law in 1998, the government made a new design in 1996. Furthermore, in 1994, 1995, 1999, and 2000 the government published several reports with information about energy permits. Thus, we observed no actions whatsoever by the industry association.

Overall top-down regulation

Based on the above, we can conclude that most of the observed behaviour of the industry association with regard to top-down regulation was focused on limiting excessive regulation. In that sense, it was reactive, which is in line with our expectations.

3.4.2 Interactive Regulation

One interactive instrument, the Target Group Policy, is important for all three topics (waste water, waste, and energy). This instrument will be discussed first. However, for the topic of energy, more interactive regulation has been observed. Those results will be presented after the discussion of the Target Group Policy. Appendix 3-I provides more detailed information on activities in the policy-making processes.

All topics: Target Group Policy

In the current Dutch environmental policy, an important interactive instrument is the Target Group Policy. The Dutch paper and board industry was and still is one of the target groups of this policy. In 1993, the Dutch paper and board industry and the government started the Target Group Negotiations (VNP, 1993). The government as well as the industry association performed several activities in the policy formulation. The government published four reports and organised several meetings to provide the industry association(s) with information concerning the Target Group Policy. Some of these events preceded negotiations of the government and the Dutch paper and board industry. The industry association was mainly active by means of preparing the negotiation and informing its members.

These negotiations, the policy formulation phase, eventually led to the signing of the integral environmental target plan (IETP) by the industry and government in 1996. In this integral environmental target plan, targets were specified with regard to reducing air, water, and soil pollution, saving energy, cleaning up contaminated soil, and so forth (Glasbergen, 1998). Firms were supposed to develop a Company Environmental Plan (CEP). In this plan, the firm sets its own priorities. The CEPs need to be approved by an authority. The idea is that the sum of the individual contributions meets the objective for the sector. Every four years the CEPs need to be revised. The second round of CEPs started in 1999 (VNP, 1999) and the third round in 2003 (VNP, 2003b). With the start of the first round of CEPs, a meeting was organised with the government. Firms were supposed to report annually about their results. With regard to the implementation phase, the industry association was given a key role in specifying technical requirements and monitoring results. The implementation of the target group policy was also supported by the FO-industry, an independent organisation financed by the Dutch government (FO-industrie, 2005). In 1996, the industry association asked for the integration of the environmental reporting and in 1997, the government developed a standard design for the annual progress report (VNP, 1997). Finally, the industry association organised several meetings in order to support the implementation. Summarised, we observe a proactive role of the industry association.

Energy: Interactive Regulation
In 1993, the VNP and the Ministry of Economic Affairs signed a long term agreement (LTA) (VNP, 1993). Objective was to increase the energy efficiency with 14% in the period 1989-1995 (Koopman et al., 2004). However, by 1991 they had already signed an intention statement to investigate the possibilities of energy saving. During the implementation of the Long Term Agreement, both the government (in 1995) and the industry (in 1994 and 1995) reported on the progress. The government also conducted several evaluations (1994 and 1995). Meanwhile, the industry association and the government were investigating the possibilities of a second Long Term Agreement. They organised meetings and the industry association conducted a survey among its members about the "new" LTA. As a consequence of the first LTA's positive results, a second LTA was signed in 1996. Objective was to realise an improvement of 20% in energy efficiency in 2000 compared to 1989 (Koopman et al., 2004). In 2000, an improvement of 22.9% was realised (VNP, 2003; Koopman et al., 2004). Also during this second LTA, progress reports were written by both the government (1996-2001) and the industry association (1996-2000). Moreover, an evaluation study was commissioned by the government.

A final instrument was the Convenant Benchmarking Energy Efficiency. In 1999, the Dutch paper and board industry decided to take part in this covenant (VNP, 1999): an agreement between the Dutch government and the energy intensive industry. Aim is to be part of the world top with regard to energy efficiency in 2012, implying that a firm should belong to the world's best 10% (VNP, 2003). Before signing the Convenant Benchmarking, the government and industry had several meetings in 1998 (VNP et al., 1998a). During the implementation of this covenant, the industry provided information about the approach and the government reported (2000 and 2002) on the progress. In 2003, the government made an evaluation of the first round of the Convenant Benchmarking (VNP, 2003b). Thus, in this case too we observe a proactive role of the industry association.

Overall interactive regulation
Based on the results discussed above, we can conclude that the observed behaviour of the industry association was proactive in the case of interactive regulation. The industry association was actively involved in the policy formulation as well as in supporting the industry during the implementation phase. The industry association did not only react to governmental activities, it actually initiated activities as well. Also for this type of instrument, our expectations are met.

3.4.3 Negative Economic Instruments

Negative economic instruments are also observed for all three topics. These results will now be discussed. Appendix 3-I provides more detailed information on activities in the policy-making processes.

Waste Water: Negative Economic Instruments
Levies have been important for the topic of waste water. In 1980, modifications on the levy system were proposed by the government and in 1981, a new system was introduced. The industry association objected against these changes, but in 1983, the government decided to continue the levy. Once again, in 1985, new changes were proposed by the government to which the VNP reacted by sending a letter to the government. Finally, in 1994, an evaluation study was carried out by the government to get insight into the competitive position of the Dutch paper and board industry with regard to the WVO and the corresponding levies (Board RTM, 1994).

Waste: Negative Economic Instruments
In 1995, the Act Tax on Environmental Ground (Wbm) was executed (Ministerie van Financien, 1997). Already during the policy formulation, the industry gave clear arguments to counter the implementation of this instrument. As a result, the de-inking sludge was exempted from the Wbm for the period 1994-1997. At the end of this period, the industry asked for another period including a coarse rejects exemption. After an evaluation by the government in 1996, the exemption with regard to de-inking sludge was continued in 1997, yet coarse rejects were not tax exempted (Ministerie van Financien, 1997). In 2000, the tax on waste increased.

Energy: Negative Economic Instruments
Two important taxes (negative economic instruments) are the eco-tax and the fuel tax. The eco-tax was executed in 1996 and is part of the Act Tax on Environmental Ground (Wmb) (RIVM et al., 2005). The fuel tax has been raised since 1991 and is part of the Wmb since its execution in 1995 (RIVM et al., 2005). Firms with their own combined heat power-installations (CHP-installations) are exempted from the fuel tax in certain cases. In 2002, the VNP asked the government to exempt also the smaller CHPs from the fuel tax. Firms are now exempted from the eco-tax, as they participate in the Convenant Benchmarking. In 1997, when the second LTA was effective, the VNP objected against the eco-tax, because of the exertions of the industry by means of the LTA. However, at that time, the industry was not exempted from the eco-tax. Although some indirect grants were made possible by the government, it was not sufficient according to the industry.

Overall negative economic instruments

For each of the topics (waste water, waste, and energy) the industry association reacts to the government and tries to avoid regulation. Therefore, we can label the behaviour of the industry association as reactive with regard to the policy-making process of negative economic instruments. This is in line with our expectations as set out in the theoretical framework.

3.4.4 Positive Economic Instruments

Positive economic instruments were only observed for the topic of energy. However, we focus on a subset of positive economic instruments. Some positive economic instruments stimulate research projects, but these instruments are not taken into account in this research due to limitations of data. Therefore, the number of observed events is small. The results will now be discussed. Appendix 3-I provides more detailed information on activities in the policy-making processes.

Energy: Positive Economic Instruments

In 1980, an energy bonus of 10% was introduced and in 1982, several other stimulation instruments were introduced by the government; the energy bonus was increased, and investment credits were introduced. Finally, an arrangement for large-scale consumers was implemented. As a consequence of this regulation, self-generators received a reduction on the electricity tariffs. This latter instrument was also evaluated in 1982. The VNP was content with this instrument and asked for an extension in 1982.

More activities were observed in 1994. At that time, there was some communication about possible cut backs in the availability of means for the stimulation of energy savings. Finally, two other positive economic instruments were introduced. In 2001, a regulation on the reduction on remittance was executed (VNP, 2003). In 2003, the environmental quality of Power Production Act (MEP) came into force (VNP, 2002), providing for the valuation of electricity produced by CHP plants (VNP, 2002).

Overall, the behaviour of the industry association was proactive (asking for an extension) as well as reactive (avoiding cut backs). The small number of events makes it difficult to draw unambiguous conclusions concerning the type of behaviour (reactive versus proactive), but it can be best typified as proactive.

3.4.5 Relative role

Figure 3.4 shows how the various events (n = is the number of observed events) are distributed among government and industry association, for each type of instrument and for the different steps in the policy-making process.

We start discussing the relative role of the industry association in the different steps in the policy-making processes for the different types of instruments. With regard to top-down regulation, we observe a small relative role of the industry association. Moreover, the industry association only participated in the implementation phase. This latter observation was not according to our expectations, as we expected the industry association to react in the policy formulation phase. It is possible that industry interacts and consults with government on an informal basis and that the response from industry surveys and written government communications do not reveal the true nature of the interaction.

With regard to interactive regulation, we observe proactive participation of the industry association in different phases of the policy-making process. Only in the evaluation phase we did not observe any events in our time-period. Thus, our expectations concerning interactive regulation are largely confirmed by the results.

With regard to negative economic instruments, the industry association's participation is largest in the policy formulation phase. This is according to our expectations. However, it needs to be mentioned that the relative role also turned out to be large in the implementation phase.

Finally, with regards to positive economic instruments, we see a proactive industry association in the policy formulation and implementation phase. This is indeed as we expected. However, it needs to be noted that the number of observed events is small for this type of instrument. Only 12 events were observed. Therefore, these results are slightly limited and generalisation should be done with care.

We argued that the overall relative role of the industry association in the policy process is different for different types of policy instruments. We expected the relative role of the industry

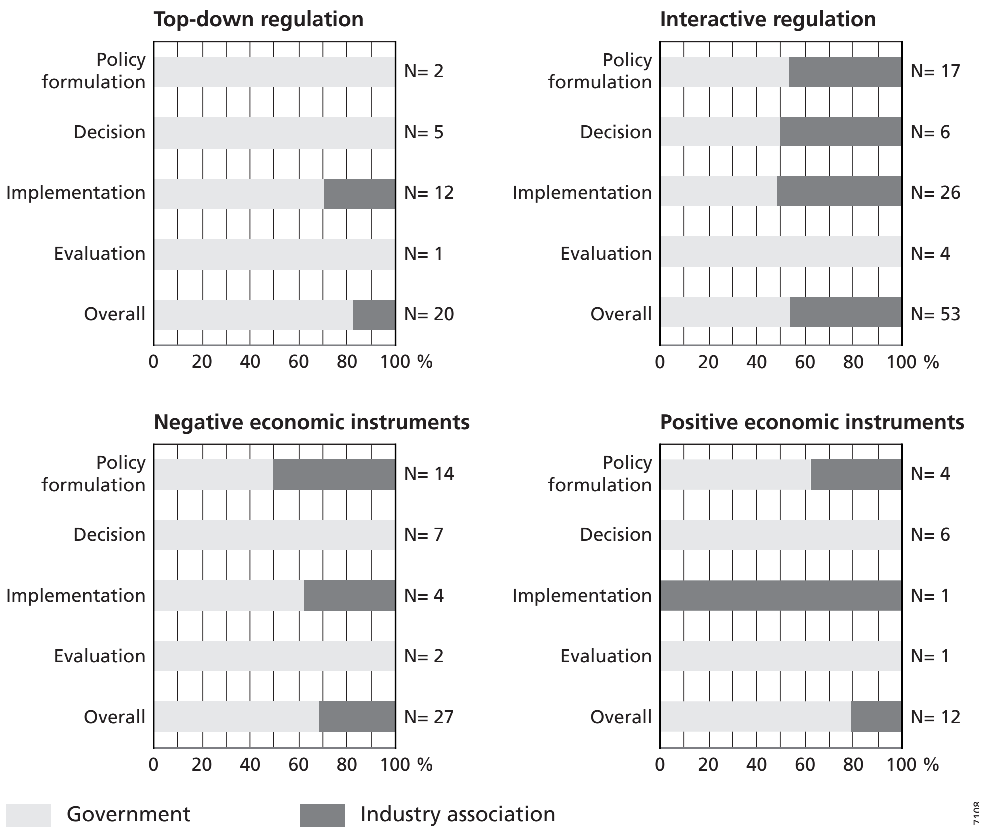

Figure 3.4 Relative roles of government and industry association in the policy process of different types of policy instruments

association to be the following (from smallest to largest relative role): top-down regulation, negative economic instruments, positive economic instruments, and interactive regulation. However, we observed the following distribution (from smallest to largest relative role): top-down regulation, positive economic instruments, negative economic instruments, and interactive regulation. It appears that the relative role of the industry association is smallest in the policy-making process of top-down regulation and largest in the interactive regulation policy-making process, as we expected. However, the relative roles for economic instruments are somewhat different from what we expected. According to our results, the relative role of the industry association is larger in the policy-making process of negative economic instruments, compared to positive economic instruments. However, we expected it to be the other way around. We already mentioned that the number of events for positive economic instruments is small and that, therefore, these results should be handled with care. It is hard to draw conclusions for this instrument on the basis of such few events. We can conclude that the results are in line with our expectations with regard to top-down regulation, negative economic instruments, and interactive regulation.

3.5 Discussion and conclusion

Objective of this study was to get insight into the relative role of an industry association in the policy-making processes of different policy instruments. Three topics of the Dutch paper and board industry have been analysed: waste water, waste, and energy efficiency. Before we turn to the conclusions, several remarks need to be made. First, only one (well organised) industry has been analysed. As a consequence, it is not possible to simply generalise these results for all industries. However, it still provides valuable insights into the work of an industry association. Second, with regard to the documents that were used, it needs to be stated that some documents were not available. However, as different types of documents described the same events, this drawback was reduced to a minimum. Third, we focused our data collection on the documentation of the industry association itself. Since we were interested in the role of this association and as we were looking at the relative role of the industry association for different types of instruments, this could possibly bias the outcome since government may have a different, and possibly more correct perspective on the role of the intermediary organisation, especially in the policy formulation phase where undocumented, informal contacts were not recorded or reported. Finally, with regard to positive economic instruments, it was not possible to take into account subsidies with a specific focus on research projects, due to data limitations. This resulted in a small number of events that were observed for this type of instrument. As a consequence, the results for positive economic instruments are sensitive to change and should be handled with care.

Despite these limitations, the results offer interesting insights into the (relative) role of an industry association in policy-making processes for different policy instruments. It becomes clearly visible that the industry association plays a different role when different instruments are used. In that sense, this study contributes to the existing literature in which the roles of intermediary organisations are assumed to be quite static. Our study provides a more robust description of the roles of the intermediary organisation.

We expected the relative role of the industry association to increase from top-down towards interactive regulation. Moreover, we expected the steps in which the role of the industry association is largest to vary for the different instruments. Finally, the behaviour of the industry association was expected to be reactive for top-down regulation and negative economic instruments, and proactive for positive economic instruments and interactive regulation. Figure 3.5 shows our expectations in more detail (A) as well as our observations (B). Our conclusions will be now be discussed per type of instrument.

In the case of *top-down regulation,* the role of the industry association is reactive and largest during the implementation. Yet, we expected the relative role to be largest in the policy formulation step. An explanation for this difference might be that the industry association did

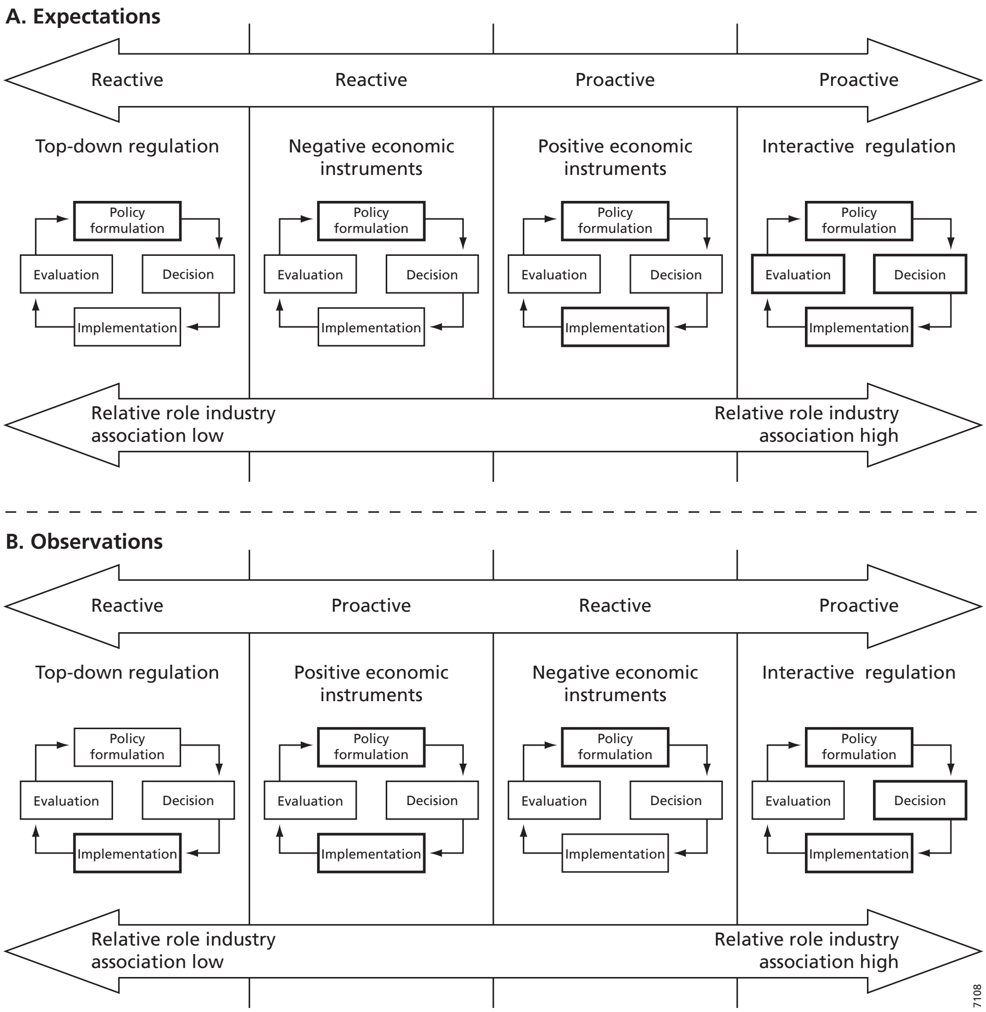

Figure 3.5 Expectations versus observations

not timely realise what the consequences of new regulations implied, or perhaps they were simply not aware of the existence of new regulations. We do not know if this is indeed the case, yet we consider it a possibility. Finally, the relative role is smaller compared to the other types of instruments.

In the case of *interactive regulation,* the role of the industry association is proactive and large in all steps, with the exception of the evaluation step. Evaluation activities of the industry association were not observed. However, we do know that in 2004, the industry association published a report in which the results of the eight years of Target Group Policy were presented. However, due to the fact that the time period we observed was 1980-2003, this event was not taken into account. Finally, the relative role is larger compared to the other types of instruments.

In the case of *negative economic instruments,* the role of the industry association is reactive and largest in the policy formulation step. Finally, the relative role is larger compared to top-down regulation but smaller compared to interactive regulation.

The case of *positive economic instruments* appears to differ somewhat from our expectations. As mentioned before, the small number of observed events causes some difficulties in the interpretation of these results. However, the industry association is active in the policy formulation phase as well as in the implementation phase, just as we expected (NB: here too, the number of observed events is small). Finally, the relative role is smaller than we expected. It was smaller compared to negative economic instruments. Concerning this type of instrument, it would be better for future research to focus on the entire set of positive economic instruments and not merely a subset, as we did in this research. If this is not possible, we propose it is preferable not to take this type of instrument into account.

On the basis of our results, we can conclude that there are clear differences in the role of the industry association for different types of instruments. However, we do not know if these differences also result in a change of policy effectiveness. Therefore, for future research it would be interesting to see if policy instruments in which the relative role of the industry association is larger and/or proactive, are more effective. Another challenge for future research is to focus on differences between events. In this research, we counted the events and treated them all equally. However, it is possible that some events are more important than others. It would be interesting to develop a measure for the "intensity of events". Our approach (a long time period and a retrospective analysis), made this impossible. However, a real time analysis might enable this. In other words, there are still challenges left for future research.

4 Dynamic perspective on the relation between environmental policy and eco-efficiency[8]

Based on: Chappin, M. M. H., M. T. H. Meeus, M. P. Hekkert, W.J.V. Vermeulen (2007). "Dynamic perspective on the relation between environmental policy and eco-efficiency: The case of waste water treatment, waste and energy efficiency in the Dutch paper and board industry." Progress in Industrial Ecology – An international Journal 4(1/2): 19-40.

4.1 Introduction

The effect of environmental policy on industry is heavily debated in literature. Some articles argue that regulations adds to the firm's costs (Rothwell et al., 1981; Rothwell, 1992; Braun et al., 1994; Hitchens et al., 1998; Marcus et al., 2002). This results in a reduction of money available for innovation in general. They also argue that environmental regulations limits the options for environmental innovation: environmental regulation is said to reduce the time to find an optimal solution (Rothwell et al., 1981; Rothwell, 1992), to decrease the freedom to innovate and to increase the bureaucracy (Braun et al., 1994). Finally, it is argued that managers of firms are uncertain about the regulation (Marcus, 1981; Rothwell, 1992; Meijer et al., 2007) and the behaviour of the regulators (Marcus, 1981; Rothwell et al., 1981; Gunningham et al., 1998; Meijer et al., 2007). As a consequence of these aspects managers develop risk-avoiding behaviour, resulting in less environmental innovation. Other authors argue the opposite. They state that environmental regulation saves money since environmental innovations can reduce the variable or fixed costs, when for instance the input of raw material in the production process is reduced (Wiener, 2004). Furthermore, they argue that environmental regulation can create the necessary market, because it can provide directions for technical change and product attributes (Ashford, 2002) and may open market niches, creates demands and opportunities (Braun et al., 1994). They add that a threat from outside is necessary to get attention to a problem. Without such a threat, like environmental regulation, the behaviour will not be changed (Van de Ven, 1986; Van de Ven et al., 1992; Van de Ven et al., 1999) and environmental innovation will not take place in the absence of environmental regulation.

These conflicting views may partly be explained by the fact that these studies discuss different types of policy instruments. Remarkable is that they often discuss only the effects of one type of instrument. Policy evaluation studies often focus on one policy instrument, although they often acknowledge the fact that different policy measures are present at one time (Vermeulen, 1988; Schuddeboom, 1990; Vermeulen, 1992). There is a so-called accumulation of measures over time. Therefore, the focus on just one measure results in simplified evaluation studies. We haven't found studies that focus on the effect of accumulation of policy measures.

It is acknowledged that the environmental problems, especially global environmental problems, are still serious and that innovation is necessary to reach sustainability (Elzen et al., 2005). With regard to sustainable development eco-efficiency became an important topic at the end of the nineties (Hoffrén, 2000). Eco-efficiency is defined by the WBSDC (world Business Council for Sustainable Development) in the following way: "Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity" ((Verfaillie et al., 2000) p.7). The aim of future policy is to stimulate eco-efficiency. Therefore, this chapter is an attempt to gain insight into the way the accumulation of policy measures affects the innovative activities and affects the eco-efficiency of an industry. In the innovation process, research activities are considered as very important (Rogers, 2003). In this chapter we focus on research activities as being part of the innovation process. We are interested in the following question:

To what extent does the accumulation of policy measures result in an increase in research activities and in an increase in eco-efficiency?

Table 4.1 The accumulation of policy measures with regard to waste water, waste and energy in the Dutch paper and board industry in the period 1980-2003

Year	Measure	Environmental topics
1981	New calculation system levies	Waste water
1982	Reduction electricity prices for self-generators	Energy
1989	Electricity Law	Energy
1990	Bees-directive: Decision Emission Demands Heating Installations	Energy
1991	Declaration of intent	Energy
1991	Fuel tax	Energy
1993	Long term agreement 1 (LTA)	Energy
1994	De-inking sludge exempted from Wbm	Waste
1995	Act Tax on Environmental Ground (Wbm)	Waste
1996	Prohibition to landfill packaging waste	Waste
1996	Long term agreement 2 (S) (LTA)	Energy
1996	Integral environmental target plan (IETP)	Waste water, waste and energy
1996	Eco-tax (part of Act Tax on Environmental Ground (Wbm))	Energy
1997	Continuation exemption de-inking sludge (s)	Waste
1998	Electricity Law (S)	Energy
1999	Covenant Benchmarking Energy Efficiency (S)	Energy
1999	2nd round Company Environmental Plan (CEP) (S)	Waste water, waste and energy
2000	Reduction on the remittance	Energy
2000	Increase in tax on waste (s)	Waste
2001	Prohibition to landfill waste (s)	Waste
2003	Environmental quality of power production act (MEP)	Energy
2003	3rd round Company Environmental Plan (CEP) (S)	Waste water, waste and energy

(S) = substitute: the measure substitutes another measure. This other measure expires.

The Dutch paper and board industry is an interesting example at which different environmental policy instruments are aimed and where different environmental topics are important. In this chapter we focus on the three environmental topics, waste water, waste, and energy. For each topic the government implemented several policy measures. These are given in Table 4.1. This table is a clear example of the concept of accumulation of policy measures. In Appendix 4-I and Chapter 3 more information about the content of these measures can be found.

The remainder of the chapter is divided into four sections. Section 4.2 describes the theoretical background. Then the research design is elaborated in Section 4.3. We then describe our results. Finally, the discussion and conclusion are given in Section 4.5.

4.2 Theoretical background

Governmental policy is in the literature described as a process (c.f.(Winsemius, 1989; Vermeulen, 2000)) For this research we use the work of Vermeulen (2000), in which he proposes a model of policy making, as a starting point. His model consists of several steps starting with the "formulation of primary policy" and it ends with the "realisation of final policy goals". In between evaluation and monitoring activities are assumed to take place. We extent the model and assume the following process to occur. The environmental impact of a particular industry is recognised as being problematic and policy is formulated with the aim to stimulate the industry to increase its eco-efficiency. As a consequence, the government implements policy instruments. The government can and, at least in The Netherlands, does make use of different policy instruments to influence the behaviour of firms (Rothwell, 1992; Skea, 1994; Zito et al., 2003). In this research we focus on three groups of measures: top-down regulation, interactive regulation and economic instruments. Permits, standards and laws are examples of top-down regulation. With regard to interactive regulation, instruments like covenants and long-term agreements are being used. Within the group of economic instruments one can distinguish measures that result in higher costs for the firms exposed to the regulation, such as levies and taxes, and measures that result in a decrease of costs, such as subsidies (Vermeulen, 1989). The former subgroup will be referred to as negative economic instruments in this research, whereas the latter is referred to as positive economic instruments.

After the implementation of the policy instruments, reactions of the target group, an industry, are expected (Vermeulen, 2000). When an industry is confronted with policy instruments that aim at improving its level of eco-efficiency, industry practices need to be changed in order to comply with governmental aims. In many cases industry associations perform a coordinating and mediating role in this process (Van Lente et al., 2003). If the existing knowledge is not sufficient, new knowledge needs to be developed to change existing industry practices. Therefore, research projects are expected to take place in the period after the policy instruments are introduced. This research can be conducted by the firms. In addition, it is also possible that industry associations set up collective research projects. This latter type of research can be used to raise awareness in the industry of new technologies and processes that can be used to increase eco-efficiency (Vermeulen et al., 1995). The knowledge generation by means of (collective) research projects should eventually result in generation and/or adoption of innovations by the firms, which they then need to implement.

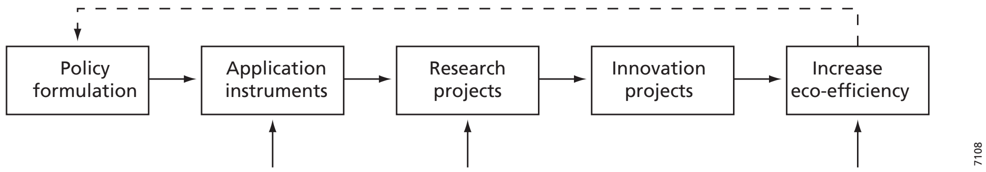

Figure 4.1 Policy-effect cycle (Vermeulen, 2000)

The final step is that these innovation projects of the firms result in an increased eco-efficiency of the industry. As stated in the introduction, eco-efficiency link economy and the environment (Hoffrén, 2000; Fet, 2003); achieving greater value with lower adverse environmental consequences (Verfaillie et al., 2000). The above is visualised in Figure 4.1. In this study we focus on the following aspects: the application of instruments; research projects; eco-efficiency (see the vertical arrows in Figure 4.1).

In short, the process with regard to these three concepts is the following: Measure x is applied at T_0. If the existing knowledge is sufficient, the research activities remain constant and the eco-efficiency will increase at T1. If the existing knowledge is not sufficient, then the intensity of the research activities increases at T_1 and at T_2 the increase in eco-efficiency becomes visible.

This is the hypothesis when we assume that only one policy measure is applied. However, as we have already stated in the introduction, an industry is not exposed to one policy measure. Over time many policy measures are applied and these accumulate. In this chapter this phenomenon is called policy pressure. We will now define a new set of hypotheses that incorporates this policy pressure. In line with the reasoning with regard to the existence of one policy measure at the same time, firms have two options if policy pressure increases. First, they may have valid solutions that need no additional research activities. In that case eco-efficiency should improve in due course. Second, in the case of additional resource activities, the eco-efficiency improvement will clearly be time lagged. Since many research programmes have long durations, the effect on eco-efficiency is expected to appear many years later. In the short term, the eco-efficiency of the industry is expected to remain constant. This results in hypotheses 1a and 1b:

H1a: If the policy pressure increases and the policy goals do not call for new knowledge, then the research activities are not likely to increase and the eco-efficiency is likely to increase

H1b: If the policy pressure increases and the policy goals call for new knowledge, then the research activities are likely to increase and the increase in eco-efficiency is likely to be time-lagged

But reality may even be more complex. If the policy pressure grows this may lead to competition between policy instruments. Firms must decide how to prioritise eco-efficiency goals and how to divide available time and budget. Furthermore, a decreasing motivation of firms to comply with policy measures is expected when these firms are confronted with too many initiatives. This may result in a smoothed and delayed increase in research activities (if existing knowledge is not sufficient) and eco-efficiency. This results in hypothesis 2a and 2b:

H2a: If the policy pressure increases and new knowledge is not necessary, the likelihood increases that the research activities will remain constant and that the improvement of eco-efficiency is smoothed and delayed, due to the fact that companies need to prioritise eco-efficiency goals

H2b: If the policy pressure increases and new knowledge is necessary, the likelihood increases that the increase in research activities and the improvement of eco-efficiency will be smoothed and delayed, due to the fact that companies need to prioritise eco-efficiency goals

4.3 Research design

To study the effect of policy measures on research activities and eco-efficiency, we will study their effects for the three environmental topics as stated in the introduction: energy, waste water and waste. For each domain several trends will be identified. The aim is to identify all trends for the period 1980-2003. The trends are:

1. The implementation of governmental environmental policy measures directed at the paper and board industry with regard to energy, waste water, and waste (see Table 4.1 in the introduction).
2. The development of collective research activities with regard to energy, waste water, and waste[9].
3. The development of the eco-efficiency of the industry over time.

In Tables 4.2 and 4.3 the operationalisation with regard to the collective research projects and the eco-efficiency is presented. In the first column the main categories are given. The second column contains the different classes that belong to a main category. In the third column the indicators are given.

To compose trends of eco-efficiency the figures of discharges, disposal and energy use are divided by sales[10]. This is the opposite of how it is often measured. Normally, eco-efficiency is measured by means of the product or service value per environmental influence (Hoffrén, 2000; Verfaillie et al., 2000; Fet, 2003). However, we decided to measure it in this way, because this is more in line with the type of objectives of the existing policy measures, which are evaluated in this chapter. Moreover, it does not have any consequences for the reliability of the results.

Table 4.2 Operationalisation research activities

Category	Classes	Indicators
Knowledge generation and collection for waste water, waste and energy	Collective R&D project	Start R&D project
	Collective Pilot project	Start pilot project
	Collective Desktop/literature research project	Start desktop/literature research project

Table 4.3 Operationalisation eco-efficiency

Category	Classes	Indicators
Eco-efficiency: The presence, the emission or discharge of substances divided by sales for waste water, waste and energy	Waste water	Discharge Zinc per sales
		Discharge Copper per sales
		Discharge Nitrogen per sales
		Discharge Phosphorus per sales
	Waste	Landfill Coarse rejects per sales
		Landfill Waste water treatment sludge per sales
		Landfill De-inking sludge per sales
		Landfill Paper rejects per sales
	Energy	Primary energy use per sales

The only consequence is that the reader should be aware that if in this thesis the eco-efficiency increases we would observe decreasing trend! We will remind the reader of this fact when it is first discussed in the results.

To determine if the research activities increase as a consequence of an increase in policy pressure, the number of new projects that started in a specific year is measured. The following equation is used:

(1) Δ Research activities year t_{0+1} = number of new projects started in year t_{0+1} – number of new projects started in year t_0

To determine if eco-efficiency changes as a consequence of an increase in policy pressure, the change in environmental indicators divided by the industry's sales is measured. The following equation is used:

(2) Δ Eco-efficiency year t_{0+1} = (environmental indicator x year t_{0+1}/sales year t_{0+1} – environmental indicator x year t_0/sales year t_0)/(environmental indicator x year t_0/sales year t_0)

The conduct the research the following documents are analysed:

- the annual reports of the Royal Netherlands' Paper and Board Association (Koninklijke VNP)[11]
- minutes of the Research Unit of the Dutch Paper Industry[12]
- minutes of the Research, Technology and Environmental Group of the VNP[13]
- minutes of the Centre of Competence Paper and Board Industry
- some yearly overviews of the Research Unit of the Dutch Paper Industry[14]
- project plans of the Centre of Competence Paper and Board
- monitoring reports of the FO-industry; the organisation that supports the implementation of a specific policy measure, namely the Target Group Policy (see Appendix 4-I for more information)
- PhD thesis of Bram Bouwens; this thesis describes the development of the Dutch paper and board industry (Bouwens, 2004)
- the documentation centre of the Royal Netherlands' Paper and Board Association was searched for the following key words: energie (=energy), water (= water), milieu (=environment), afval (=waste), emissies (=emissions), efficiency (=efficiency).

4.4 Results

In this section the results of the research will be presented. First, the results for the three domains (waste water, waste, and energy) are presented and discussed. Then the overall results are given.

4.4.1 Waste water

Figure 4.2 shows the number of cumulative research projects in the period 1980-2004. More specifically, the figure shows by means of a cumulative number how many collective projects (R&D projects, pilot projects or desktop research projects) are started each year. A marginal increase in area indicates that new projects were started in that specific year. In addition Figure 4.2 shows in which years different policy measures were introduced. With regard to policy measures, different types of instruments are distinguished and it is indicated if a policy measure

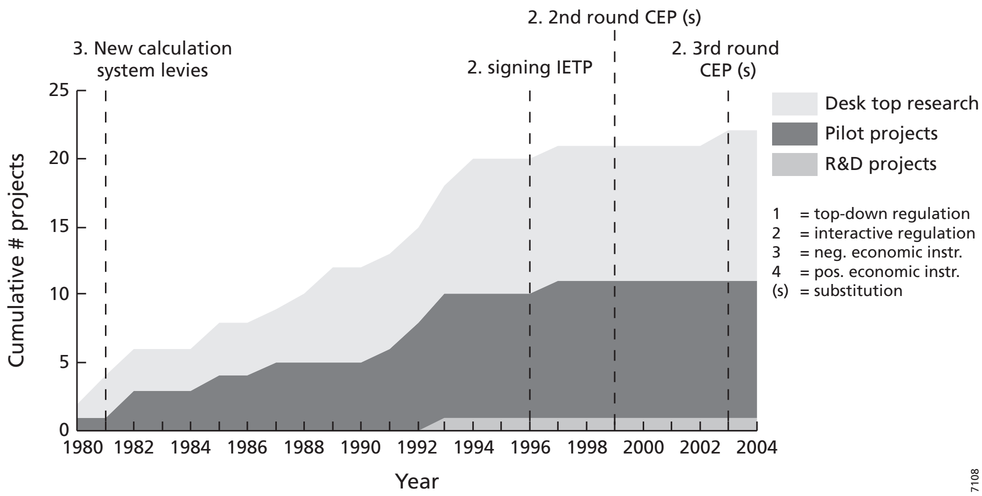

Figure 4.2 Research projects started for waste water in the period 1980-2004. Abbreviations can be found in Table 4.1.

substitutes another policy measure (indicated by an (s))[15]. Several observations can be made with regard to Figure 4.2. First, we observe little increase in policy pressure over time. Second, almost all projects were pilot projects or desktop research projects. R&D projects were hardly observed. Finally, it is striking from the data that since 1994 very few projects have been started. In the period before 1994, a large and constant increase is visible in the cumulative number of projects. This can be explained by the fact that this topic has been important since 1970, when the WVO was first implemented. In the period 1970-1981 the pollution was reduced to a great extent (VNP, 1981). In the period 1980-1994 further reductions took place and collective research projects were conducted. In the period after 1994 the topic was already on the agenda of the individual firms and much progress had already been made. In the same period the main development activity with regard to waste water treatment was the fine-tuning of the installations. There was no longer need to conduct collective research projects. As a consequence the collective research activities remain constant (first part hypotheses 1a and 2a).

The discharges that are most important with regard to waste water are zinc, copper, nitrogen and phosphorus. The discharges of zinc and copper exist because of the use of additives and leftovers of ink in recovered paper and because heavy metals are mobilised by the use of ground and surface water and the use of wood. Nitrogen and phosphorus are added during the treatment process and these discharges have to do with the fine tuning of waste water treatment installations (Koninklijke VNP, 2004a). As a consequence of the WVO many paper mills have built their own waste water treatment installation (Koninklijke VNP, 2004a). In Figure 4.3 an overview is given of the eco-efficiency for the domain of waste water for the period 1985-2003. The discharges of zinc, copper, nitrogen and phosphorus are indexed (1985 = 100). This is also done for the sales (1985 = 100). The ratio of these numbers, "discharge/sale" (the left vertical axis), and the absolute number of sales (the right vertical axis) are shown in Figure 4.3. In this figure the implementation of different policy instruments are also shown. Sales and eco-efficiency

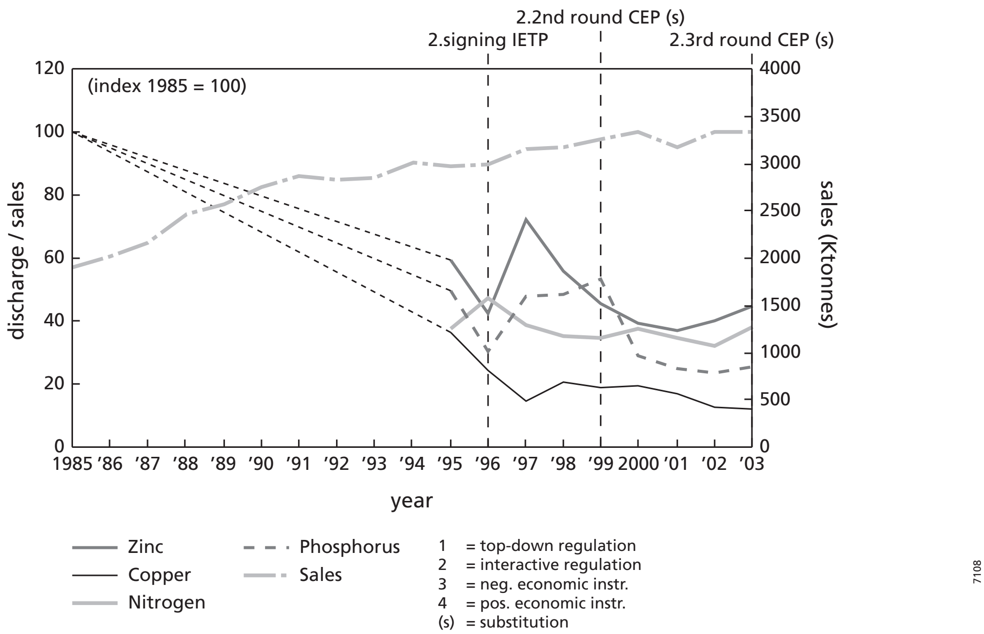

Figure 4.3 Eco-efficiency for waste water for the period 1985-2003 (FO-industrie, 2004) Abbreviations can be found in Table 4.1.

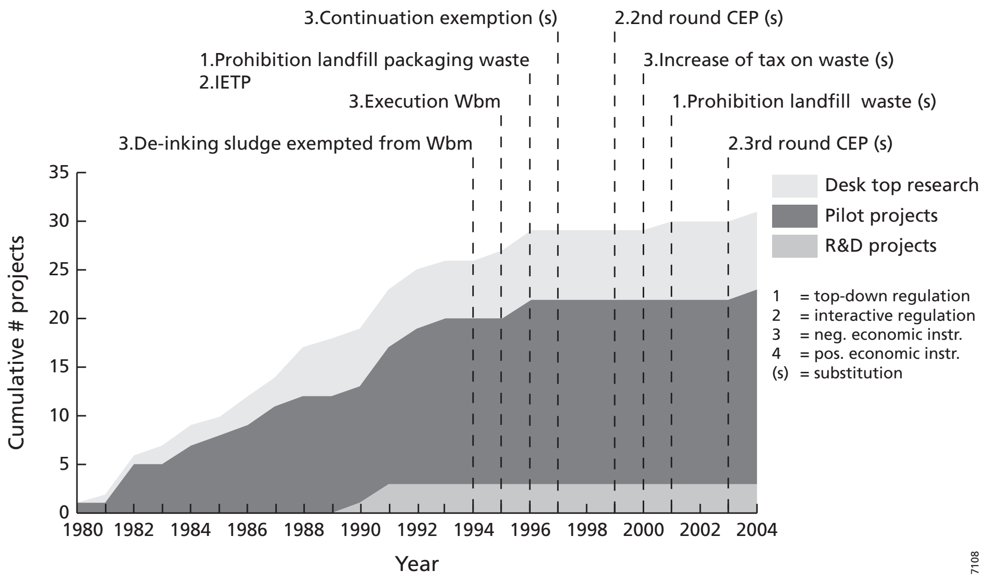

Figure 4.4 Research projects started for waste in the period 1980-2004. Abbreviations can be found in Table 4.1.

increased in the period. As we have already pointed out in the research design: an increase in eco-efficiency is visible by a decreasing trend in the figures, because we decided to divide the environmental indicator by sales instead of the other way around. However, in some years a decrease in eco-efficiency is visible. These decreases are probably caused by a higher content of heavy metals in the ground and surface water that were used in the production process or in the wood that was used. Fluctuations in the discharges of nitrogen and phosphorus are the result of fine tuning of waste water treatment installations. Policy objectives with regard to discharges to waste water aim at an absolute reduction of the discharges. Sales and growth of sales are not taken into account in these objectives. The policy objectives that were stated for the year 2000 with regard to discharges were not realised[16]. However as stated above, in terms of eco-efficiency we observe a increasing trend over time and we observe a little increase in policy pressure. The increase in eco-efficiency of three of the four indicators becomes visible a few years after this increase in policy pressure. The eco-efficiency with regard of the fourth environmental indicator also increases, but the increase is smaller and seems to start earlier in time. Overall, there seems to be a short time lag between the increase in policy pressure and the increase in eco-efficiency.

4.4.2 Waste

Figure 4.4 presents the collective research projects concerning waste for the period 1980-2004. Most of the projects are pilot projects. Over the years a great deal of research has been done

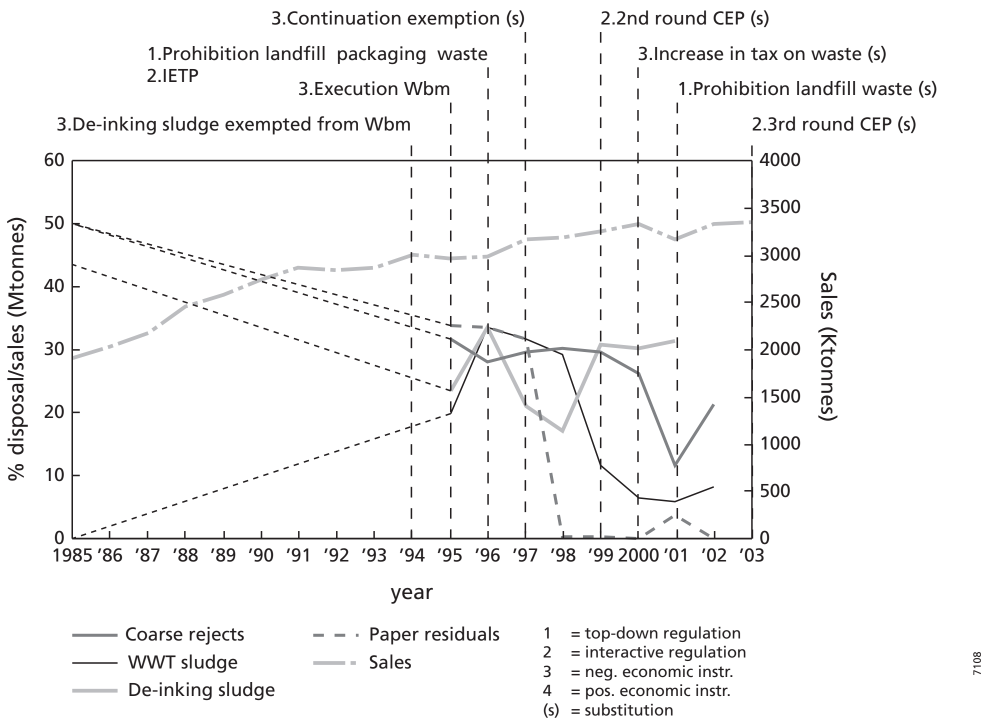

Figure 4.5 Eco-efficiency for waste for the period 1985-2002 (FO-industrie, 2004). Abbreviations can be found in Table 4.1.

into the separation of waste streams. A large and more or less constant increase is visible in the number of projects started in the period 1980-1996. Since 1996, a few new collective research projects have been started. The policy pressure increased in the period 1994-1997, and since 1997 several measures have been substituted. This suggests that it was no longer necessary to gain new knowledge, although the policy pressure increased (first part of hypothesis 1a and 2a).

As stated in the introduction, the paper and board industry have to deal with several waste streams. These waste streams have different causes: rejects in recovered paper; sludge of the waste water treatment installation; residuals of the de-inking process; paper rejects that can no longer be reused. Figure 4.5 shows how the disposals of these waste streams divided by the sales have developed over time. In addition, the absolute number of sales is presented as well as the application of different policy instruments. As was the case for waste water, the policy objectives for this environmental domain were also stated in absolute numbers; the original objective was to prohibit land filling of waste after 2000. However, the Dutch paper and board industry was given permission to postpone it until 2004. Figure 4.5 shows decreasing trends, which implies an increase in the eco-efficiency, in waste disposal with the exception of the de-inking sludge. The disposal of de-inking sludge remains more or less the same even though the policy pressure has increased since 1994. With regard to the other waste streams we observe an enhanced improvement since 1997. In conclusion, there is a short time lag visible between an increase of the policy pressure and an increase in eco-efficiency.

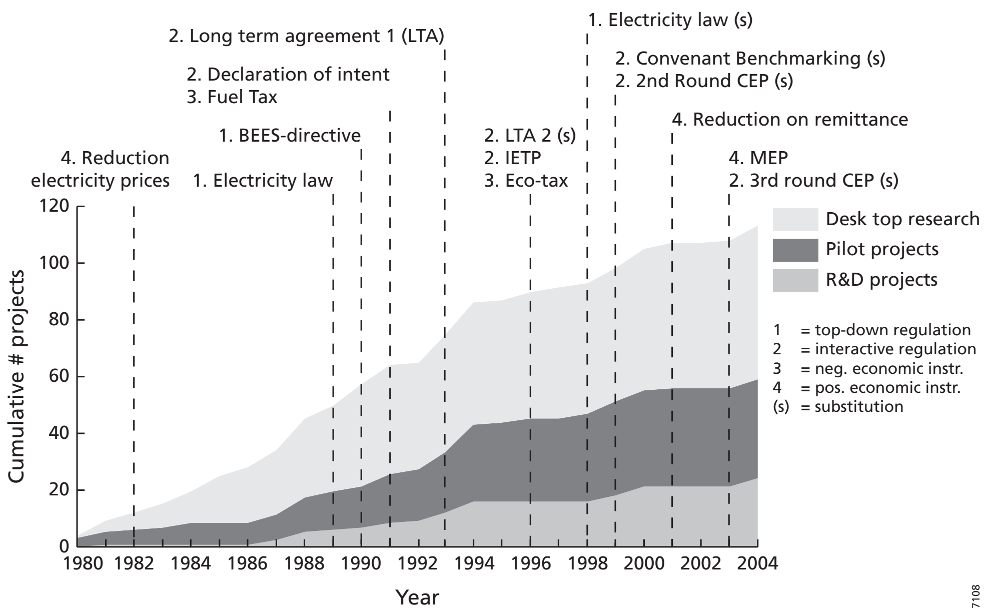

Figure 4.6 Research projects started for energy in the period 1980-2004. Abbreviations can be found in Table 4.1.

4.4.3 Energy

Energy has been an important topic for the industry for a long time (VNP, 2003). As it was stated earlier, the production of paper and board is energy intensive. As a consequence, the energy costs are a considerable part of the total cost price. Therefore, an increase in energy efficiency results in a profit in economic as well as in environmental sense. Figure 4.6 shows the collective research projects for the topic of energy. It is clear that the topic is of interest during the whole period because the number of projects started increases during the entire period. The increase seems to be somewhat higher in 1992-1994, just after the increase of policy pressure in the period 1989-1993. Furthermore, in 1997-1999 a second increase in the research activities is visible. This might be linked to the fact that since 1996 several measures were substituted and new objectives were formulated. On the basis of these observations it can be concluded that an increase in policy pressure results in an increase in research activities (first part of hypothesis 1b and 2b)

In the 80's the use of primary energy still increased. However, since the 90's the primary energy usage has remained stable. Moreover, the increase in sales in the period 1980-2003 is large. The sales are almost doubled. Therefore, the improvement in energy efficiency of the industry is high. Figure 4.7 presents this energy efficiency for the period 1980-2000 (figures are missing for the period 1990-1992). In addition, the absolute number of sales and the application of policy measures are given. It appears that the ratio energy use-sales has decreased over time. The use

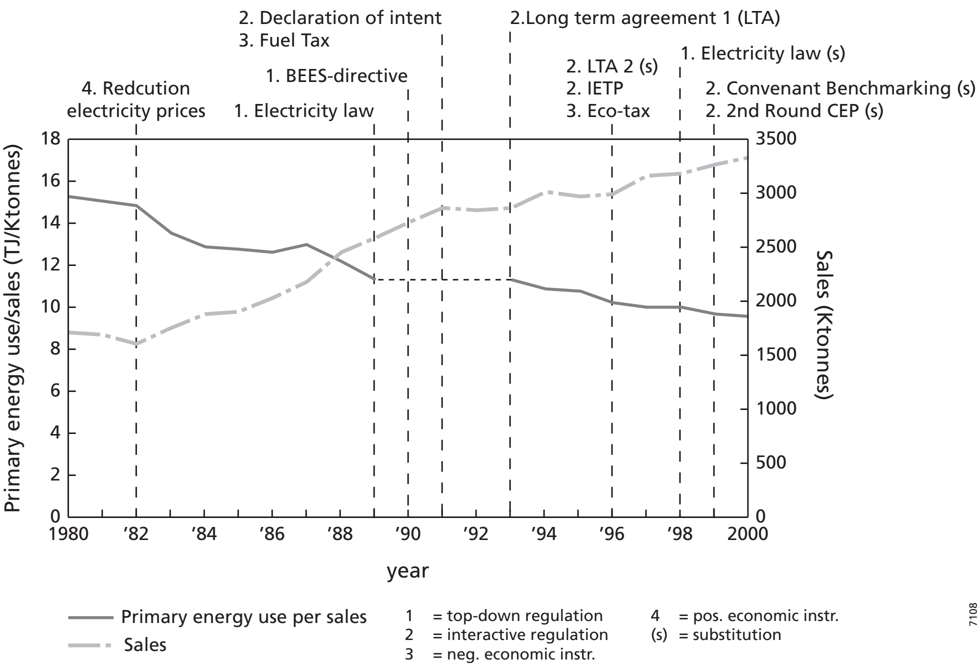

Figure 4.7 Eco-efficiency for energy for the period 1980-2000 (Cuelenaere et al., 1992; Koopman et al., 2004). Abbreviations can be found in Table 4.1.

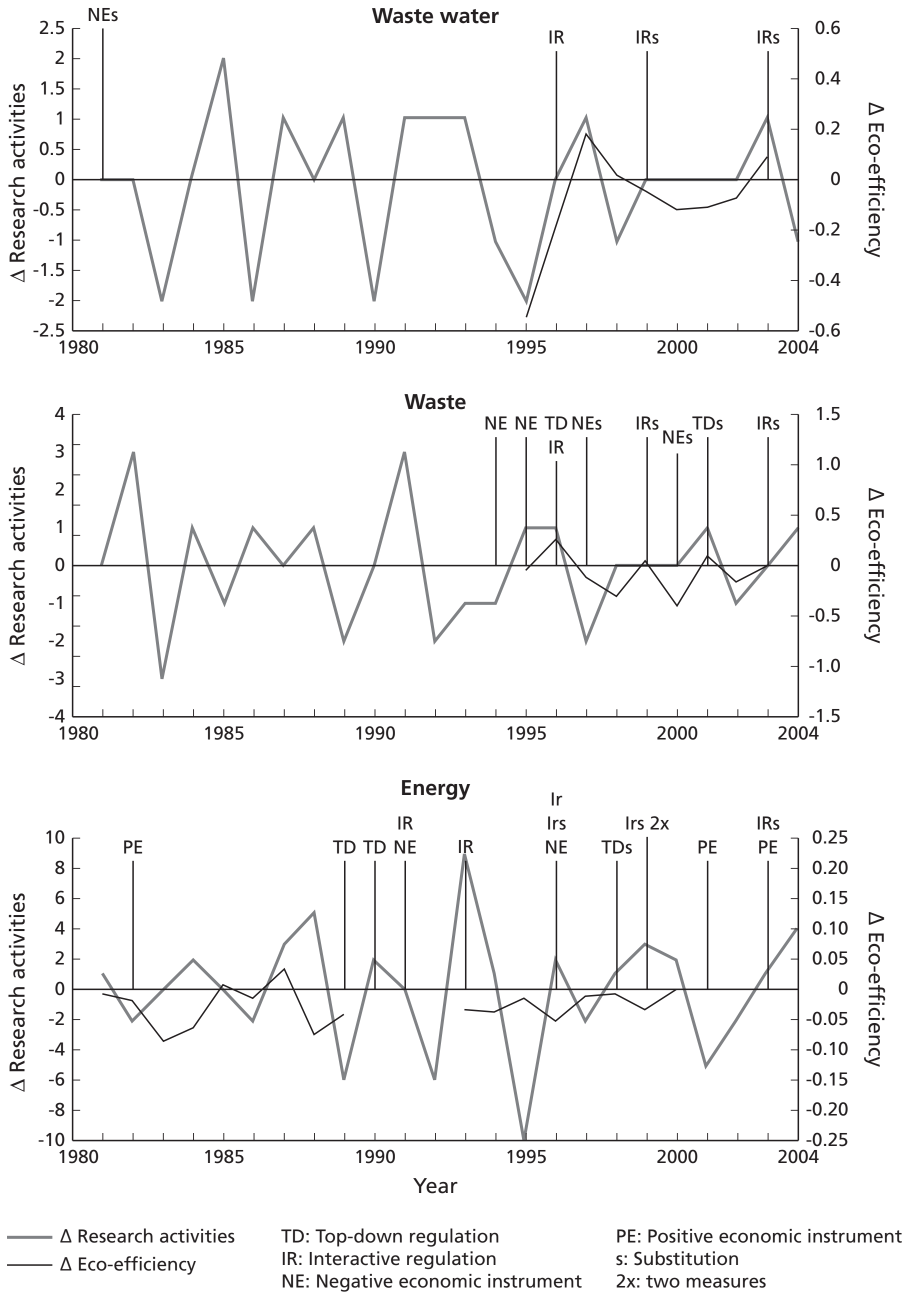

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Figure 4.8 The overall results

of CHP (combined heat power) has contributed most to this reduction. (VNP, 1986; Koopman et al., 2004). Policy objectives (see Appendix 4-I) are realised for this domain. After a period of increasing policy pressure (1989-1993) we observe an increase in the eco-efficiency a few years later (1995-1999). In conclusion, a time lag is visible between the increase in policy pressure and the increase in eco-efficiency.

4.4.4 Overall results

In Figure 4.8 the overall results are given. For each environmental domain the application of different policy instruments is shown by means of vertical arrows in the graphs. In addition, Δ Research activities and Δ Eco-efficiency are given in the figure. A positive number for Δ Research activities indicates that research activities increased in that year. A negative number for Δ Eco-efficiency indicates an increase of eco-efficiency in that year. For waste water and waste we used several indicators for eco-efficiency. In Figure 4.8 the mean of these indicators per environmental domain is presented.

For the domain of waste water, Figure 4.8 shows a little increase in policy pressure since 1996. For waste, Figure 4.8 shows that the policy pressure started to increase from 1994 onwards, while for the energy domain the largest increase in policy pressure took place between 1989 and 1993. Furthermore, Figure 4.8 shows that Δ research activities, with regard to waste water, become 0 in 1999. The eco-efficiency fluctuates over time, however it seems that the eco-efficiency start to increase and therefore in Figure 4.8 Δ Eco-efficiency becomes negative at the end of the nineties. Because the increase in policy pressure took place in 1996, there is a visible delay between the increase of policy pressure and the increase of eco-efficiency. These results confirm hypothesis 2a.

With regard to waste Figure 4.8 shows that the Δ research activities become 0 in 1998. In the meantime, the Δ eco-efficiency fluctuates. Since 1997 the eco-efficiency is increasing, because since then Δ eco-efficiency is negative for most observations. Based on these results, hypothesis 2a is best confirmed. The observation that there is a delay between increase of policy pressure and the increase of eco-efficiency (hypothesis 2a) is in line with the fact that the original objective of the policy was postponed from 2000 to 2004.

The observations are somewhat different for the energy domain. As mentioned earlier, Δ research activities increase in the periods 1993-1994 and 1998-2000 after an increase in the policy pressure (1989-1993) and after some substitutions of measures (1995-1999), respectively. Figure 4.8 shows that in the mean time the eco-efficiency increased gradually; Δ Eco-efficiency does hardly change. A time lag between the increase in policy pressure and the increase in eco-efficiency is not observed. As a consequence, hypothesis 1b is confirmed on the basis of these results.

4.5 Discussion and conclusion

It was the objective of this study to gain insight into the way accumulation of policy measures affects research activities and eco-efficiency. Three environmental domains have been researched for the Dutch paper and board industry: waste water, waste and energy. Before we turn to the conclusions two remarks need to be made. First, only one industry has been analysed. This is a very well organised industry that has been developing and implementing environmental innovation for a long time. As a consequence, it is not possible to generalise these results for all industries. Second, with regard to the documents that were used, it needs to be stated that some documents were not available (see notes 11-14). However, since different types of documents described the same events, this drawback has been reduced to a minimum. Besides, due to data limitations it was for the domains of waste water and of waste only possible to give the eco-efficiency trend for 1985-2003, because there is a lack of data for the intermediate years in the period 1985-1995. For the energy domain it was only possible to give the eco-efficiency trend for the period 1980-2000, of which the years 1990-1992 are missing. However, we still think that these remaining periods result in interesting insights and valuable conclusions.

It can be concluded that the results of the waste water domain and waste domain confirm hypothesis 2a; a time lag was observed between the increase in policy pressure and the increase in eco-efficiency. For either domain research activities did not increase after the increase in the policy pressure. It is possible that new knowledge was not necessary. However, in this research we used the number of collective research projects as an indicator for research activities. The collective research projects act as means to raise awareness in the industry for new technologies and processes. As a consequence, if the industry is aware of the possibilities, the collective activities are no longer necessary. It is possible that regarding these environmental domains the industry was already aware of the possibilities and firms were doing research by themselves. If research activities were conducted within firms, these activities are not taken into account in this research. This is a possible explanation for the fact that in our research the research activities do not increase for the waste water and waste domains. Moreover, it may also explain why a time lag is observed in the increase in eco-efficiency. If the firms were doing research themselves, the eco-efficiency will only improve at the time that these research projects are finished. Therefore, in addition to the fact that the policy pressure can cause problems with prioritising goals, which results in a delay in the increase in eco-efficiency, it is also possible that firms conducted their own research projects, which cost time and resulted in a time lag.

The results for the energy domain confirm hypothesis 1b; an increase in policy pressure was followed by an increase in research activities and an increase in the eco-efficiency. In contrast to results of the other environmental domains (waste water and waste), for this domain a delay between the different indicators policy pressure, research activities and eco-efficiency, was not observed. It have been stated in earlier sections that there is an obvious gain in economic as well as in environmental terms if the energy efficiency of the process is increased. This is a possible explanation for the observation that the eco-efficiency with regard to energy increases relatively fast in the Dutch paper and board industry.

As indicated in the introduction, this research was a first attempt to see in what way the accumulation of policy measures influences the research activities and eco-efficiency of an industry. Although the results are interesting, we think that it will be even more interesting if future research focuses on the firm level and if process theory is used. It will then be possible to gain insight into the underlying learning processes and gain a better understanding of the extent to which and the way in which different policy measures influence the innovation process. Therefore, we aim to conduct future research that focuses on the firm level and on specific innovation projects.

5 Enlarging understanding of the role of environmental policy in environmental innovation: Adoption explained by the accumulation of policy instruments and agent-based factors[17]

5.1 Introduction

Different and sometimes even conflicting theoretical and empirical findings on the relation between environmental policy and environmental innovation are found in the literature (Sanchez, 1997). There is ambiguity about the effects of environmental policy on innovation; environmental policy stimulates or impedes environmental innovation. In addition, there are also different explanations given in the literature. A review in the next section will give a more detailed insight into these ambiguities. We think that some additional ideas might help explain these ambiguities. There are two reasons in the case of environmental policies, why we cannot simply attribute environmental impact reductions to the governmental environmental policies. First, we are dealing with an accumulation of policy instruments, which implies that, in relatively short time periods, a number of policy instruments are implemented aiming at the achievement of related policy goals. Therefore, one cannot simply allocate impact reductions to merely one of those instruments (Chappin et al., 2007). Earlier work shows that evaluation studies do not pay sufficient attention to this accumulation of policy instruments (Schuddeboom, 1990; Rennings, 2000; Vermeulen, 2002; Dieperink et al., 2004; Vollebergh, 2007). Second, environmental friendly behaviour of firms is also influenced by other factors, such as intra-organisational factors. Not only policies influence the decision to behave in an environmentally friendly way. Strategic reasons, for instance, can also explain behavioural change. For instance firms innovate to be ahead of the competition. Or firms launch a new environmental friendly product for a better corporate image. To gain a broader insight into the effect of different policy instruments on innovation and in order to incorporate policy accumulation and intra-organisation factors, we advance an alternative approach, that instead of evaluating specific policy instruments solely also evaluates the behaviour of firms regarding the adoption of environmentally friendly technologies.

As to the environmental innovation, focus is on the adoption of CHP-installations (cogeneration of heat and power) in the Dutch paper and board industry. CHP is the simultaneous generation of electricity and heat and is more efficient than separate generation. This results in an increase of energy efficiency (defined as primary energy use/sales) and a reduction of CO_2-emissions. Over the last decades the adoption and implementation of CHP-installation has been an important measure of the industry to achieve an increase in energy efficiency (VNP, 1986; Koopman et al., 2004)[18]. In the course of the years, the Dutch government developed elaborate series of policy initiatives to stimulate an increase in industrial energy efficiency. These governmental policy objectives concerning energy savings have been attained (VNP, 2003a; Koopman et al., 2004). It is specifically this serial and simultaneity of implemented policy initiatives that raises the issue of attribution of effects to specific isolated measures. Therefore, we are curious about the perception of firms, paper and board factories in our case, about the role of policy instruments compared to other intra-organizational factors in the adoption processes.

We aim to answer the following two questions: *to what extent is according to the perception of the paper and board factories, the adoption process of CHP-installations in the Dutch paper and board industry influenced by environmental policy instruments and intra-organisational factors? And to what extent are these results time-dependent?*

In the next section, we start with the literature review on the relation environmental policy and innovation. Subsequently, the theory framework is explained in more detail in Section 5.3. In Section 5.4 the research design is presented. Section 5.5 shows the results. A final conclusion and discussion follow in Section 5.6.

5.2 Literature review: Environmental policy inducing innovation?

In Table 5.1, a short overview of a number of studies is presented that shows how inconsistent findings are as to the impacts of environmental policies on environmental innovation. In their theoretical review Grubb and Ulph (2002) of environmental innovation (especially of energy efficient technologies) and environmental policy, conclude that there is little evidence of consistent and strong effects of environmental policy on environmental innovation and that it is often difficult to prove that policies actually induced the innovation. In their empirical review they conclude that the effect of policies on environmental innovation turns out to be weak, and the largest effects appear in the long term, when learning-by-doing has taken place (Grubb et al., 2002). Other studies provide opposing conclusions. With regard to the generation of innovation, it is empirically observed that environmental policy, operationalised as pollution abatement costs and pollution abatement expenditures, results in an increase in innovation, measured by means of the number of patents (Lanjouw et al., 1996; Brunnermeier et al., 2003). On the contrary, Jaffe and Palmer (1997) did not find a statistically significant relationship between regulation compliance expenditures and patenting activity. However, they did find a significant positive relation between regulation compliance expenditures and R&D expenditures (controlled for industry) (Jaffe et al., 1997). A final conflicting finding is that in the Dutch industry the innovation intensity has been influenced negatively by complying to environmental regulations and environmental demands (CBS, 1998).

Van Soest (2005) focused on the impact of environmental policy instruments at the timing of the adoption. On the basis of a simulation model, he concludes that there is no unambiguous difference between different types of instruments (command and control versus market-based instruments) and the speed of adoption (van Soest, 2005). However, other studies did find differences between different instruments and were able to rank the different instruments (Requate et al., 2003; Tarui et al., 2005).

Table 5.1 An overview of studies on the effects of environmental policy on environmental innovation

Article	Focus	Operationalisation	Conclusions
(Lanjouw et al., 1996)	Generation	Pollution abatement costs; number of patents.	Positive relation between pollution abatement costs and number of patents
(Jaffe et al., 1997)	Generation	Regulation compliance expenditures; patenting activity; R&D expenditures (controlled for industry).	No significant relation between regulation compliance expenditures and patenting activity Positive relation between R&D expenditures and patenting activity
(Brunnermeier et al., 2003)	Generation	Pollution abatement expenditures; number of patents.	Positive relation between pollution abatement expenditures and number of patents
(van Soest, 2005)	Speed of adoption	Timing of adoption (simulation modelling)	Neither instrument (command and control or market-based instruments) is unambiguous preferred to the other for early adoption
(Requate et al., 2003)	Adoption	Investment incentive under taxes or subsidies, auctioned permits or grandfathering, command and control with and without anticipation of new technology (simulation modelling)	Without anticipation of new technology, taxes give the highest incentive. With anticipation of new technology, permits and taxes induce the first best-outcome if implemented after the first investments
(Tarui et al., 2005)	Adoption	Investment under taxes and standards with and without update of policy (simulation modelling)	Taxes are superior to standards if the policy is updated upon learning new information
(CBS, 1998)	Innovation intensity and output	Innovation expenditures as percentage of sales; percentage of new or improved product; compliance with regulation or environmental demands	Results show that the innovation intensity was negatively influenced by complying to environmental regulation and environmental demands; the innovation output is hardly influenced by this factor
(Grubb et al., 2002)	Review theoretical & empirical work	Conclusion theoretical review: no clear relation between environmental policy and environmental innovation. It is often difficult to prove that policy induced innovation. Conclusion empirical review: effect of policies is weak. Largest effects in the long term.	

These examples clearly show the ambiguity about the effects of environmental policy on innovation. Several explanations can be found in the literature. Some scholars argue that regulations add to the firm's costs (Rothwell et al., 1981; Rothwell, 1992; Braun et al., 1994; Hitchens et al., 1998; Marcus et al., 2002). This results in a reduction of financial means available for innovation in general. A related argument is that environmental regulations limit the options for environmental innovation: environmental regulation is said to reduce the time to find an optimal solution (Rothwell et al., 1981; Rothwell, 1992), to decrease the freedom to innovate, and to increase the bureaucracy (Braun et al., 1994). Finally, it is argued that managers of firms are uncertain about the regulation (Marcus, 1981; Rothwell, 1992; Meijer et al., 2007) and the behaviour of regulators (Marcus, 1981; Rothwell et al., 1981; Gunningham et al., 1998; Meijer et al., 2007). As a consequence, companies develop risk-avoiding behaviour, resulting in less environmental innovation.

Other authors argue the other way around, and state that environmental regulation saves money since environmental innovations can reduce the variable or fixed costs, due to efficient resource use and a low waste production (Wiener, 2004). Furthermore, it is argued that environmental regulation can create the necessary market for environmental innovations, thereby creating demands and opportunities (Braun et al., 1994) and providing directions for technical change (Ashford, 2002). They add that a threat from outside is necessary to get attention to a problem. Without such a threat – as for instance environmental regulations –, behaviour will not change (Van de Ven, 1986; Van de Ven et al., 1992; Van de Ven et al., 1999) and environmental innovation will not take place in the absence of environmental regulation.

Furthermore, we can identify several limitations of the empirical studies we discussed above. First, in these studies, indirect measures are often used for the operationalisation of the concepts. For instance, in several studies, policy pressure is operationalised by means of policy abatement expenditures. Another example is the use of patents in general, instead of a specific focus on patents related to environmental innovation. In addition, policy accumulation is neglected or not properly taken into account. Furthermore, these studies only focus on a short time period. Finally, other additional, e.g. intra-organisational factors are ignored (with exception of some control variables). On the basis of these results, we will now discuss our theoretical framework.

5.3 Theoretical framework

It is remarkable to see how most of these explanations black box the adopting unit, and on the one hand ignore behavioural and intra-organisational explanations other than resource based impacts of environmental policies. Whereas, on the other hand there could have been more attention for the complexities caused by the fact that so many policy measures with related environmental targets have been put to work in parallel. In our theoretical framework (Figure 5.1), we try to incorporate these issues. Figure 5.1 also presents in what way this research complements to regular effect evaluations, in which goal attainment is the primary focus. As firm behaviour often is not taken into account in these normal evaluations, it has been put in a dotted framework in the top half of Figure 5.1. In this research we shift towards an agency perspective.

Intra-organisational factors
We know that the adoption, which is the decision to make use of an innovation, depends on many different factors, apart from environmental policies (Rogers, 2003). In the introduction, we already pointed out that if these additional factors are neglected, it will be difficult to determine the effectiveness of a policy instrument. With regard to these additional factors, several groups can be found in literature (Frambach et al., 1998; Waarts et al., 2002; Wejnert, 2002; Rogers, 2003; Dieperink et al., 2004). Generally, they can be summarised in the following groups: innovation characteristics, characteristics of innovators, and context characteristics. In the first

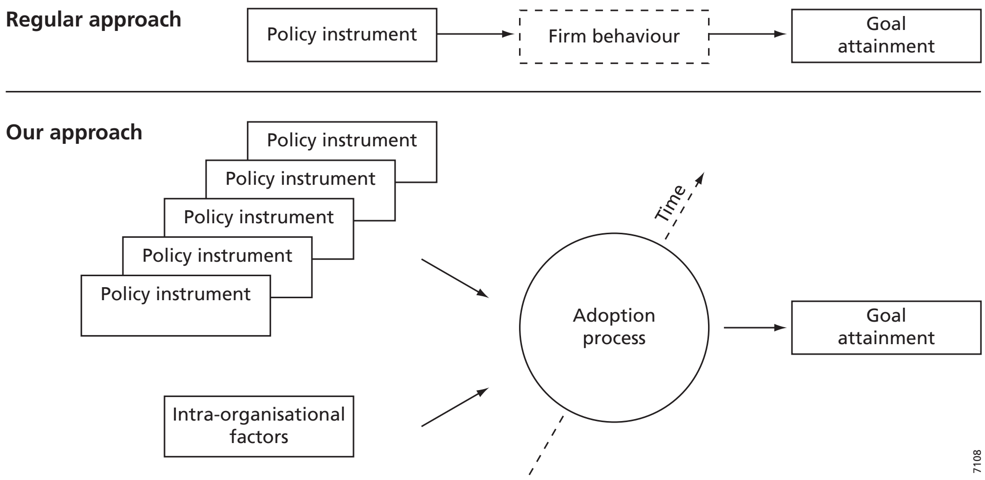

Figure 5.1 Our approach compared to regular evaluations

group, 'innovation characteristics', five factors that are often mentioned are relative advantage, complexity, compatibility, triability, and observability (Rogers, 2003).

The characteristics of the innovator are diverse. One can think of the age and size of a firm (Frambach et al., 1998) and its position in a network (information flows) (Wejnert, 2002). But also the familiarity with the innovation (Wejnert, 2002) and the financial resources available are factors that can influence the adoption process (Waarts et al., 2002).

The final group of factors is 'context characteristics'. With respect to this group, four main factors are political conditions (regulatory pressure), public concerns, demand conditions, and competition (Florida et al., 2001; Waarts et al., 2002; Wejnert, 2002). In this chapter, we are interested in the reasons why firms decided to adopt CHP-installations. These reasons (factors that influenced the adoption process) can originate from all three groups of factors.

There are several studies substantiating the model we advance in Figure 5.1. Dupuy (1997), for instance, integrates in addition to environmental policy – in his study on the Province of Ontario's Municipal Industrial Strategy for Abatement (MISA) -factors such as cost savings or material savings. It appeared that policy played a central role in the adoption process (Dupuy, 1997).

Brand et al (1999) conducted a meta-study of studies that focused on the diffusion of energy saving technologies, such as heat pumps, high efficiency boilers, photovoltaic cells and solar energy, insulation material, and combined heat and power[19]. They conclude that although general insight was gained into factors that did or did not play a role, a ranking between different factors was missing (not possible). Moreover, they conclude that insufficient attention has been paid to the role of environmental policies in the adoption process. Finally, they conclude that the studies they analysed, focus on one set of variables from one perspective only; they recommend future studies to integrate different perspectives and to take even more factors into account. Although more factors are indeed focused on, the accumulation of policy measures is, once again, not properly taken into account in these studies.

Policy accumulation

Now let us turn to the accumulation of instruments. The Dutch government applied a variety of policy instruments to influence the behaviour of firms (Rothwell, 1992; Skea, 1994; Keijzers, 2000b; Keijzers, 2002; Vermeulen, 2002; Zito et al., 2003). In previous chapters, we used the distinction between top-down regulation (command and control), interactive regulation, and positive and negative economic instruments (subsidies and taxes, respectively). We will apply these categories in this chapter as well. The mechanisms behind these instruments are different. The first category, top-down regulation, is described by Rothwell (1992) (p.449) as "a standard imposed by the government, which is legally and administratively enforceable, which must be met, or which must not be exceeded as an absolute threshold of performance" (Rothwell, 1992). However, interactive regulation, such as covenants and voluntary agreements, are defined by Glasbergen (1998) (p.694) as "a more or less formal agreement between a governmental organisation and a representative of the private sector with the intent of achieving national environmental policy aims on a voluntary basis". The relationship tends to be more cooperative when interactive regulation is used compared to top-down regulation (Sunnevag, 2000). Finally, economic instruments are an attempt to promote allocative efficiency through monetary incentives (Rothwell, 1992). We distinguish between negative economic instruments, resulting in higher costs, and positive economic instruments, resulting in cost reduction (Vermeulen, 1989).

Quite often, more policy instruments are in force simultaneously, all stemming from the policy mechanisms mentioned above. In previous literature, it is acknowledged that little attention is paid to this accumulation of policy instruments (Schuddeboom, 1990; Dieperink et al., 2004). We define policy accumulation as the implementation of a number of policy instruments focusing on a specific target group, or on several target groups, and aiming at the achievement of related policy goals in relatively short time periods. This policy accumulation often implies a mixture of policy instruments with a variety of underlying mechanisms that enable the achievement of policy goals. Policy accumulation entails major complications in terms of efficacy of implemented policy measures, some of which are dealt with in this chapter, and which are contingent on: a) the time span of implementation of different yet related policy measures, b) the (in-)consistency of mechanisms of the implemented policy instruments, c) the possibility of policy evaluation of separate policy measures due to causal ambiguity.

The time span in which related policy instruments are implemented determines the policy pressure for target groups, as they are confronted with new instruments to comply with. If implemented in too short a time span, policies will create pressure that may amount to behavioural resistance of the target group. For example, we observed this behaviour in the Dutch paper and board industry when policies changed frequently in the late nineties and they indicated they had become more risk-averse.

If the set of policy instruments is based on related mechanisms that contribute to target achievement in distinct ways, policies not only accumulate but also reinforce each other. For instance the implementation of a financial stimulus in addition to top-down regulation, interactive regulation, or subsidies. An example is the exemption of paper and board factories from eco-tax (a tax that is imposed on natural gas and electricity that are not "green"), when they participate in the "Convenant Benchmarking" (interactive regulation) (see Chapter 4 and (Chappin et al., 2007)). However, another possibility is that the mechanisms of the instruments are related yet inconsistent, thus leading to compliance based on contradictory mechanisms. This was for instance the case when one paper and board factory built an installation in which rejects were processed to fuel pellets in order to save energy (KoninklijkeVNP, 2004). In the end it appeared that at that time burning of these pellets was not possible in The Netherlands due to legislation. Policy makers must take such flaws into account, and the fact that they are more likely to occur as the variety of policy measures grows, especially in a short time span. For this reason, it is also interesting to explore how policies develops over time.

Time

The accumulation of policy instruments indicates that conditions change over time. As a consequence, time should be an important aspect in diffusion research (Jaffe et al., 2002). In addition, not only policy instruments accumulate and change over time, other intra-organisational factors may also differ in different time periods. Waarts et al (2002) also propose to take time into account, as factors will change over time. Indeed, they observe a difference in the explaining factors over a period of time (Waarts et al., 2002). Therefore, the accumulation of policy instruments as well as intra-organisational factors are taken into account and determined, both over the time period. This is a first attempt trying to reveal the relative influence of environmental policies on environmental innovation in this manner.

5.4 Research design

Our approach aims to determine the relative role of environmental policies in the adoption process of CHP-installations in the Dutch paper and board industry. At the beginning of 2006 – the period we collected our data -, the Dutch paper and board industry consisted of 27 paper factories[20]. When we gathered the data, seventeen factories made use of a CHP-installation[20].

We gathered the data by means of interviews. Our response rate is 100%. Thirteen interviews were held to obtain the necessary information. This difference (13 versus 17) is due to the fact that one interviewee was involved in the processes of five factories. At that time, these five factories were all part of one company which employed the interviewee. The interviewees were selected with the help of the industry association, which resulted in a proper representation.

In preparation of the interview we made a gross list of all policy instruments relevant for CHP implemented between 1977 and 2003 by means of desktop research (see also Figure 5.3). During the interviews, the adoption process was reconstructed with the interviewee. One theme in this reconstruction was governmental policies. During the interview, we showed the overview of policy instruments and asked if these instruments had influenced the decision. If indeed this was the case, we asked whether and why it had accelerated or delayed the decision. In addition to this gross list of policy measures, we asked about other factors influencing the decision. First, we inquired about some key events[21] and the need for cost price reduction. Second, the respondents were able to indicate other factors that had influenced their decision. Also for these events and factors we asked whether and why they had accelerated or delayed the decision. Finally, we asked the respondents to rank all the different factors. See also Figure 5.2. Ideally, all possible influencing factors should be drawn up beforehand. However, due to the fact that we focused on a relatively long time period, this was not possible due to data unavailability. Therefore, we identified factors that we were able to find and let the respondents indicate the remaining factors.

I Adoption

1. Can you indicate in which month (if possible) in what year your company decided to buy a CHP-installation?

II Policy instruments

On the basis of the gross list of instruments (Figure 5.3), we asked the following questions *for each* instrument:

2. Did this instrument influence the adoption process?
   • Yes, continue with question 3
   • No, continue with question 5
3. Can you indicate if the instrument accelerated or delayed the adoption process and why?
   • Accelerated / Delayed
   • Why?
4. Can you indicate in which year the influence of the instrument was experienced?
   • If this is the same year as the year in which the instrument was enforced, please indicate if the influence was experienced before, at the same time or after the enforcement of the instrument.
5. Are there any other policy instruments, which were not present in the gross list, but which did influence the adoption process?
   • Yes , continue with question 3
   • No

III Key events and reduction cost price

We distinguished three key events in the literature: the oil crisis of 1973, the establishment of "Projectbureau Warmtekracht" (Project Bureau which support cogeneration of heat and power) in 1987 and the moratorium of EnergieNed en SEP in 1994 (for a period of 8 months plans for new installations > 2 MW were stopped or cancelled). In addition to these key events, we asked about the factor "Reduction of the cost price". For these key events and factor the same questions of box **II Policy instruments** (nr 2-5) were asked.

IV Other factors

The respondents were able to mention other factors that influenced the adoption process as well. For these factors again the questions of box **II Policy instruments** (nr 2-5) were asked.

V Relative influence

We now have a list of all factors influencing the adoption process.

6. Can you order these factors? Starting with the most important factor for the adoption process and ending with the least important factor.

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Figure 5.2 The reconstruction of the adoption process with the repondents

We are aware of the possible disadvantages of the approach, as some projects took place many years ago. As a consequence, the decision makers may have left the organisation and we relied on the long term memory of the interviewees. However, most of our respondents were personally involved in the adoption processes, and if that was not the case, they were often informed by their predecessors. In addition, by showing the overview of policy instruments, by mentioning other key events, and by recalling the context to the respondents, we stimulated their memory. During the interviews, we got the impression that the respondents were very well able to reconstruct the process. The individual who was interviewed for Factory A (see next section) was even able to reconstruct the process that took place more than 40 years ago. He had started working in the firm when the CHP-installation was implemented.

5.5 Results

In this section, the results will be presented. First, we will present the overview of policy instruments and discuss the accumulation of these instruments. Subsequently, an overview of the adoption processes will be given and the reasons why firms adopted CHP-installations will be discussed. Finally, the role of policies after the adoption process will be discussed.

5.5.1 The policy instruments

Figure 5.3 presents the policy instruments with regard to CHP that were implemented during the period 1977-2003. Figure 5.4 shows the cumulative picture of these instruments. In literature, we did not observe policy instruments with regard to CHP in the period before 1977. The distinction between different types of instruments is also shown in this figure, represented by the numbers 1-4: 1: top-down regulation, 2: interactive regulation, 3: negative economic instruments, and 4: positive economic instruments.

These figures shows that the government implemented a large number of instruments during this period. However, negative economic instruments were not observed. The figures show the accumulation of policy instruments. In a relatively short time period, a number of policy instruments were implemented aiming to achieve related policy goals. Based on these figures, we can discern different policy regimes over time. Or, in other words, we can discern periods in which different governmental policy strategies are observed and in which different effects of policy accumulation are encountered.

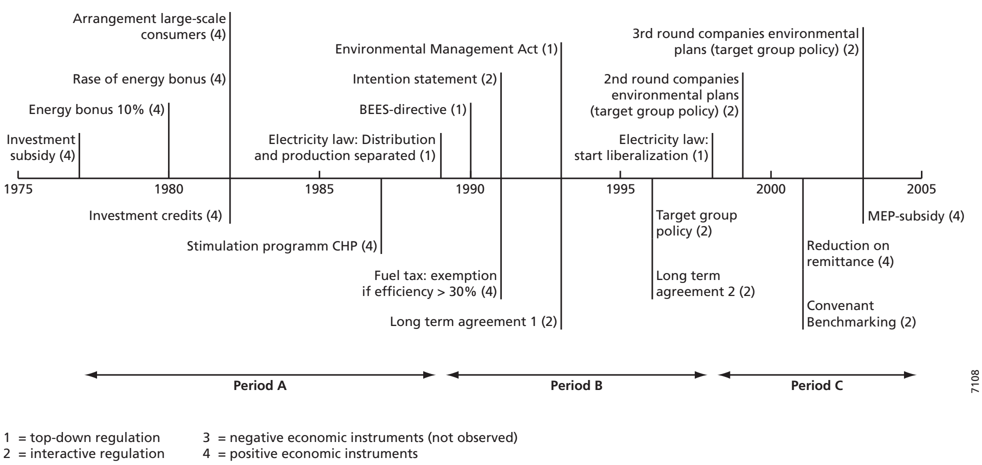

Figure 5.3 The accumulation of policy instruments with regard to CHP in the Dutch paper and board industry for the period 1977-2003.

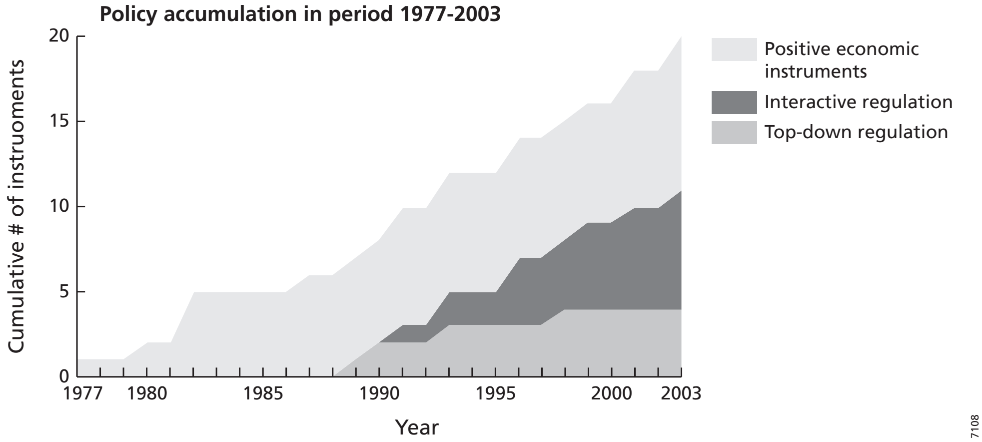

Figure 5.4 Policy accumulation: the cumulative number of instruments in the period 1977-2003

The first period (Period A) started in 1977 and lasted until 1989. In this period, the governmental policies were based on stimulating the diffusion of CHP by means of positive economic instruments (e.g. several subsidies and a stimulation programme). At that time the accumulation of policy instruments was such that these instruments reinforced each other. In this period, it was not interesting to produce more electricity than used by a factory, as there were no proper feed-in tariffs (the compensation a mill receives if they deliver electricity to the grid). As a consequence, the capacities of the installations originating from that period were based on the local electricity demand. This resulted in sub-optimal installations. The ratio heat/power in those situations was not ideal. This situation changed in the second period.

This second period (Period B) started in 1989 with the implementation of the Electricity Law. As a consequence of this law, the production and distribution of electricity were separated. The only way that distribution firms could 'produce' electricity was to form a joint venture with the industry. Therefore, the distribution firms became interested in cooperating in CHP. From that moment onward, large CHP-installations were built producing more electricity than the paper factories used. This was economically feasible, for there now was a proper feed-in price as a result of the Electricity Law of 1989. The large CHP-installations provided the paper and board factories with heat and electricity. The remaining electricity went to the electricity distribution firm. Another top-down instrument that was implemented in this second period, was the BEES-directive (Decision Emission Demands Heating Installations = Besluit Emissie-Eisen Stookinstallaties). This directive dealt with NOX-emissions. Whereas a gas turbine emits NOX, a steam turbine does not emit NOX, due to better circumstances with regard to the burning of natural gas. Therefore, CHP-installations based on gas turbine technology needed adjustment, contrary to CHP-installations based on steam turbine technology. In this second period, several covenants (interactive regulation) between government and industry were used as well. Long Term Agreements 1 and 2 were signed, which aimed at an improvement of the energy efficiency of 14% in 1995 and 20% in 2000 respectively, compared to 1989. The Target Group Policy, yet another interactive regulation instrument in this period, set target with regard to reducing air, water, and soil pollution, to saving energy, cleaning up contaminated soil, and so forth (Glasbergen, 1998). Finally, also in this period, a positive economic instrument was used. Firms were exempted from fuel tax, if the efficiency of the CHP-installation exceeded 30%. All these instruments were implemented parallel in a relative short time span. The top-down instruments sometimes caused problems. Installations just implemented before the introduction of the BEES-directive needed adjustments. However, the interactive instruments were developed in cooperation with the industry, which in general resulted in a positive attitude of the industry towards these instruments.

The third and final period (Period C), started in 1998, when the first Electricity Law was replaced by the second Electricity Law. This second Electricity Law resulted in the liberalisation of the energy market. As a result of the liberalisation, energy prices changed and the feed-in prices decreased. In 2003, the MEP-subsidy (Environmental Quality of Power Production Act) was implemented: a subsidy per kWh of 'sustainable' produced electricity, which included a subsidy for CHP and which compensated some of the 'losses' due to lower feed-in prices. Here we see another type of accumulation of policy instruments. In sum, the implementation of the Second Electricity Law disturbed the situation. To offset negative effects for an industry like the Dutch paper and board industry another instrument (positive economic instrument) was implemented.

Another positive economic instrument was the reduction on remittance, implemented in 2001. Installations with a certain efficiency gained extra allowance for electricity that was delivered back into the grid. Finally, also in this period, covenants were present. After the duration of Long Term Agreement 2, "Convenant Benchmarking Energy Efficiency" was signed in 1999. Its aim was to be among the best 10% of the world in 2010. The Target Group Policy was extended in 1999 (2nd round of CEPs) and 2003 (3rd round of CEPs).

5.5.2 The adoption processes

Figure 5.5 shows when different factories (A-Q) adopted a CHP-installation. For each factory, only the most recent installation is presented.

Figure 5.5 shows that there were two main periods in which most of the current adoptions took place. One main period started at the end of the seventies and ended in the mid eighties (Period II in Figure 5.5). The other period was the first half of the nineties (Period III in Figure 5.5). These two adoption periods correspond with the first two policy regimes (Periods A and B in

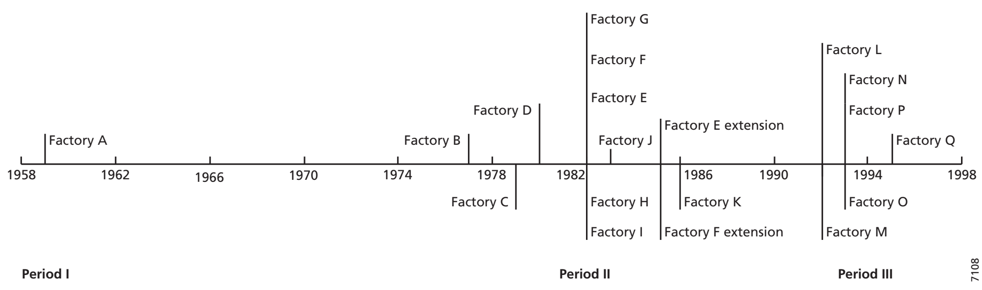

Figure 5.5 The adoption of the current CHP-installations in the Dutch paper and board industry

Figure 5.3). During the first policy regime (Period A: 1977-1989), firms B-K adopted their CHP-installations. In this period, the governmental policies were mainly based on subsidies stimulating the diffusion of CHP, whereas the other period was characterised by covenants between government and industry and by the first Electricity Law of 1989. Based on these observations – that an increase in policies results in an increase in adoption -, one would easily conclude that policies are effective. Moreover, the government indicated that for instance Long Term Agreements have been effective (Das et al., 1997). However, we will now determine whether, from an agency perspective (the perspective of the decision makers in firms), this impact of policies on environmental innovation is attributed the same importance or whether other factors were more important.

Around 1960, there was also a period in which CHP-installations were adopted. However, most of these installations have now been replaced. Therefore, only one of these original adoptions of Period I, namely Factory A, is shown in this figure.

As mentioned in the Research Design, firms were asked if and in what way the policy instruments had influenced their decision and what other factors had influenced the adoption. The following factors appeared to be important in the adoption processes:

- Top-down regulation.
- Positive economic instruments.
- Interactive regulation.
- High energy prices in combination with threat of regulation (High energy prices/threat of regulation): Factories C, E, F, J, and O were part of a large company. One employee of this company was involved in all of the adoption processes for these five factories. The oil crisis (1973) led firms to save money in this manner. In addition, the factories of this company had only just shifted from coal to oil and, subsequently, from oil to natural gas. The Dutch Prime Minister Den Uijl predicted that it would not be easy to obtain natural gas in the future and that it should be used with care.
- High energy prices in combination with cost price reduction (High energy prices/cost price reduction): These concepts are related since a higher energy price results in a higher cost price. This is why they are treated as one factor.
- Extension capacity and better reserve position with regard to electricity.
- Replacement of existing heat provision.
- Avoided investments: If the production of a factory increased and it required more electricity for its production process, there were two options available. On the one hand firms could invest in a supplier relation with the electricity company (buy a thicker cable = more electricity). On the other hand, firms could invest in building its own electricity provision (a CHP installation). If this latter option turned out to be cheaper, there were avoided investments. Or in other words, if the adoption of CHP turned out to be a more efficient investment, investments were avoided.
- 'Green' policy of firms: The environmental friendliness of firms led to an earlier adoption of CHP-installations.
- Strategic reasons: Competitors had also adopted CHP-installations.
- Off-balance financing: The possibilities to get off-balance financing stimulated several firms to adopt a CHP-installation.

Table 5.2 The ranking of influencing factors per factory per period.

	Factory																						
Period	**I**		**II**												**III**								
Factors	**A**	**Tot I ***	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**Tot II**	**Mean ****	**L**	**M**	**N**	**O**	**P**	**Q**	**Tot III**	**Mean**	**Tot**
Top-down regulation																x	6			4	3	4,17	3
Pos eco instruments			2	2	2	2	2	2	x	3	2	x	10	2.05	4	x	5		3		4	3.63	14
Interactive regulation															3	x	1			3	4	2	4
High energy prices/threat regulation				1		1	1				1		4	1									4
High energy prices/cost price reduction			1		1			1		2		x	5	1.4	1	x	4		2	1	5	2.1	10
Capacity extension										1			1	1			2		1		2	1.5	3
Replaced existing heat provision	1	1										x	1	1.2									2
Avoided investments					3								1	3									1
Policy of firm																				2	1	2	1
Strategic reasons															2						1	2	1
Off-balance financing																	3				1	3	1
Survival of firm									x				1	1.5									1
Closedown of associated company																		1			1	1	1

*: Tot = total number of observations in a period or overall

**: = mean of relative influence of a factor in a period. If respondents were not able to rank the different factors, the X is calculated by taken the mean out of the number of points this firm would normally have distributed if they did rank the factors. If we take Factory H as an example. Two factors were said to be important. Normally the respondent would have distributed 3 points in total (1+2). These 3 points are divided by the number of factors (two). So, for Factory H X = (1+2)/2 = 1,5. For Factory K X =(1+2+3)/3 = 2 and for Factory M X =(1+2+3+4)/4 = 2,5.

- Survival of firms: Upon facing bankruptcy and needing to downsize its production, a firm (H) required a new and smaller CHP-installation.
- Closedown of an associated firm: The CHP-installation was moved from that firm.

Table 5.2 presents the factors that influenced the adoption process of each factory and, the ranking of these factors. If a ranking was not available, – some respondents found it impossible to rank the different factors – all relevant factors were marked "x". For each period, the importance of these different factors will be discussed. In view of the fact that Factory A was the only factory in Period I, we will first discuss its adoption process, after which Period II and III will be discussed.

Factory A adopted a CHP-installation in 1959. Its existing heat provision at the time, coal-fired boilers, needed to be replaced. As a new heat provision was needed, the technical director wished to be innovative. As a consequence, a CHP-installation was chosen. At that time, this type of CHP-installation was regularly seen in sugar factories and breweries. There were no other factors, such as environmental policy instruments, influencing the decision.

Period II

In period II, 10 factories adopted a CHP-installation. Two respondents were not able to rank the reasons. Therefore, these two adoption processes will be discussed before we turn to the results of the other 8 factories.

Factory H and K adopted a CHP-installation in 1982 and 1986, respectively. In 1982, Factory H faced bankruptcy. Factory H already used a CHP-installation. However, the factory would continue with a smaller production and the capacity of the existing CHP-installation was too large. In order to survive, a new CHP-installation was required. Subsidies and a credit grand were next to the need to survive conditional for the adoption. In sum, it was a combination of financial stimuli and the need to survive the situation of bankruptcy. Factory K had a high pressure boiler with a poor availability. The boiler often failed and therefore boiler needed to be replaced. At the same time, the possibility arose of an external party to finance the project and to supply the technological services. Reasons for Factory K to adopt the CHP-installation were the need to replace the existing heat provision, the possibility of providers of capital, subsidy possibilities, and energy savings (high energy prices/cost price reduction).

With regard to the other eight factories of this period, we can observe from Table 5.2 that only a few factors were mentioned in this period: the attractivity of positive economic instruments, pressures of high energy prices/threat regulation, high energy prices/cost price reduction, extension capacity, and avoided investments. The factors that were most important (position 1 in ranking) were high energy prices/threat regulation (4 times: Factory C, E, F, and J), high energy prices/cost price reduction (3 times: Factory B, D, and G), and capacity extension (Factory I).

For this latter factory, Factory I, high energy prices/cost price reduction was the second most important factor. For the other factories, the second most important factor was positive economic instruments (subsidies). It was often mentioned by the respondents that subsidies would never be the most important reason to adopt a technology. However, subsidies did accelerate the decision, as it decreased the costs associated with the investment. For Factory I, positive economic instruments were also an important factor of decision; it was ranked in the third place. For Factory D, avoided investments were the third factor influencing the adoption.

Overall in this period, the high energy price, combined with the reduction of the cost price or the threat of regulation were the most influential decision factors. Positive economic instruments were important in all decisions, yet it was never the most important reason. In several of these decisions different positive economics instruments were relevant simultaneously, reinforcing each other.

Period III

Six factories adopted a CHP-installation in this period. One respondent (Factory M) could not rank the factors. We will start by discussing this latter adoption process. For Factory M, the reasons to adopt a CHP-installation were the opportunity to reduce the cost price and, simultaneously, to realise the environmental policy goals of Long Term Agreement 1[22], thus obtaining subsidies. A final element influencing the decision was the Electricity Law of 1989. As a consequence of this law, it was possible for Factory M to adopt a large CHP-installation in a joint venture structure. This, however, slowed down the decision, as Factory M would have liked to adopt the large installation much earlier. In 1984, Factory M adopted a CHP-installation. As mentioned before, at that time it was not possible to deliver electricity back into the grid at a reasonable feed-in price. Therefore, in 1984, they had no choice but to adopt a sub-optimal CHP-installation dimensioned to the local electricity demand, instead of an optimal installation which would be dimensioned to the local heat demand.

Top-down regulation appeared not to be that important in the adoption processes. A top-down regulation instrument was mentioned only twice. For Factory N, the BEES-directive was, in addition to other factors, the sixth factor to adopt a new CHP-installation. The old installation did not meet the requirements of the BEES-directive. For Factory Q, the Environmental Management Act (Wet Milieubeheer) influenced the adoption and implementation process by causing some delay. With respect to this act, they applied for a permit. However, the soil appeared to be polluted. Therefore, a new application for a permit was required, thus causing the delay. It was the fourth and final factor influencing the adoption process of Factory Q.

Positive economic instruments were also important in this period, although not as important as in Period II. This can be concluded from the following two observations. First, two of the six factories did not mention this factor as an influence on their adoption process, whereas all factories mentioned it in Period II. Moreover, the ranking of this factor differs from period II. It is now ranked less important as 3, 4, and 5.

Interactive regulation is important for some factories in this period. For Factory N, it was the most important reason of adoption. This factory was part of a large company. At that time, Factory K was also part of this company. The need to reach the objectives of the Long Term Agreement 1 for the company as a whole was the main reason why this factory (Factory N) adopted a new CHP-installation. For two other factories (Factory L and Q), Long Term Agreement 1 was important as well, yet not as much, since it was ranked at the third place. We already mentioned the importance of Long Term Agreement 1 for Factory M.

Similar to Period II, in this period the high energy prices/cost price reduction was an important factor as well, mentioned by four factories. It was ranked as being the most important factor twice (Factory L and Q). For Factory P, it was the second most important factor, after capacity extension (mentioned below). Finally, for Factory N, this factor was ranked fourth.

The capacity extension or a better reserve position was mentioned twice in this period. For Factory P, it was the most important factor influencing the adoption of the CHP-installation. The old CHP-installation threatened to become too small. Therefore, Factory P entered into a joint venture with the distribution firm and adopted a large CHP-installation. This new installation was even less efficient than the old installation, yet its capacity was larger.

For Factory N, it was the second most important factor. Their reserve position (with regard to their energy provision) was worse; adopting a new CHP-installation improved this position.

Other factors:
Four factors were mentioned only once. First of all, due to the fact that an associated firm closed down, the CHP-installation moved from that firm to Factory O. Therefore, the closedown of an associated company was the most important and only factor influencing the adoption of Factory O. Secondly, at the time that Factory Q adopted the installation (1995), the pay-back time was relatively long. However, Factory Q considered energy saving to be important. Therefore, despite the long pay-back time, the environmental policy of the firm influenced its decision in a positive sense. The policy of the firm was the second most important factor. Third, for Factory L, strategic reasons were second most important in their decision. Finally, for Factory N, the fact that off-balance financing could be obtained was an influencing factor (3rd place in ranking).

Overall, the high energy prices/cost price reduction is the most important reason for adoption in this period. Another influence is environmental policies. In this period three types of policy instruments influenced the adoption decisions, of which interactive regulation was most influential. Four out of six installations were influenced in their adoption process by the Long Term Agreement. For three these adoptions positive economic instruments were relevant as well. And in that sense these instruments (Long Term Agreement and positive economic instruments) reinforced each other.

Period II versus Period III
If we compare Period II and Period III, we observe differences as well as similarities. Period III is different from period II in the sense that the factors influencing the adoption processes of the factories are more diverse in Period III. In contrast to Period II, in Period III top-down regulation and interactive regulation mattered. In addition, the average number of factors that influenced the decision was higher in Period III compared to Period II (3.7 and 2.3, respectively). However, for Period II as well as for Period III intra-organisational factors are more important than policy instruments. In both periods high energy prices, combined with cost price reduction or threat of regulation were the most important reasons.

After Period III….
Since 1995, no new adoptions have taken place. At the end of the nineties, some factories investigated the possibilities of a new CHP-installation. However, these projects stopped

when the liberalisation of the energy market came into sight. Nowadays, it is economically no longer feasible to adopt a new CHP-installation. Moreover, most respondents indicated that governmental policies have been changing too often during the past ten years, which made them much more risk-averse with regard to energy efficiency. Only if the pay-back time is short they will adopt energy saving measures. Thus, in this case, the effect of environmental policies on environmental innovation is the opposite of what was expected: instead of stimulating innovation it impeded innovation. This is in line with what was discussed in the theoretical section. Uncertainty concerning regulations and the behaviour of regulators resulted is risk-avoiding behaviour of managers, subsequently resulting in less environmental innovation (Marcus, 1981; Rothwell et al., 1981; Rothwell, 1992; Gunningham et al., 1998; Meijer et al., 2007). This is also in line with the findings of Mueller (2006). In their research on the adoption of CHP-installation, they conclude: "…firms abandon the adoption process due to concerns about the complexity of regulatory requirements" (Mueller, 2006). This clearly indicates the possible (negative) effect of policy accumulation.

5.6 Discussion and conclusion

In the introduction and review, we highlighted the ambiguities in the effect and explanations of environmental policy on innovation. Different and sometimes even conflicting theoretical and empirical findings on the relation between environmental policy and environmental innovation are found in literature. We argued that previous policy evaluations have some limitations and that more insight into the effect of different policy instruments is preferred. Therefore, in this chapter we shift towards an agency perspective and focused on one technology in one industry: CHP in the Dutch paper and board industry. We studied a 40 year period of CHP-adoptions within the industry and took all policy instruments related to energy efficiency into account. Finally, we studied intra-organisational factors influencing the adoption decision. The aim was to develop and test a new approach by means of the following questions: *to what extent is according to the perception of the paper and board factories, the adoption process of CHP-installations in the Dutch paper and board industry influenced by environmental policy instruments and intra-organisational factors? And to what extent are these results time-dependent?*

We already mentioned some drawbacks in the approach in the Research Design. It would have been better if all factors had been objectively identified instead of some being identified by respondents. However, we already explained that this was not possible due to the long time period we focused on. In our opinion, the advantage of focusing on a longer time period counter-balances the possible subjectivity of the identification of influencing factors. The second disadvantage was the fact that some of the processes we analysed took place a long time ago. However, during the interviews we noticed that this time aspect did in practice not lead to retrieval problems for the respondents. Even though these disadvantages should be kept in mind, the results appear to be fruitful nevertheless.

Three periods of adoptions were observed, of which period I consisted of only one adoption process. Therefore, the remaining part of the discussion focuses on Period II and III. The results showed some similarities and differences for these distinguished time periods. In period II, the high energy price, combined with the cost price reduction or the threat of regulation were most influential in the decisions. Furthermore, positive economic instruments were important in all of the decisions. In Period III, the high energy prices/cost price reduction was an important reason for adoption as well. Positive economic instruments were important in this period as well, although not as much as in Period II. In addition, interactive regulation was important in Period III.

After Period III, no new adoptions took place. At that time, policies impeded innovation: due to governmental policies, the economic situation of CHP changed and due to frequent policy changes, firms became more risk-averse.

Overall, we can conclude that policies are relevant, yet it is only one of the factors influencing the adoption process. Its relative importance varies over time and per adoption process. This implies that a more full fledged approach of explaining environmental innovation is fertile soil for further research, and that assessments of impacts of environmental policies should be dealt with in tandem with intra-organisational, and market factors. We believe this might explain why previous studies, often operationalising environmental policies and/or environmental innovation in a relative simple way (see table 5.1), have difficulty determining the effect of policies. The most important reason appeared to be the high energy prices combined with the cost price reduction or the threat of regulation. These finding differ from the results of Dupuy (1997), as policy was the most important reason for adoption in his study.

However, our conclusion is only based on direct effects of governmental policies. An important indirect effect of government interventions is the effect on the 'energy price', which is partly, indirectly influenced by governmental policies. Since the energy price was such an important influencing factor in the adoption process, one can conclude that indirect effects of policy instruments were also present and relevant.

The results also show different effects of distinct types of policy instruments and show different effects of accumulation of policy instruments. As explained in the theoretical section, each type of instrument applies a distinct behavioural mechanism to achieve its targets. Overall, we can conclude that the role of top-down regulation was perceived as limited in the adoption processes, whereas interactive regulation turned out to be important for several factories in period III (in period II, there was no interactive regulation yet). Negative economic instruments were not observed, whereas the role of positive economic instruments turned out to be large. Although positive economic instruments were important for almost all of the adoption processes (it was not mentioned in only three out of seventeen cases), it was never and, according to the respondents, will never be the most important reason for adoption. With regard to the effects of the accumulation of policy instruments, we observed instruments positively reinforcing each other. For instance, different subsidies were implemented in the late seventies, early eighties, all stimulation the diffusion of CHP. So, these measures reinforced each other. Furthermore, we observed that implementation of instruments disturbed situations originating from earlier policy instruments. The implementation of the Second Electricity Law resulted in negative changes for CHP-owners in energy prices and feed-in prices. Finally, we observed that the implementation of several instruments in a short time span resulted in negative behaviour, namely risk-averse behaviour. This complex interaction of policy effects on firms' innovative behaviour also explains why some researchers that do evaluate policies separately find negative impacts whereas others do find positive impacts.

Policy makers should be aware of these results. On the basis of our results, we can conclude that it would be naive to neglect intra-organisational factors (such as cost price reduction or the replacement of an existing installation) and to think that a policy instrument is effective if policy goals are attainted. In our case policy goals concerning energy efficiency were obtained, however to the perception of the paper and board factories, policy was one of the factors influencing the adoption process, and in fact entrepreneurs became quite policy-averse over time. Moreover, policy makers should be aware that different instruments are based on different behavioural mechanisms. Insight into the industry, its behaviour, production processes, hot topics, problems, etc. before policies are implemented, can result in a better alignment of aims of both government and industry. This can result in a more effective policies. It is obvious that time horizons of firms and government are different. Firms' capital-intensive investments are based on long time horizons (for instance 15 years), whereas governmental policies and the direction of the policies are known to change more often. We believe it may be useful to implement a specific mixture of policy instruments, attuned to the specific industry and reinforcing each other. Moreover, goals should be consistent over time to avoid risk-averse behaviour, which we saw after Period III.

Finally, we are convinced of the usefulness of the approach to help solve the ambiguities in the effect and explanations of environmental policies on innovation. It enabled us to focus on the accumulation of policy measures and on intra-organisational factors over a longer time period. Had we neglected the non-policy factors in the approach, we would have missed important explanations. On the other hand, if only the most important factor for each factory (adoption process) was taken into account, neglecting the other factors, the importance of environmental policies would have appeared to be very low. This latter observation would also have been the case had we focused on one group of instruments only or on one policy instrument only. This would have given a wrong, incomplete, and simplified representation of reality, whereas policies have indeed been relevant. The overview of policy instruments results in a better insight into the role of policies. Finally, the conclusion can be drawn that the longitudinal approach is important. More insight is gained compared to the focus on one short time period. The role of policies appears to be different in the various time periods. As this research was only a first attempt, for future research we recommend the investigation of different technologies/technological trajectories and of the same technologies/technological trajectories in different industries.

6 Explaining compositions of learning structures in the adoption and implementation of CHP-installations[23]

6.1 Introduction

If we define an innovation as 'something being perceived as new by a unit of adoption' (Rogers, 2003), one can argue that in general learning is required to use it. In other words, an innovation process reflects a learning process (Lundvall, 1992). There are different possibilities for firms to acquire knowledge (Powell et al., 1996; Meeus et al., 2000; Gherardi, 2001) necessary for the innovation process. This implies that there are different possibilities to design a learning process. These possibilities can be labelled learning structures. The structure can for example be based on internal knowledge. Or it can be such that other actors are being involved and that in this way external knowledge is acquired. In the late eighties, Lundvall (1988) introduced the notion of interactive learning, which aims at the latter structure about involving other actors to contribute to the innovation process. It took several years before these interactive learning processes were empirically explored and tested. Meeus and colleagues conducted several studies in which they focused on the level of interactive learning between the innovating firm and its suppliers, customers, or the knowledge infrastructure (Meeus et al., 2001a; Meeus et al., 2001b; Meeus et al., 2004). Building upon the work of Meeus et al (2001a; 2004) a resource base perspective and an activity-based approach are also combined in this chapter. We are especially interested in two possible explaining factors for the learning structures with regard to adoption and implementation: strength of the internal resource base and technological complexity.

Meeus et al. (2004) end their conclusion with the recommendation (page 348-349) "to concentrate on specific technologies within sectors, and concentrate on large sets of projects that are analysed on a longitudinal base". This chapter is a first attempt in doing this by focusing on the adoption and implementation of one specific technology in a sector over time. Especially these temporal aspects (an analysis on a longitudinal base) need more attention, because so far they are neglected in most studies, in the sense that context and conditions are often implicitly assumed to be stable over time. Yet, we do know that within an industry the frequencies of adoptions are distributed over time in a Gaussian way (e.g. the diffusion curve) (Rogers, 2003) and simultaneously the situation within an industry changes over time. Waarts et al (2002) propose to take time into account, because factors will change over time. Indeed, they observe a difference in explaining factors in their research on the adoption of enterprise resource planning (ERP) software (Waarts et al., 2002). Poole (2004) also advocates to take time into account in studies on innovation and change, because the social, economic or other functional impacts of innovation only become clear over time. One main contribution of our study is that we develop the theory of interactive learning further by adding a temporal element to it.

Our research object is the adoption and implementation of CHP-installations (co-generation of heat and power) by the *Dutch paper and board industry*. CHP is the simultaneous generation of electricity and heat and is more efficient than separate generation. This results in an increase of energy efficiency (defined as primary energy use/sales) and a reduction of CO_2-emissions. Over time it turns out that the use of CHP-installations has been an important energy-efficiency improvement measure for this sector in the last three decades. In the period 1979-1984 more than 50% of the decrease in energy use can be allocated to CHP-installations (VNP, 1986). In the period 1989-2001 42.2% of the reduction in energy use/sales is caused by the implementation of CHP-installations (Koopman et al., 2004).

CHP can be characterised as an *environmental* process innovation, which adds a specific element to our study, as compared to industrial product innovations. Because environmental innovation does not concern the core business of firms, this will also affect the learning structure that a firm chooses or is able to choose. Despite the environmental benefits, the technology that is investigated, CHP, can also lead to a cost price reduction. The Dutch paper and board industry is an energy-intensive industry and energy has been an important topic for decades. As a consequence of the oil crisis in 1973 the topic energy-saving has gained more attention and remains an important topic (VNP, 2003)[24].

This study aims at identifying temporal patterns in learning structures that are used, and getting insight into factors that explain the preference for a specific learning structure. This results in the following research questions:

1. Which temporal patterns can be distinguished in learning structures for the adoption and implementation of CHP-installations in the Dutch paper and board industry?
2. To what extent can factors derived from the theory of interactive learning explain these learning structures?

The contribution of our study is threefold. First, we will focus on a broader set of actors that can be involved during the adoption and implementation process, because it likely that several actors are involved during these processes (Fleck, 1997). The existing literature on interactive learning processes focuses on dyadic relations. A second contribution of our study is the longitudinal approach. We try to incorporate changes in context and conditions over time in the analysis. A final contribution is the focus on adoption and implementation of environmental innovations. We are shifting from innovation in general to non-core process innovation. In the next section, theoretical framework, we will elaborate further on these concepts and the relations among them. Then the approach is described in Section 6.3. In Section 6.4 the results are given. A final conclusion and discussion follow in Section 6.5.

6.2 Theoretical framework

In this chapter the explanation of the choice for specific learning structures is derived from the theory of interactive learning. This notion of interactive learning was introduced by Lundvall (1988) about two decades ago. While Lundvall introduced this concept, he did not empirically test it. In several studies Meeus and colleagues explored and tested interactive learning (Meeus et al., 2001a; Meeus et al., 2001b; Meeus et al., 2004). In these studies interactive learning processes are conceptualised as dyadic relations (e.g. learning from supplier). Nooteboom also studied the concept of interactive learning. Nooteboom concludes (2000) (p.290) "Learning to interaction requires on the one hand sufficient cognitive distance to yield novelty, and to the other hand sufficient proximity to yield understanding". This suggest an inverted U-shape between the cognitive distance and the effectiveness of learning by interacting. In recent work, Nooteboom et al (2007) indeed find support for an inverted U-shaped effect of cognitive distance on innovation performance of firms.

We adapt the notion of interactive learning by including the configuration of partners, which reflects a variety of learning structures. In other words, we expand this notion of interactive learning from a dyadic perspective to a more community approach. In the literature we come across technology communities (Tushman et al., 1992; Van de Ven, 1993; Lynn et al., 1997; Taminiau, 2006) and technological systems studies (Carlsson, 1997). A technological community is defined by Tushman et al. (1992) as the set of organisations that are stakeholders in a particular technology. A technological system is defined as knowledge and competence networks supporting the development, diffusion and utilisation of technology in established or emerging fields of economic activity (Carlsson et al., 1991). Both definitions have in common that around the development of a specific technology a group of actors is situated. This group of actors may consist of suppliers, customers, universities and industry, and governmental agencies. Sometimes an innovation champion exists in such community or system. Such a champion has a strong belief in an innovation (Buswick, 1990) and will perform promotional activities for this innovation such as by communicating strategic meaning around it, securing resources, involving and motivating other to support the innovation (Howell et al., 2004). This technological community or system enables firms to obtain knowledge in their innovation processes. The knowledge available in the community or system can be exploited by the firms (Carlsson, 1997).

Hence, our learning structures are operationalised as varying network configurations representing distinct ways of engaging external and internal partners in the adoption and implementation of CHP-installations. Our research model (Figure 6.1) focuses on the strength of the internal resource base and the technological complexity, whereby time is acting as a moderating variable (c.f. " it affects the strength and/or direction of the association between another independent variable and an outcome variable" (Bennett, 2000) (p.416).

The focus on environmental innovation has some implications for the concepts and relations we study. The non-core element of environmental innovation suggests that more often than in the case of core innovation competences will be missing and new knowledge and routines will

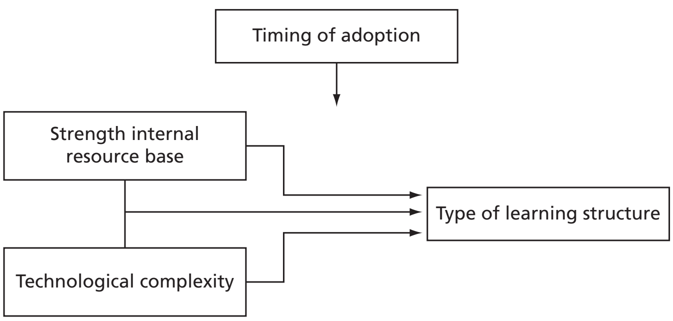

Figure 6.1 The conceptual model

be more often required (Ehrenfeld, 1999; Marcus et al., 1999). In addition, if actors are to be involved, it is plausible, in the case of environmental innovation, that these actors are outside the "normal" network (value chain) of the firm (Ehrenfeld, 1999).

In sum, we will test the conceptual model of Figure 6.1. The different relations of this model will be discussed below, after discussing the dependent variable, learning structures, in more detail.

6.2.1 The dependent variable: learning structures

A firm is surrounded by a lot of different actors with whom the innovating firm can enter into relationships, such as; suppliers, customers, universities and industry, and government agencies (Dodgson, 1994; Edquist, 1997). In the case of environmental issues specialised consultancy and technical services are probably available, in addition to manufacturing of environmental friendly technology (Skea, 1994). The newness of the innovation requires learning of the innovating firm. Specific knowledge is required. In the literature several ways to acquire knowledge are given (Powell et al., 1996; Meeus et al., 2000; Gherardi, 2001; Zahra et al., 2002): an innovating firm can rely on the knowledge available at that moment, can learn from the experience of other organisations, can recruit bearers of knowledge necessary to the organisation but which it does not posses, and it can develop alliances with other organisations to acquire the knowledge. These different options and combinations of these options are labeled as learning structures in this research. We distinguish three main compositions of structures, namely rely on own knowledge, enter in knowledge based relationships, and outsourcing. Furthermore, for each of these structures there is also the possibility to hire new personnel (recruit bearers of knowledge). This results in six different structures, which are presented in Table 6.1.

A relative simple option for the innovating firm is to outsource the project (structures 3a and 3b) because the risks are carried by the outsource partner and only a few actors are involved. A more complex structure is to enter into (new) knowledge relationships (structure 2a). This structure is more complex, because the firm needs to maintain several relationships and the firm carries more risks. It becomes even more complex, if they hire new personnel as well (structure 2b). Structure 1 is less complex. Only supplier firms are involved and in the case of learning structure 1b new personnel is hired.

The question for the adopting firm is to what extent they elaborate this set of partners. It is not plausible that firms randomly select a learning structure. It is suggested that firms will collaborate (go outside for partners) when they are not able to innovate themselves (Miotti et al., 2003). It is not an exception that innovation processes require integration of different sources (Dodgson,

Table 6.1 The different compositions of learning structures in this research

		Compositions of Learning structures
1	A	Learning structure by applying own knowledge and supplier relations
	B	Learning structure by applying own knowledge, supplier relations, and hiring new personnel
2	A	Learning structure by using/entering in knowledge relationships
	B	Learning structure by using/entering in knowledge relationships and hiring new personnel
3	A	Learning structure by outsourcing the project
	B	Learning structure by outsourcing the project and hiring new personnel

1994). The difficulties of such innovation processes also play a role in the decision. Firms will consider whether they are able to innovate on their own or whether they need to look outside for partners. In sum, the extent to which the adopting firm will elaborate the set of partners (select a different composition of learning structure) in the adoption and implementation processes will be a function of the strength of the internal resource base and the technological complexity.

6.2.2 Strength of internal resource base

The resource based theory of the firm represents the firm as a bundle of resources (Penrose, 1959). These resources enable the firm to achieve a sustainable competitive advantage if they are valuable, rare, imperfectly imitable, and strategically unique with no substitutes (Barney, 1991). An important assumption in the resource base view of the firm is the heterogeneity among firms (Combs et al., 1999), which implies resource differences among firms. These differences in resources result in different innovation processes and therefore in different learning structures. If the adoption and implementation processes require knowledge that is available in the firm, there is no need for a firm to search for collaborations with other actors and it can rely on its own knowledge and supplier relations (structure 1a). On the other hand, if existing knowledge within the firm is not sufficient for the adoption and implementation processes, so called resource deficits emerge, and the possibility increases that knowledge outside the firm is necessary (Teece, 1986; Meeus et al., 2000). Nooteboom (2000) is referring to cognitive distance. Firms tend to collaborate when they need complementary knowledge. However, there is an optimum for the distance between knowledge bases of the two firms. If the knowledge cannot be understood by the innovating firm is useless, as well as it is useless if the firm already possess the knowledge (Nooteboom, 2000).

As we explained, environmental innovation is a special case, because this type of innovation is not the core business of the paper and board industry. Whereas the internal resource base of a firm is depending on the business of the firm, it is much more likely that in the case of environmental innovation competences are missing and new knowledge and routines are required (Ehrenfeld, 1999; Marcus et al., 1999). Therefore, in the case of CHP, an environmental innovation, one would expect learning structures 1b, 2 a and b or 3 a and b to occur more frequently than learning structure 1a.

Several studies of Meeus et al. report on the strength/quality of the internal resource base in relation to interactive learning (Meeus et al., 2001a; Meeus et al., 2001b; Meeus et al., 2004). In this research interactive learning is reflected by learning structures 2 and 3. They found support for different relationships between the internal resource base of the innovating firm and the extent to which external actors are involved. These results are also shown in more detail in Table 6.2. However, these studies did not differentiate between generation and adoption of innovation, whereas this study focuses explicitly on adoption and implementation of environmental innovations. We expect in our case a negative monotonic relation; a very strong internal resource base accompanies learning structure 1a and a weaker internal resource base accompanies learning structure 1b, 2 or 3.

This results in hypothesis 1: *A strong internal resource base of the adopter company increases the likelihood of learning structure 1a, whereas a weak internal resource base of the adopter company increases the likelihood of learning structure 1b, 2a/b and 3a/b*

6.2.3 Technological complexity

In addition to the strength of the internal resource base the technological complexity is also expected to affect the type of learning structure. As Lundvall (1988) already pointed out in his work, a higher complexity occasions interaction and interactive learning (Lundvall, 1988). Collaboration (interactive learning) is a means for firms to deal with complexity (Dodgson, 1994; Rycroft, 2007). This should be especially the case for environmental innovation, which involves non-core innovation.

The relation between complexity and collaboration or interactive learning has been empirically tested in some studies. The study of Nagarajan et al (1998) examines the relationship between different types of technological change (complexity in our research) and different ways of acquiring technology (learning structures in our research). Their findings suggest that more complex technological changes (defined as more encompassing and complementary technological change) require interorganisational relationships, whereas incremental technological change induce internal R&D (Nagarajan et al., 1998). This is in line with findings of Meeus et al. (2000), who report a positive relation between complexity of innovative activities and interactive learning. They have tested this relationship in several studies and have tested a positive monotonic (/:a higher complexity increases the probability of interactive learning) as well as a negative non-monotonic relation (∩: a moderate level of complexity has the largest effect on levels of interactive learning.). See Table 6.2 for an overview of their results. Meeus et al (2004) give two arguments why after a certain point higher complex products would not result in higher probability of interactive learning. There is the possibility of a reputation effect (Huber, 1991) and the difficulty of finding partners. The reputation effect entails the "fear" of firms to admit that they are not capable of solving their own problems, because it can result in a damaged reputation. The second argument lies in the fact that in case of more complex innovations, less external partners will be able to provide the required complementary knowledge.

Question is however, whether these two arguments apply in the case of environmental innovation. Because it is a process innovation that only impacts on cost price levels, the innovating firms will not be as sensitive about its reputation. Furthermore, because energy efficiency is in general less of a core competence, it is more likely that actors outside the firm's normal network will be involved and provide the complementary knowledge. Therefore, we expect a positive monotonic relation between technological complexity and learning structures with an external focus.

This results in hypothesis 2: *A high technological complexity increases the likelihood of learning structure 2b, or 3a/b, a medium technological complexity increases the likelihood of learning structure 1b or 2a, and a low technological complexity increases the likelihood of learning structure 1a*

6.2.4 Interaction effect

In addition to individual effects of the internal resources and technological complexity on the preferences for specific learning structures, we do expect these effects to interact with each other. The complexity of the technology has an effect on the existing capabilities of the firm. A high complexity requires skills, capabilities, and/or knowledge, which most innovating firms do not have internally (Zahra et al., 2002). Thus, it is the technological complexity of an innovation that determines if the internal resource base is sufficient and therefore influences the choice for a specific learning structure. A more complex technology has an increased probability that the internal resource base and supplier relations are not sufficient and/or that a learning structure

Table 6.2 Overview of the results of Meeus and colleagues (Meeus et al., 2001a; Meeus et al., 2004)

	Interactive learning with			
	Customers	**Suppliers**	**Universities**	**TNO-institutes**
Strength internal resource base		∩ (A, B)	/ (C) ∩ (B)	/ (C)
Complexity	/ (A, B, C)		/ (A, C) ∩ (A, B)	∩ (A)
Interaction term strength internal resource base and complexity	∩ (A, B)		U (A, B)	U (A, B)

A: total sample = all firms, B: firms with less than 100 employees, C: firm with 100 employees or more.

is chosen with the focus on acquiring external knowledge. Meeus et al tested the influence of a combination of the strength of the internal resource base and the complexity on the level of interactive learning. They found a negative non-monotonic relation for interactive learning with customers (∩) (Meeus et al., 2001a). In contrast to their expectations, they found a significant positive non-monotonic relation in the case of interactive learning with the knowledge infrastructure (U) (Meeus et al., 2004). See also the overview of the results of Meeus and colleagues in Table 6.2. Concerning the set of partners we assume also for this variable a linear relation. So, relying only on supplier relations and own knowledge will be the case if the internal resource base is sufficient (strong) and the technological complexity low.

This leads to hypothesis 3: *A strong internal resource base and low technological complexity results in Learning Structure 1, whereas a weak internal resource base and high technological complexity results in Learning Structure 2 or 3.*

6.2.5 The importance of time

The final variable to explain is *time*. In the introduction we touched lightly on the importance of time. Adoptions within an industry take place over time and both the context of the industry and of the firm are in flux over time. In this research the timing of the adoption and implementation is seen as a moderating factor for the relation between the independent variables (the strength of the internal resource base and the technological complexity) and the dependent variable (the choice for a specific learning structure). This implies that time affects the strength and/or direction of the association between these independent variables and the dependent variable (Bennett, 2000).

But why would this relation be affected by time? The main reason is that we expect knowledge to accumulate over time. We explained that around the development of a specific technology a group of actors is situated, the technological community or system. It is likely that the knowledge base in the community or system grows over time (Nelson, 1998). Or in other words knowledge will be accumulated. We expect that this accumulation will take place within the community as well as within firms. It is this accumulation of knowledge why we expect differences in the strength and/or direction between our independent variables and the choice for a specific learning structure over time. Namely, a growing knowledge base of firms will result in an increase of learning structure 1a eventually.

This accumulation of knowledge will be visible in our results in two ways. First, one would expect to observe an increase of learning structure 1a for technologies with a similar complexity over time. Moreover, in later periods one would expect to observe firms that are able to adopt and implement even more complex types without external acquisition of knowledge (learning structure 1a). Second, we discussed the option to hire new personnel as a way to acquire the required knowledge. Because we expect an accumulation of knowledge within the firm, and the community over time, the likelihood increases that it is no longer necessary to hire new personnel in later periods.

So hypothesis 4 reads as follows: *Learning structures based on hiring new personnel (1b, 2b, and 3b), are especially expected in earlier periods, whereas in later periods learning structure 1a are more often expected also in the case of complex installations.*

6.3 Approach

6.3.1 Data collection

In the beginning of 2006, the period in which we collected our data, the Dutch paper and board industry consisted of 27 paper mills[20]. When we gathered the data, 17 factories made use of a CHP-installation[20]. Interviews were held to obtain the necessary information. During these interviews the adoption and implementation processes were reconstructed with the interviewee. Several aspects of these processes are discussed, namely general information about the timing of adoption and implementation; characteristics of the CHP-installation; the relative role of different policy measures, as well as other reasons, in the adoption of the CHP-installation (see Chapter 5); the strategy of the factory with regard to energy-saving investments, in particular CHP-installations; the interactions during the adoption and implementation process and finally the internal education/training of people and the hiring of new people.

To record the adoption and implementation of all 17 CHP-installations 13 persons were interviewed. This difference (13 versus 17) is due to the fact that one interviewee was involved in the processes of 5 factories. These five factories were at that time all part of one company and the interviewee was also employed in this company and a typical example of an innovation champion (see also the Box in Section 6.4.1).

6.3.2 Operationalisation

In this chapter learning structures are operationalised by means of network configurations of actors that engaged in the CHP-innovation adoption of the focal unit. This measurement extends the operationalisation of interactive learning by Meeus et al (2001a; 2004) from a dyadic measure to a network measure. Meeus et al. limited the interactions to buyers, and suppliers (Meeus et al., 2001a), or the knowledge infrastructure (Meeus et al., 2004). The final network measures relational as well as attribute data. First, we discuss the relational data. The networks in this research are ego-centered networks, which Wasserman et al (2005) (p.42) define as a network that: "…consists of a focal actor, termed ego, as set of alters who have ties to ego and measurements on the ties among these alters." In this research the egos, the focal actors, are the Dutch paper and board factories, which adopted a CHP-installation. We asked them which firms contributed to the adoption and implementation process of the CHP. In this way the ego-centered networks are constructed.

The three different types of network (1, 2 and 3) will all have some specifications. The network of learning structure 1 consists of relationships with suppliers only. The network of learning structure 2 is characterised by relations with consultancy firms. Finally, a relation with an outsource partner is characteristic for the network of learning structure 3.

In addition to these relational data, we asked the focal actors, the paper and board factories, about some firm characteristics. In social networks the measurement of these characteristics are called attribute variables (Wasserman et al., 2005). Examples of attribute data are age, profit, etc. In this research the attribute data are focused on hiring new employees. If a firm indeed hired new employees as a consequence of the adoption and implementation, this is made explicit in the network. In sum, the six structures, which were defined in the theoretical section, will be constructed of relations with other actors (the alters) and attribute data.

The strength of the internal resource base (IRB) is measured as the fit between the technology and the competences of the firm at the time of adoption. We asked the respondents the following question to determine the strength of the internal resource base: 'please indicate to what extent, according to your estimation, the technology fitted the competences of the firm at the time the adoption took place?' The following values are distinguished in this chapter:

- Technology and competences fitted completely → IRB very strong = 4
- Technology and competences fitted moderately → IRB strong = 3
- Technology and competences fitted weakly → IRB weak = 2
- Technology and competences fitted not at all → IRB very weak = 1

As to the measurement of technological complexity, a relative measure is used here. It compares the complexity of a product or technology to that of a closely related product or technology. This is done in most studies of complexity due to the difficulty to establish absolute or context-free measures (Singh, 1997). With regard to CHP-installation different types can be distinguished. There are relative simple CHP-installations, which are composed of a HD boiler and a steam-turbine or a LD boiler and a gas turbine. However there are also more complicated types with several turbines. Four main types can be distinguished. For two of these types two different options exist. The installation can be based on the electricity demand or on the heat demand. An installation based on the heat demand is more complex than one based on the electricity demand (De Gram, 2007). In order to rank these different types of installations we acquired judgments from two CHP-experts. This resulted in the following ranking with regard to the complexity of the installations (least complex (Type 1) – most complex (Type 4)) (De Gram, 2007):

- Type 1: HD boiler and steam-turbine
- Type 2a: LD boiler and gas-turbine based on the electricity demand
- Type 2b: LD boiler and gas-turbine based on the heat demand
- Type 3a: HD boiler, steam-turbine and gas-turbine based on the electricity demand
- Type 3b: HD boiler, steam-turbine and gas-turbine based on the heat demand
- Type 4: HD boiler, steam-turbine, gas-turbine and condensation steam-turbine

At first sight the above operationalisation might suggest that the independent variables (strength of the internal resource base and technological complexity) partially overlap. That could be the case, but we think we should to measure them separately and they do not overlap. For the measurement of the strength of the internal resource base, we look at the fit of the resources and the technology without looking at the complexity of the technology as such. For instance, one can adopt a simple installation, but may not have the resources (a weak internal resource base) or adopt a very complex installation but do have the resources internally (a strong internal resource base). Whereas, the technological complexity is based on expert judgment. Therefore, we think both these concepts have their unique explanatory value.

6.4 Results

In this section the results will be presented. First, we will shed some light on the technological community. Next, the different learning structures will be discussed in more detail and observed examples will be given. Third, the observations will be given, where after these observations are explained.

6.4.1 The technological community

During the interviews several actors (alters) were mentioned by the interviewees with whom these paper and board factories had a relation during the adoption and/or implementation. In this way we reconstructed the technological community with regard to CHP in the Dutch paper and board industry. We classified these alters of the community into the categories which are shown in Table 6.3. Table 6.3 also shows in which period the different categories occurred. The periods are distinguished on the basis of Figure 6.3.

On the basis of Table 6.3 we see the evolution of the technological community. Two types of actors are observed in all three periods (see for the categorisation of the periods the Section 6.4.2 "The observations"). Then there are several actors that are involved in the adoption and implementation processes in Period II as well as in Period III. Finally, three types of actors are only involved in Period III, namely Juridical agency, Maintenance company and Joint venture partner. These latter actors were involved in adoption processes and implementation processes of large and complex installations, which could not be adopted in earlier time periods (see also note 25).

Table 6.3 The occurrence of categories of alters during a time period

Categories of alters	Period of occurrence
Supplier main components CHP-installation	I; II; III
Consultancy firm	I; II; III
Supplier other components CHP-installation	II; III
Electricity and/or natural gas company	II; III
Industry organisation	II; III
Financial Agency	II; III
Validation Agency	II; III
Outsource Partner	II; III
Juridical Agency	III
Maintenance company	III
Joint venture partner[25]	III

The innovation champion

Factories C, E, F, J and O were part of the same company. One employee of this company was involved in all adoption processes for these five factories. Moreover, he conducted a pre-study of several years. Before the first CHP was adopted and implemented within this company, research was conducted to get insight into the energy use of different factories of the company and the possibilities to save money and energy. The oil crisis (1973) was crucial in starting to save money in this manner. In addition, the factories of this company just shifted from coal to oil and from oil to natural gas. The prime minister Den Uijl predicted that it would not be easy to obtain natural gas in the future and that it should be used with care (only for splendid solutions, which meant for the industry a saving of at least 20%). This was an extra driver to look for appropriate solutions, because he did not want to shift back to neither oil nor coal. When energy saving has reached its maximum, it becomes useful to adopt a CHP-installation: "everything that you do not need, is always cheaper, than if you buy it cheap". In this pre-study the design of the CHP-installations was also drawn up. To accomplish this he contacted and visited several suppliers and concluded: "build small and modular installations, which do not need extra employees and which fit exactly to the electricity requirements of the factory. When the energy use of a factory increases you can add an extra module and when it decreases a module can be shut down". In 1979 the first CHP-installation was adopted in the company. In 1982 he founded a user club in order to learn from each other. Moreover, firms of other industries, such as the chemical industry, also made use of his knowledge and he was also indirectly involved in some adoption processes of other paper and board factories.

In the paper and board industry there are some larger companies of which several factories are subsidiaries. One of the advantages of such larger company is that knowledge within the company can be transferred and the external knowledge of consultancy firms is less required. This knowledge exchange within companies has also been observed in this study.

An important factor in the development of the CHP-technology community was the work of one innovation champion within this industry. In the Box this is explained in more detail.

6.4.2 Learning structures

In the previous section (Approach) we identified some specifications for the different learning structures. In learning structures 1a and 1b supplier relationships play a relative large role. With regard to learning structures 2a and 2b the relation with a consultancy firm was unique. Finally, learning structures 3a and 3b were defined by a relation with an outsource partner. For these main learning structures apply that the difference between a and b is the structure to not hire versus hire new personnel, respectively. Based on results of the interviews, examples of networks of these different learning structures are given in Figure 6.2. Structure 3b was not observed and is therefore not shown in Figure 6.2.

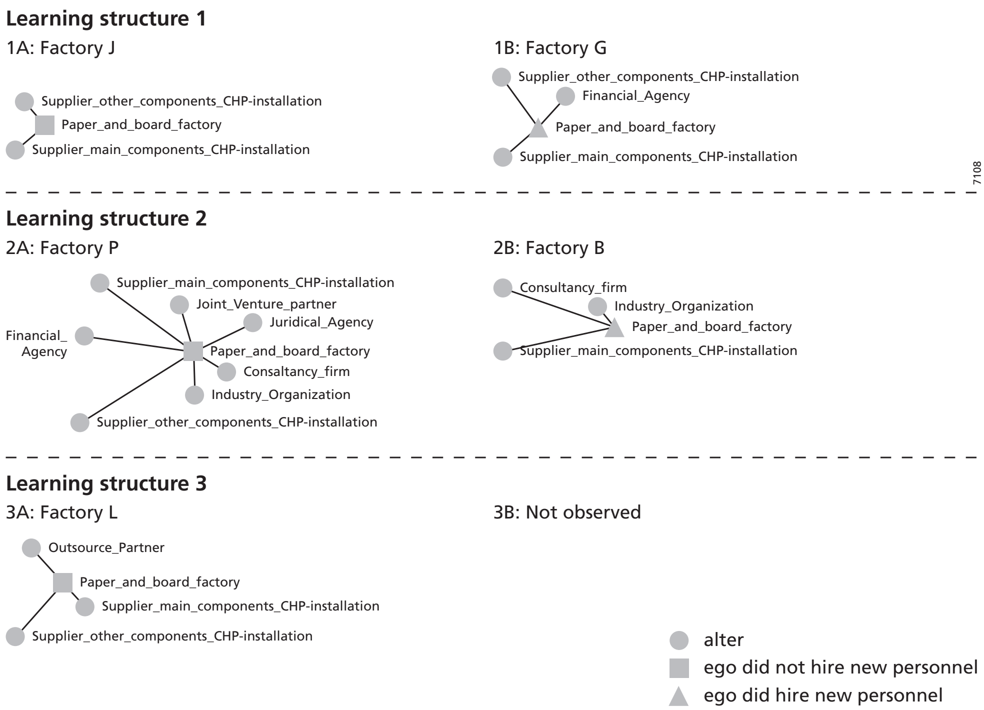

Figure 6.2 The different networks

6.4.3 The observations

Table 6.4 and Figure 6.3 display the period when the different factories adopted the CHP-installations. In addition, the complexity (the type CHP-installation), the strength of the internal resource base (the fit between the technology and the competences), and the learning structure followed are shown. A more detailed story for each factory is given in Appendix 6-I. In this appendix the networks are given for each factory. On the basis of these networks we determined the learning structure.

On the basis of Table 6.4 and Figure 6.3, three observations can be made. First, there are two main periods in which most adoptions took place. The first period is between the end of the seventies until the mid eighties. The second period is the first half of the nineties. As from the late fifties of the 20th century the first CHP-installations were adopted. However, most of these installations are now replaced. Therefore, only one of these original adoptions of this period, namely Factory A, is still shown in this figure.

Second, with regard to the complexity, type 2b is not observed and 3b only once. This has to do with possibilities to deliver electricity back to the grid. In 1989 the Electricity Law was implemented. As a consequence of this law the production and distribution of electricity were separated. The only way the distribution companies could "produce" electricity was to form a joint venture with industry. Therefore, the distribution companies got interested to cooperate in

CHP. Since that time large CHP-installations have been built that produced more electricity than the paper mill used (Factory M, N and P). This was economically feasible, because there was now a proper feed-in price as a result of the Electricity Law of 1989. The large CHP-installations provide the paper and board mill with heat and electricity. The remaining electricity goes to the electricity distribution company. Such installations are based on the heat demand. In the period before the Electricity Law of 1989 it was not attractive to produce more electricity than a factory uses, because there were no proper feed-in tariffs. As a consequence the capacities of the installations originating from that period are based on the local electricity demand.

Table 6.4 An overview of the observations for each factory

	Time	Complexity	Internal resource base	Learning Structure
Factory A	1959	Type 1	Weak	2b
Factory B	1977	Type 4	Strong	2b
Factory C	1979	Type 2a	Strong	1a
Factory D	1980	Type 1	Strong	2a
Factory E	1982	Type 2a	Strong	1a
Factory F	1982	Type 2a	Strong	1a
Factory G	1982	Type 3a	Very weak	1b
Factory H	1982	Type 3a	Very strong	1a
Factory I	1982	Type 3a	Weak	2a
Factory J	1983	Type 2a	Strong	1a
Factory K	1986	Type 3a	Weak	3a
Factory L	1992	Type 3a	Strong	3a
Factory M	1992	Type 4	Very strong	1a
Factory N	1993	Type 3b	Very strong	1a
Factory O	1993	Type 2a	Strong	1a
Factory P	1993	Type 4	Strong	2a
Factory Q	1995	Type 2a	Weak	2a

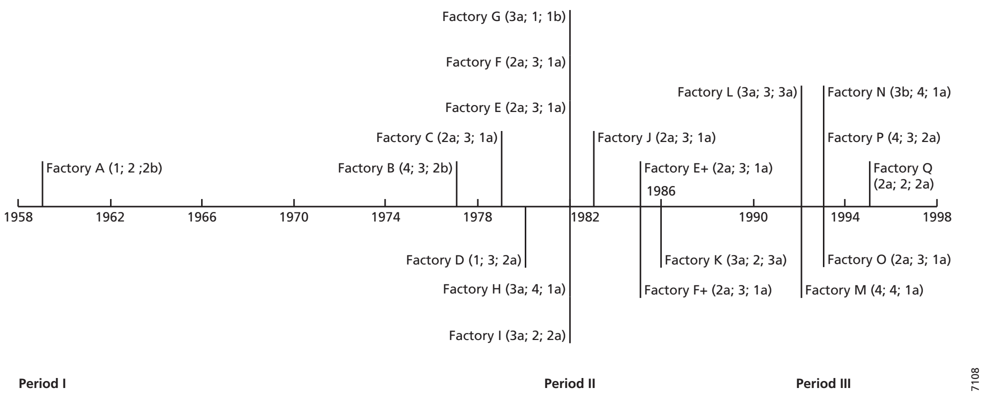

Figure 6.3 Adoption of the current CHP-installations in the Dutch paper and board industry. The numbers between brackets stand for the complexity, the internal resource base and the learning structure respectively. + = extension [26]

As to learning structures it turns out that learning structure 1 (1a and 1b) is applied most frequently (9 out of 17 firms), which means that most focal firms learned from their supplier networks. Learning structure 2, occurs in all periods at 6 out of 17 firms, indicating that these more elaborate networks also were quite fashionable. Learning structure 3 (3a) appears only twice, which suggests that outsourcing was not considered very useful for implementing CHP-installations.

Furthermore, it becomes clear that only in the beginning of the observed time period new personnel was hired. This observation fits our expectations (hypothesis 4), saying that new personnel would only be hired in early periods. Moreover, it appeared during the interviews that this new personnel originated from the shipping industry. At that time, they were already used to work with high density boilers and turbines, whereas a lot of the engineers in the paper and board factories were not.

Finally, it is hard to discover obvious patterns, with regard to the strength of the internal resource base, the technological complexity and learning structures, if we take the whole period into account. Over time all types of learning structures appear and different combinations of internal resource base – complexity are observed. However, if we take a closer look per period we do observe some trends. These will be discussed below. Period I exists of one factory (Factory A) only. The internal resource base was relatively weak and the complexity low. This factory followed learning structure 2b. This is all that is observed with regard to Period I. Therefore, this "period" will not be discussed any further below. The focus lies on period II and III. The results for each of the four hypotheses we set out in the theoretical framework will now be discussed.

Hypothesis 1: The strength of the internal resource base in relation to the learning structure.
In the theoretical section we argued in hypothesis 1 that firms with stronger internal resource bases will use its own knowledge and supplier in the adoption and implementation process (learning structure 1a) and firms with a weaker internal resource bases will have more additional partners on top of the suppliers. This would be the expected combinations:

- Very strong or strong internal resource base → Learning Structure 1a
- Weak or very weak internal resource base → Learning Structure 1b, 2a/b, 3a/b

Table 6.5 The observed combinations of learning structures and the strength of internal resource bases for Period II and III

Internal resource base	Period II				Period III			
Learning Structure[1]	Very weak	Weak	Strong	Very strong	Very weak	Weak	Strong	Very strong
1a			C,E,F,J	H			O	M, N
1b	G							
2a		I	D			Q	P	
2b			B					
3a		K					L	
3b								

1: Learning Structure: see Table 6.1 for explanations of the different structures
The characters represent the different factories.

Table 6.5 shows which combinations of learning structures and internal resource base are observed per period. Our findings in Table 6.5 confirm hypothesis 1 for 13 out of 17 cases. Only factories B, D, L, and P did collaborate more extensively than we expected. These four factories have a strong internal resource base, but did not follow Learning structure 1a. Results are very similar for the two periods.

Overall, we found a relative large support for hypothesis 1.

Hypothesis 2: The technological complexity in relation to the learning structure

For a full confirmation of hypothesis 2 we expect the following combination of technological complexity and learning structures: the more complex the technology the more additional partners – on top of the suppliers – will be engaged in the learning structure. This would be the expected combinations:

- Low technological complexity (type 1 and 2a and 2b) → Learning Structure 1a
- Medium technological complexity (type 3a and 3b) → Learning Structure 1b and 2a
- High technological complexity (type 4) → Learning Structure 2b or 3a/b.

Table 6.6 shows combinations of learning structures and technological complexity per period. On the basis of Table 6.6 we found confirmation of Hypothesis 2 for 7 out of 10 cases in Period II and for 1 out of 6 cases in Period III.

Hence, for period II we do observe for most factories that more complex types are adopted by means of learning structures with a focus on external knowledge, although there are some exceptions. Factories H adopted and implemented a relative complex type, without the acquisition of external knowledge, whereas in the case of Factory D it was the other way around: a relative simple installation was adopted with learning structure with an external focus. Finally, Factory K adopted and implemented an installation with a medium complexity, but, in contrast to our expectations, outsourced the project.

Period III is a different story, because we did not find support for hypothesis 2. Relative complex CHP-installations and also relative simple CHP-installations are adopted and implemented with learning structures based on supplier relations and internal knowledge as well as with learning structures based on acquiring external knowledge.

Table 6.6 The observed combinations of learning structures and technological complexity for Period II and III

Complexity[1]	**Period II**						**Period III**					
Learning Structure[2]	**1**	**2a**	**2b**	**3a**	**3b**	**4**	**1**	**2a**	**2b**	**3a**	**3b**	**4**
1a		C,E, F, J		H				O			N	M
1b				G								
2a	D			I				Q				P
2b						B						
3a				K						L		
3b												

1: Complexity: See approach for the specification of the different types of complexity.
2: Learning Structure: see Table 6.1 for explanations of the different structures.
The characters represent the different factories.

Overall, we found a relative large support for hypothesis 2 in Period II, but not in Period III.

Hypothesis 3: The interaction effect of the internal resource base and technological complexity in relation to the learning structure

The technological complexity and the strength of the internal resource base can also have an interaction effect on the choice of learning structures. In the theoretical section we made clear that the technological complexity determines if the internal resource base is sufficient and therefore influences learning structure. We argued that a strong internal resource base and a low complexity increases the likelihood that the set of partners will be limited to supplier relations and the firm will furthermore rely on its own knowledge (Learning structure 1). We will discuss the results per period.

Period II

Figure 6.4 shows for Period II which factory followed learning structure 1 and 2, as well as the strength of the internal resource base and the technological complexity of these firms. Learning structure 3 was only followed by one factory (Factory K), and is for this reason not shown in the figure. The internal resource base of this Factory K was weak and the installation relative complex installation. This factory did not hire new personnel.

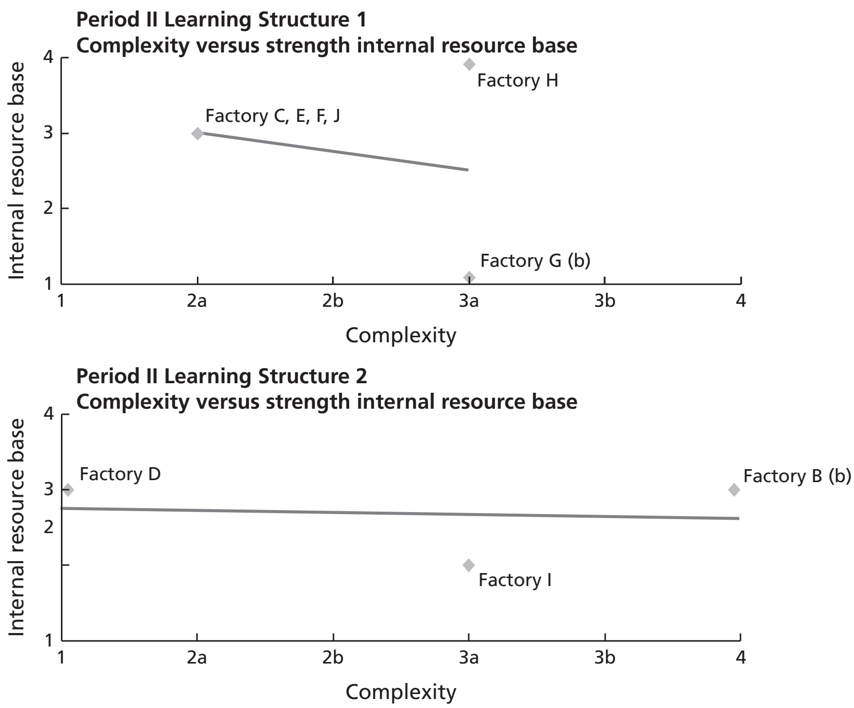

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Figure 6.4 Period II Learning structures 1 and 2, internal resource base and complexity (b) = the firm hired new personnel.

Overall, in period II learning structure 1 is characterised by on the one hand relative simple installations, with a reasonable strength of the internal resource base and on the other hand by more complex installations, but with a strong internal resource base. Compared to learning structure 2 and 3, we observe stronger internal resource bases and lower complex installations in the case of learning structure 1. So, for structure 2 and 3 the internal resource base was weaker and the installations were most of the time more complex. This supports hypothesis 3. Two exceptions were Factory D and G. Factory D adopted and implemented the installation early and despite the relative strong resource base and the low complexity of the installation, they needed external advice (learning structure 2a). Factory G with a weak internal resource base and relative complex installation followed learning structure 1b. However, Factory G had the opportunity to obtain knowledge within the company.

Period III

Figure 6.5 shows for Period III (alike Figure 6.4 for Period II) which factory followed learning structure 1 and 2, as well as the strength of the internal resource base and the technological complexity of these firms. Also in this period learning structure 3 is observed only once. The internal resource base of that factory (Factory L) was reasonable as well as the complexity. In comparison to Factory K, which also followed Learning structure 3 in the former period, the

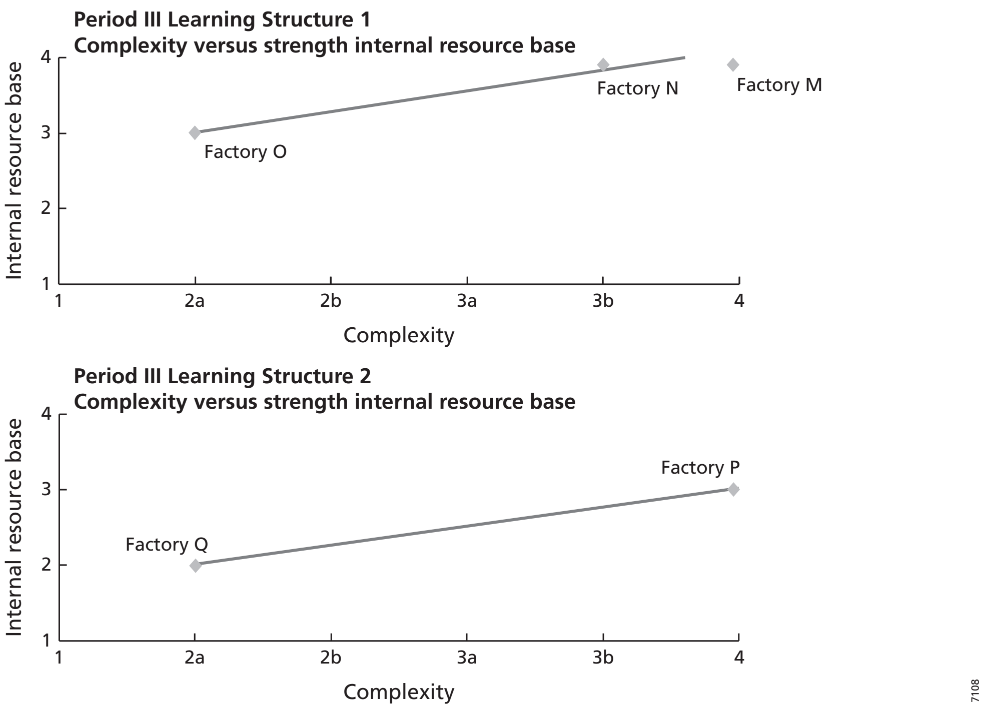


Figure 6.5 Period III Learning structures, internal resource base and complexity (b) = the firm hired new personnel.

only difference is that the internal resource base is higher for the factory in this period and the complexity is the same.

Overall, we observe in this period that the internal resource base is stronger in the case of learning structure 1 compared to learning structures 2 and 3 for adoptions and implementations of installations with the same complexity. This is visible in Figure 6.5 because the trend line in the upper part of the figure is higher located than the trend line in the lower part of the figure. These findings support hypothesis 3.

Hypothesis 4: The importance of time
As to the role of time we did argue that as knowledge accumulates and spreads throughout the CHP-technology community over time, in later periods more often (complex) installations can be adopted and implemented without external knowledge, because of accumulated knowledge bases of firms. Moreover, we argued that new people will mainly be hired in early periods, which we indeed observed (see earlier in this section).

If we compare the observed combinations of complexity and internal resource base for learning structure 1 over the different periods, we clearly see an indication for the accumulation of knowledge. With regard to learning structure 1 there is a shift from:

- Period II: presence own knowledge – relative low complexity & presence own knowledge – relative moderate complexity
- Period III: presence own knowledge – relative low complexity & presence own knowledge – relative high complexity

These results show that in later periods relative more complex installations were adopted and implemented without external knowledge and support hypothesis 4. So, time seems to play an important role!

6.5 Conclusion and discussion

The aim of this research was 1) to identify temporal patterns in the use of different composition of learning structures, and 2) to get insight into the effects of the strength of the internal resource base and technological complexity on differentiated use of learning structures. We reworked the notion of interactive learning, introduced by Lundvall and further explored and tested by Meeus and colleagues and Nooteboom. Whereas these studies on interactive learning start from a dyadic perspective, we use a community approach. We adapted the notion of interactive learning by including the configuration of partners, which reflects a variety of learning structures. We have focused on one technology, CHP-installations, in one industry, the Dutch paper and board industry.

Compared to stylised facts of variance approaches, which often suggest robust patterns, in our study it appeared difficult to identify temporal patterns over the whole time period. We identified two patterns (research question 1). However, before we will discuss these patterns, we discuss the role of one person in specific. We observed a typical innovation champion. This innovation champion was part of larger company and was involved in the adoption processes of all factories within this concern. Before the first adoption took place he conducted an extensive study to design the most optimal installation. He also founded a user club and diffused his knowledge to other paper and board factories, but also other industries. These activities started at the beginning of Period II. The period in which we see a large diffusion of CHP installations. He successfully promoted this technology and supported the (building of a) knowledge infrastructure.

We will now discuss the two patterns we observed. First, it appeared that most factories (9) relied on supplier relations only in addition to their own knowledge (learning structure 1), whereas six factories collaborated with consultancy firms or other knowledge relations (learning structure 2). Outsourcing (learning structure 3) was only observed twice. Considering that CHP is an environmental innovation, our observation that more than half of the learning structures were based on supplier relations and own knowledge solely is remarkable. As we discussed in the theoretical section, in the case of environmental innovation it would be more likely that the acquisition of external knowledge would be necessary in addition to supplier relations (Ehrenfeld, 1999; Marcus et al., 1999). However, this observation can be partly explained by the fact that although energy efficiency is an environmental topic, this topic is of economic importance for the Dutch paper and board industry as well. Energy efficiency has been on its innovation agenda for a long time. Moreover, the innovation champion by means of promoting this technology and supporting and building the knowledge infrastructure has probably played a role. The innovation champion and the tradition in improving energy efficiency may explain the fact that learning structure 1 is often observed. Moreover, this importance of energy efficiency improvement for paper and board factories may also explain the observation that learning structure 3 is followed only twice. In view of the (economic) importance of energy, the factories want to have the energy provision in their own hands. Although there is a trend during the last decade to minimise the number of employees within a firm that is working on the topic energy (De Gram, 2007). Therefore it may be possible that in the future less firms are able to innovate without the acquisition of external knowledge.

The second pattern that we identified was that only in early periods new employees were hired, which originated from the shipping industry. This is in line with what we expected about knowledge accumulation within the firm (hypothesis 4), which made it possible that new personnel in later stages need not to be hired. In addition, due to automation the installations that were adopted and implemented at later stages needed fewer engineers.

Research question 2 asked about the influence of technological complexity and the strength of the internal resource base of the innovating firm on the learning structures over time. We distinguished three time periods. Period I contained only one factory of which the strength of the internal resource base was low, as well as the technological complexity. This factory followed learning structure 2b. This is all that is observed with regard to Period I. Therefore, the remaining part of the conclusion focuses on Period II and III.

We formulated four hypotheses in the Theoretical Framework. Hypothesis 1 predicted that a firm with a very strong or strong internal resource base will follow learning structure 1a and that a weak of very weak internal resource base would result in the Learning structure 1b, 2a/b and/or 3a/b. We found relative large support for hypothesis 1 for Period II and III. Hence, it indeed seems that in the case of sufficient internal resources innovating firms have no incentive to look for external partners with the exception of supplier relations, whereas a lack resources results in hiring new personnel, in knowledge relations, and/or in outsource relations (learning structures 1b, 2a/b and 3a). This resource deficits argument is in line with earlier research (Teece, 1986; Meeus et al., 2000; Nooteboom, 2000). This means that interactive learning is broadened when the company lacks resources.

In Hypothesis 2 we proposed that for the adoption and implementation of more complex installations it is more likely to follow a structure with a focus on the acquisition of external knowledge. Where we found some support for this hypothesis in Period II, we did not found any support for it in Period III. This in contrast to earlier studies of Nagarajan et al (1998) and Meeus and colleagues (2001a; 2004). Meeus and colleagues found support for a positive linear relation between the complexity and level of interactive learning of the innovation firm with customers (Meeus et al., 2001a) and with universities (Meeus et al., 2004). They also found support for an inverted u-shape relation between the complexity and the level of interactive learning with universities and research institutes (Meeus et al., 2004). However, we observed that relative simple installations were adopted and implemented by means of the acquisition of external knowledge. An explanation for this observation can be that some innovating firms prefer to involve external knowledge resources in the case of non-core innovating activities even though the installation is relative simple. Moreover, in our case interacting with customers isn't useful anyhow. Whereas the studies of Meeus and colleagues (2001a; 2004) focus on product and process innovation in general, we focus non-core process innovation (environmental innovation).

It appeared that hypothesis 3, in which we look at the interaction effect of both independent variables (the strength of the internal resource base and the technological complexity), results in fruitful explanations. Meeus and colleagues, in their studies, found support for a u-shape relation between the interaction effect of complexity of the activities and the strength on the internal resource base and the level of interactive learning with the knowledge infrastructure (Meeus et al., 2004) and an inverted u-shape for the level of interactive learning with customers (Meeus et al., 2001a). In our study, we concluded for period II that in general learning structure 1 was associated with a lower complexity and a stronger internal resource base in comparison to learning structures 2 and 3. In the case of learning structure 2 and 3 higher complexities and weaker internal resource bases were observed. Also for Period III differences have been observed between the distinguished learning structures. With regard to Period III it can be concluded that the internal resource base was weaker for the firms that followed learning structures 2 and 3 compared to learning structure 1. Overall, we can conclude that hypothesis 3 (a positive linear relation) is supported. This implies that a high complexity requires skills, capabilities, and/or knowledge, which most innovating firms do not have internally (Zahra et al., 2002). As a consequence these innovating firms will acquire external resources and search for partners other than solely suppliers.

Finally, we can conclude that knowledge accumulation has taken place, as we predicted in hypothesis 4. We observed that in later periods firms do not hire new personnel and do not acquire external knowledge for adoptions of the same complexity due to a stronger internal resource base. Moreover, more complex installations were adopt and implement without external knowledge acquisitions in later periods. We can conclude that time is functioning as a moderating variable. Waarts and colleagues (2002) also found such a moderating effect of time.

Overall, based on this study we can conclude and learn three things. First of all, learning structures focused on the acquisition of external knowledge in addition to supplier relations and own knowledge (1b, 2a/b and 3a/b) is more likely if the internal resource base is weak, and therefore insufficient, and if the complexity is larger. The resource deficits and the large complexity determined the acquisition of external knowledge. The fact that we focus on environmental innovation is affecting the strength (or weakness) of the internal resource base concerning this type of innovation.

Secondly, knowledge accumulation takes places and can be identified if the focus of the research is on one industry and one specific technology.

Finally, as we mentioned before, we reworked the notion of interactive learning (Lundvall, 1988; Meeus et al., 2001a; Meeus et al., 2001b; Meeus et al., 2004; Nooteboom et al., 2007) by including the configuration of partners, which reflects more compositions of leaning structures to solve knowledge deficits that were encountered by the adoption and implementation of CHP-installations. This operationalisation in network configurations appeared to be a fruitful approach. Moreover, taken time into account seems to be a necessity to really get insight into the learning structures and the way in which these structures were influenced by the strength of the internal resource base and the technological complexity. It would interesting to see, if the same results show up when other technologies and/or more industries are investigated!

7 The effect of dynamics in participants' efforts and inputs in a multi-actor trial and error learning project[27]

7.1 Introduction

As discussed in the Chapter 1 and Chapter 6, we conceive innovation processes as learning processes. Either innovation entails doing the same thing in a different way, or innovation entails doing new things. In both cases the firm needs to learn. In this final empirical chapter, we want to elaborate on trial-and-error learning as this trial-and-error learning has been extensively researched by Van de Ven et al. (1992; 1999) in the Minnesota Innovation Research Program studies (MIRP). What we want to know is how this trial-and-error learning is affected by the availability, quality and volatility of inputs.

In this research we analyse a research and development project (R&D-project) of the Centre of Competence Paper and Board (Kenniscentrum Papier en Karton in Dutch). This project aims at the development of technology for sustainable production of fibre raw material. The total project has a duration of eight years, consisting of two main sub-parts. We focus on the first four years (2000-2003), where the emphasis lies on the generation of fundamental knowledge, because the final four years were not completed yet when we conducted the research. Hence, the project we study in this research focuses mainly on knowledge generation and less on further development of innovations. The environment and the reduction of environmental impact were important drivers for the start of this research project. In fact the research project is a case of environmental innovation. In this sense our case is different from the cases Van de Ven and colleagues analysed. Their cases did not focus this much on environmental innovation and knowledge generation.

The project received a subsidy of the Dutch government, namely an EET-subsidy (Economy, Ecology and Technology subsidy). At the start of the project the subsidising authority indicated that this project was a perfect example of what the subsidy aims for, namely collaboration towards a combination of Economy, Ecology and Technology. The research project we study is large collaboration of twelve (later in the project thirteen) different organisations. We can speak of a multi-actor project. It was already pointed out by the subsidising authority that it would be a difficult project due to the large number of partners and that they would look after this. It is interesting to investigate how the network of partner collaboration develops and functions over time. Although, it is often highlighted in the literature that shared visions, similar aims and commitment of partners are necessary for successful collaboration (Doz, 1996; Draulans et al., 2003; Moors et al., 2007), the effects of the dynamics in the actor network on the evolution of innovation processes are not empirically investigated before. Therefore, this research project is a good case to analyse network effects on trial-and-error learning. It enables us to relate trial-and-error learning to network dynamics.

Additionally, in R&D-projects the acquisition of human resources and the availability and quality of such a resource is a trivial issue. Although Van de Ven and colleagues talk about innovation projects and collaboration (Van de Ven et al., 1999) and about entry and exit of human resources over time (Van de Ven et al., 1992), they do not deal with these effects systematically in their analysis of the learning process. In our study these effects, availability and quality of human resources, are explicitly taken into account.

Finally, we have a methodological challenge. Similar to Van de Ven we aim to retain dynamics in trial-and-error learning by decomposing the action course in modification and continuation and outcomes in negative and positive outcomes. In contrast to Van de Ven, who combines those elements in the action course (continuation minus modification) and their outcomes (positive minus negative), we will keep them separated, resulting in four variables instead of two. The first reason for this is that they can occur within one time period; negative and positive outcomes as well as a continuation and a modification of the action course can occur within one time period. Furthermore, we expect an impact of variables on different dimensions. For instance an action course modification may result in positive as well as negative outcomes. By combining the dimensions, the dynamics will be reduced. Therefore, we will keep them separated to retain more dynamics.

Overall, the aim of this chapter is to gain insight into trial-and-error learning process and the extent to which this learning process, the sequence between actions and outcomes, is influenced by the available human resources, the performance of partners and their network dynamics. The main research question is: In what way are elements of the trial-and-error learning process interrelated to the volatility of inputs?

The following four sub questions have been formulated:

- In what way are actions and outcomes related?
- To what extent is this influenced by the availability of human resources?
- To what extent is this influenced by the performance of partners?
- To what extent is this steered by the dynamics of the collaborative network of partners organisations?

Hence, our contribution is threefold: 1) testing the learning model of Van de Ven et al. for a different type of case, namely a large multi-actor knowledge generation project concerning environmental innovation; 2) elaborating on the trial-and-error learning process by adding new variables: the availability (exit and entry) of human resources, the quality (performance) of partners, and incorporating multi-actor network dynamics into the model; 3) retaining dynamics by keeping different dimensions of variables separated.

Innovation (change and development) processes can be characterised by critical incidents, a historical context, but also by more general formative mechanisms. As a consequence, the evolution of each process is unique. To analyse such processes and take these characteristics into account, a process approach will be used (Mohr, 1982; Poole et al., 2000).

The remaining of the chapter is organised as follows. The next section presents the theoretical framework. Section 7.3 gives the methodological approach. The operationalisation, data collection and data analyses are explained. The results are then given and explained in Section 7.4. Finally, Section 7.5 contains the discussion and conclusion.

7.2 Theoretical framework

In this study we adapt the concept of trial-and-error learning. We will briefly explain the trial-and error learning process and the model of Van de Ven et al. (1992) and then explain how we elaborate the model. The core of the model of Van de Ven and colleagues is trial-and-error learning (Van de Ven et al., 1992) (p.93-94). Trial-and-error learning represents itself in an iterative sequence of actions and outcomes (Cyert et al., 1963; Levitt et al., 1988). In the innovation process studied, firms initiate actions. With the course of action chosen they strive for positive outcomes concerning the innovation project. If these positive outcomes are indeed observed, in principle there is no reason why they should alter their behaviour (action course). They do know that this action course may result in positive outcomes in the end. However, when negative outcomes are observed inducements appear to change the course of action and see whether an alternated course results in positive outcomes. The course of action will be altered until positive outcomes are experienced (Van de Ven et al., 1992; Van de Ven et al., 1999). One should for instance think of experiments and the outcomes of these experiments. If you are conducting research you have a specific goal. If the experiments that you are doing in the light of the research help you getting there (reach the goal), there is no reason to change the (setting of the) experiments. However, when the experiments are not helping you in reaching the goal, you will change your action course.

But, firms may strive for optimisation of their processes. Therefore, when the outcomes turn out to be positive and the action course is being continued, after a while, firms may change their action course to strive for even better results due to perceived reduced or negative marginal return on continuation of the action course.

Finally, over time goals and criteria shift (Van de Ven et al., 1992) and conditions within the context change (Waarts et al., 2002). Due to this change it is possible that outcomes that would be assessed as positive in earlier stages will be assessed as negative in later stages. Therefore, continuing the action course after positive outcomes can eventually result in negative outcomes. Therefore, our basic hypotheses derived from trial-and-error learning are (see also Figure 7.1):

1a Positive outcomes increase the likelihood that the action course is continued, which in turn increases the likelihood of positive outcomes, whereas negative outcomes increase the likelihood that the action course is modified, which in turn could lead to both negative as positive outcomes.

1b In the case of continuing positive outcomes the likelihood increases that over time the action course is modified.

1c In the case of a continuation of the action course after positive outcomes, firm may encounter negative outcomes.

Van de Ven et al (1992) (p.104) found support for trial-and-error learning in the developmental stage of innovation based on two statistically significant results: 1) a positive interaction effect of prior actions and outcomes on subsequent actions and 2) a positive relation between a continuation of prior action and subsequent outcomes. However, Van de Ven et al. did not find trial-and-error learning in the first stage, the initiation stage, of the innovation process (Van de Ven et al., 1992). They conclude that in this initiation stage of innovation processes firms might learn by discovery, instead of by trial-and-error learning.

In addition Van de Ven et al. (1992) incorporated the influence of contextual events, goal and/or criteria shifts[28] and interventions of the top management in the learning process. Management will decide upon the outcomes, whether or not they intervene. In the case of positive outcomes there is no reason for the management to intervene. However, if outcomes tend to remain negative then they will intervene. Their confidence in the action course that is being followed, disappears and the management wants a different course to be followed, hoping for better results. See also Figure 7.2. Management interventions in our case entail for instance that the steering group makes clear that a working group is lagging behind and that this working group should speed up its work. This has also been empirically supported by the study of Van de Ven and colleagues (1992). This results in hypothesis 2:

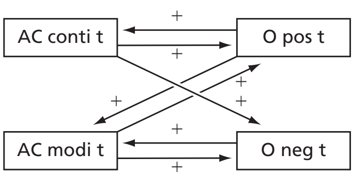


Figure 7.1 The link between actions and outcomes

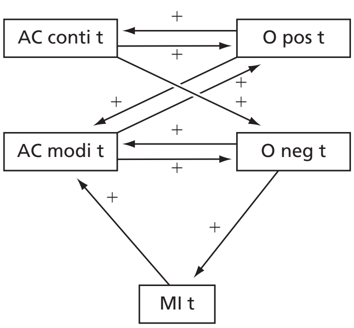


Figure 7.2 Actions, outcomes and the intervention of the management

2 In the case of continuing negative outcomes, management will intervene, with the aim to modify the action course, which should lead to positive outcomes.

For an innovation process input of resources is required. Resources are defined as all tangible and intangible assets that are tied to the firm in a relatively permanent fashion (Penrose, 1959; Wernerfelt, 1984). Several types of resources can be identified, such as financial, physical and human resources (Del Canto et al., 1999). What is not prominently present in the trial-and-error learning model of Van de Ven and colleagues is this input of resources in the innovation process. Though, the success of a multi-actor innovation project is dependent on the participation of knowledgeable human resources and the performance of partner organisations. In innovation processes, especially in the phase of knowledge generation, we expect knowledge to accumulate. The iterative sequence of actions and outcomes should result in knowledge accumulation. But we do know that resource inputs fluctuate. There is a certain turnover of members, which will impact upon the learning process. Moreover, the performance of these members as well as their interaction are determining this process of knowledge accumulation. Therefore, input on the level of the partners, the human resources and the interactions between the partners (network dynamics) will be discussed below.

Performance of partners

During an innovation project time investment and the involvement of participants change (Cohen et al., 1972). Participants are often involved in more projects at the same time. If this implies that they spend less time than needed on the project and are less involved than required this will result in reduced performance of partners. In other words, they will not perform well. If this is the case and the performance of partners is suboptimal, the outcomes of the project will also negatively be influenced. Whereas, good performance of partners will result in positive outcomes. On the other hand outcomes will also influence the performance of partners. We do know that the motivation of people is depending on intrinsic factors as well as extrinsic factors. Feedback is such an extrinsic factor (Moynihan et al., 2007). Positive outcomes may stimulate and motivate partners (Brown et al., 1997). As a consequence they will be more committed to the project, are more willing to continue and even do some extra work/exertions for the project. The partners will perform better. But negative outcomes give rise to uncertainty and may result in undesired behaviour of partners. They may become risk-averse and follow a wait-and-see strategy (Van de Ven et al., 1999). This negative performance enhances the chance of negative outcomes. This results in hypothesis 3a:

3a Positive performance of partners increases the likelihood of positive outcomes, which in turn increases the likelihood of positive performance of the partners, whereas suboptimal performance of partners increases the likelihood of negative outcomes, which in turn increases the likelihood that partners will perform below expectations.

As explained earlier management intervenes with negative outcomes and will modify action courses. In case of suboptimal performance of partners we specify these negative outcomes. Also here we expect management to intervene. Yet, in R&D-projects this is not a trivial issue, because this suboptimal performance is really a matter of evaluation, which is sensitive for all kinds of

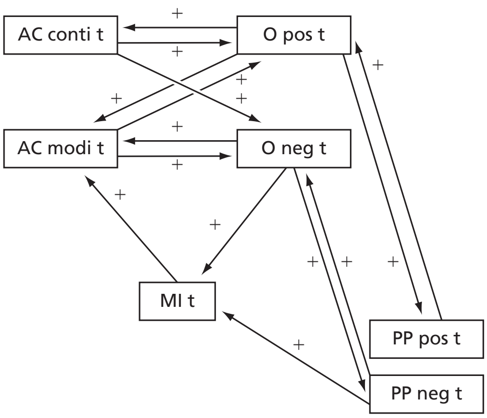


Figure 7.3 The loop of action, outcomes, management interventions and the performance of partners

external effects. An example of suboptimal performance is a partner doing other things than agreed on in the research proposal. This relation is displayed in Figure 7.3 and hypothesis 3b:

3b In the case of suboptimal performance of partners, the likelihood increases that management will intervene.

Availability of human resources
The availability of qualified people is another aspect we want to take into account in this study. When trial-and-error learning was not observed in a certain period of the case studies of Van de Ven and colleagues they noticed that in the same period turnover of personnel was large. They see this turnover as an explanation for this "non-learning" (Van de Ven et al., 1992).

Turnover of personnel is discussed in the literature in which positive as well as negative consequences of such turnover are reported (Staw, 1980; Dalton et al., 1982). Personnel turnover implies that members leave and new members join. The members that leave, will take valuable and strategic knowledge with them. If this knowledge is tacit, it will permanently disappear from the project. On the other hand, an advantage of members leaving the project, may be the possibility to change the existing practices/routines and modify the action course. Otherwise a relative redundancy of members' perspective can develop (Reagans et al., 2001). These new members may bring new knowledge, fresh ideas and creative problem solving (Madsen et al., 2003). Thus, more diverse inputs, in other words, new members, may result in better performance (Reagans et al., 2001). But, a high turnover also causes problems for the continuity of the project (Pfeffer, 1985). Hence, in the literature we found support for a duality of effects. Beforehand we do not know which effect dominates. Therefore, we will test a competing set of hypotheses. See also Figure 7.4. This results in the following hypotheses:

4a The entry of human resources can result in a continuation as well as in a modification of the action course.
4b The exit of human resources can result in a continuation as well as in a modification of the action course.

Such a change in the availability of human resources can be the result of management interventions. It is a task of the management to facilitate and steer such processes. Lado et al (1994) (p.720) conclude that "managers may need continuously to question and re-examine their assumptions regarding what constitutes a distinctive competence for their firms" (network project in our case). Negative outcomes may, according to the management, require a different employment of human resources in the hope that it results in a new action course, which in turn produced in positive outcomes.

However, a change in the availability of human resources can also be the direct effect of outcomes. Negative outcomes may stimulate members to leave the project (Olk et al., 1997). See also Figure 7.4. This results in hypothesis 4c:

4c Changes in the availability of human resources, the entry or exit of human resources, are likely to be the consequence of management interventions after negative outcomes, whereas the exit of human resources can also be the direct effect of negative outcomes.

Network dynamics
A final variable is about the interplay between the participants. The participants in our case form a network. Networks are said to "…channel direct flows of information and resources from position to position within a social structure" (Owen-Smith et al., 2004) (p.5). The social interactions among individuals result in the development and transfer of knowledge across organisations (Nonaka, 1994). If this knowledge is deliberately distributed, innovation may be stimulated (Tsai, 2001). A higher network density is said to have a positive impact on innovation outcomes (Reagans et al., 2001). More frequent communication result in more knowledge sharing (Uzzi, 1997; Reagans et al., 2003). Hence, learning depends on the levels of interaction among the members (Inkpen, 1995). A high participation can been seen as a reflection of the level of commitment of partners, which is suppose to have positive effects on performance (Brush et al., 1999). Important moments when this knowledge is developed and exchanged in our case are the meetings of the working groups. Therefore, to facilitate this knowledge exchange

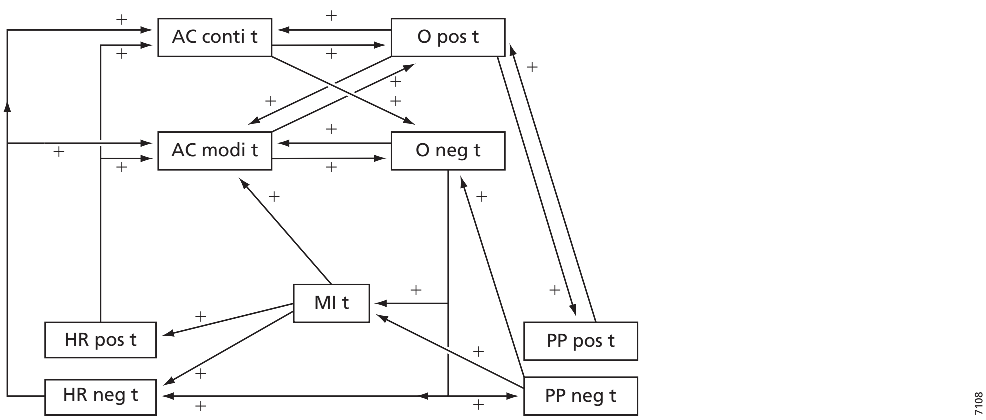


Figure 7.4 The relation between actions, outcomes, management interventions, the performance of partners and the availability of human resources

a high participation in these meetings is important. Especially, in diverse teams the presence of participants during meetings is important. If each participant has its own specialisation and competences, the difficulties as a consequence of absence are larger than in the situation that participants are able to perform each others tasks.

In addition, stability of the network is required. A small network, such as we are looking at, remains stable if the composition remains unchanged (Palla et al., 2007). If in each meeting other persons turn up, which reflects a volatile network, it will be difficult to learn from earlier events. This hinders knowledge accumulation. It may also have a discouraging effect, because news on progress is not known to all. This network volatility is important for the meetings of a working group, but is also important for the knowledge exchange between different working groups.

These network dynamics (participation and volatility) can influence all other variables. See also Figure 7.5. This results in the final set of hypotheses:

5a A high participation increases the likelihood of positive outcomes, a continuation of the action course, positive performance of the partners, less management interventions, and less exit of human resources.

5b A high volatility (of the working group and for the project as a whole) increases the likelihood of negative outcomes, a modification of the action course, suboptimal performance of the partners, more management interventions and more exit of human resources.

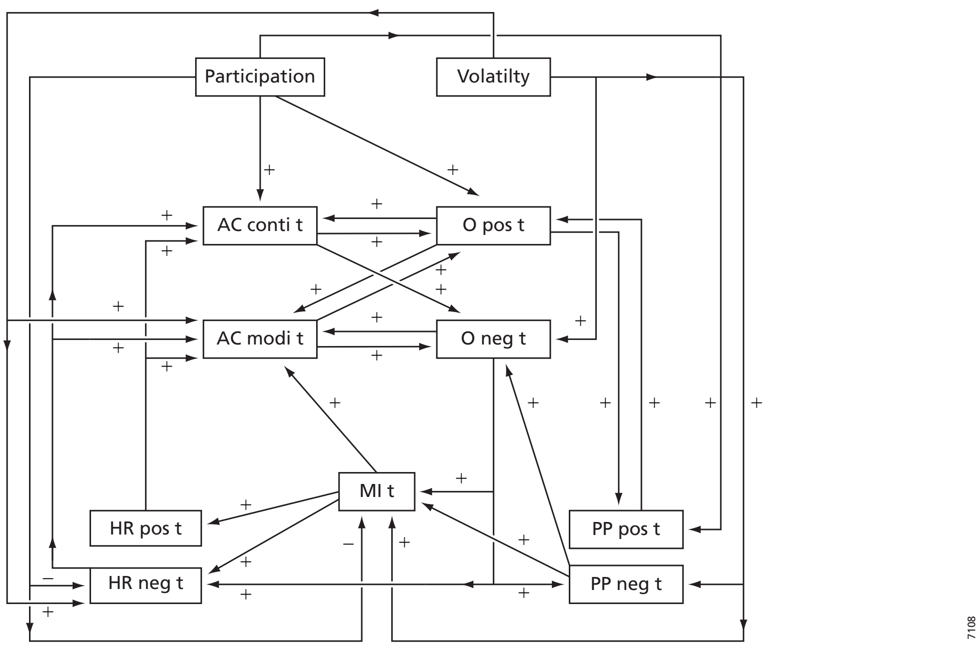


Figure 7.5 Conceptual model of actions, outcomes, management interventions, performance of partners, availability of human resources and the network dynamics

The hypotheses of this section can be linked to the different sub-questions stated in the introduction. We can link them as follows:

- In what way do trial-and-error learning processes develop? → Hypotheses 1a, 1b, and 1c. However, we will discuss hypothesis 2 in this light as well.
- To what extent is this influenced by the availability of human resources? → Hypotheses 3a and 3b
- To what extent is this influenced by the performance of partners? → Hypotheses 4a, 4b, and 4c
- To what extent is this steered by the dynamics of the collaborative network of partners organisations? → Hypotheses 5a and 5b.

7.3 Methodology

In Table 7.1 the operationalisation (coding scheme) is given. The first column gives the different concepts we used (see theoretical section) and the second column the different dimensions of

Table 7.1 Operationalisation of variables

Concepts	Dimensions	Indicators	Variables	Example events*
Action Course	Continuation	A continuation of an course such as an experiment, literature study, desk top research	AC conti = 1; else 0	Partner x will continue experiments to look at y
	Modification	A modification in the action course such as an experiment, literature study, desk top research.	AC modi = 1; else 0	Before a detailed work plan will be made member x first wants to make an inventory about y
Outcomes	Positive	Results of experiment, literature study, desk top research are positive or in line with the expectations	O pos = 1; else 0	It was concluded that for process x, y is an interesting additional process variable.
	Negative	Results of experiment, literature study, desk top research are negative or not in line with expectations	O neg = 1; else 0	Partner x concluded that y is not an option to study.
	Mixed	Results of experiment, literature study, desk top research are positive as well as negative	Omixed: split in ½ Opos and ½ Oneg; else 0	x led to a better correlation than y however y still gives significant higher values in the case of z.
Management interventions Partners	Presence	Clear statement in minutes about intervention of management (steering group or project management team) with regard to partners	Intervention partners present = 1; else 0	Steering group send letter to partner to ask for indemnification

(Table 7.1 continued)

Concepts	Dimensions	Indicators	Variables	Example events*
Management interventions General	Presence	Clear statement in minutes about intervention of management (steering group or project management team)	Intervention general present = 1; else 0	Steering group has decided that this topic does not fit in the aims of our current project
Performance of partners	Positive	Positive assessment about the performance of partners	O + partner = 1; else 0	Partner x: they are on time and are doing fine
	Negative	Negative assessment about the performance of partners	O – partner = 1; else 0	More input should be obtained from partner x
	Mixed	Assessment about the performance of partners with a positive as well as a negative judgment	Omixed partner split in ½ O + partner and ½ O – partners; else 0	Partner is being taken over, but future looks promising.
	Modification	A partner changes it contribution in the project	Omodi partner split in ½ O + partner and ½ O – partners; else 0	Partner undergoes restructuring. Its task will be performed by another part of the organisation
Availability of human resources	Positive	New project members arrive	HR + = 1; else 0	Person x is a new employee of partner y who will be working within the project.
	Negative	Project members leave or new project members are not available	HR – = 1; else 0	Person x will leave partner y.
	Mixed	Positive as well as negative announcement about human resources	HR mixed split in ½ HR + and ½ HR -; else 0	Person x is due to fill in the vacancy, but there are problems with official papers.
	Modification	Project members are replaced	HR modi split in ½ HR + and ½ HR -; else 0	Person x will be taking the place of person as the working group A representative of partner x.
Network dynamics: Participation working group		Presence during meeting x/theoretical presence of meeting x (who should been present)	Participation lies between 0 and 1	N/A
Network dynamics: Volatility working group		Volatility t_{and} t_1: # of nodes changed t_{and} t_1/ total # nodes t and/or t_1 t and t_1 are subsequent meetings of one working group	Volatility lies between 0 and 1	N/A
Network dynamics: volatility total project		Volatility: # of nodes changed t_{and} t_1/total # nodes t and/or t_1 t and t_1 are subsequent meetings in the project	Volatility lies between 0 and 1	N/A

*Due to confidentiality, the specific content of the events has been made anonymous.

these concepts. The third column shows when incidents are coded/identified as such. The fourth column gives the specific coding of incidents. Finally, the fifth column gives example events.

In their study on the relation between actions and outcomes, Van de Ven and colleagues, use one resultant for the action course (continuation minus modification) and one for the outcomes (positive minus negative). As one can see in the operationalisation above, we will use separate variables for modification and continuation of the action course as well as separate variables for positive and negative outcomes. We already explained in the introduction that in this way more dynamics is retained.

At first sight it might seem that performance of partners and network dynamics measures overlap. However, this is not the case. Performance of partners is based on assessments of performance, whereas network dynamics are based on attendance during the meetings.

To analyse this project we have taken the following six steps:
1. Building the database of incidents
2. Coding the incidents
3. Check coding
4. Time series construction
5. Ordinary least squares based Time Series Analysis (OLS)
6. Two stage least squares analysis based Time Series Analysis (TSLS)

1. Building the database

The first step was to build a database. The idea is simple. We listed all incidents that took place within the project. In practice, this procedure is time consuming. To build the database we used the following sources:
- Minutes of meetings of working groups, project management team, and steering group
- Reports written for the project
- Presentations within the project
- Archive Centre of Competence Paper and Board
- Some face-to-face talks for clarification

With regard to the network data, we had the availability of the following data about persons in the project:
- Presence during meetings
- Memberships of working groups, project management team, and/or steering group
- Organisation
- Type of participating organisation (university, research institute, industry supplier, paper and board mill)
- Budget of the organisation (and total amount of subsidy received)

The next step was coding these incidents into events.

Table 7.2 Number of codes per working group

Working group	Number of distinct codes
WG A	239
WG B	199
WG C	247
WG D	139
Total	824

Table 7.3 Interrater Reliability of researcher and three coders

	Overall agreement	Change agreement	Cohen's Kappa
Coder 1	0.90	0.089	0.89
Coder 2	0.92	0.073	0.91
Coder 3	0.85	0.032	0.85

2. Coding these incidents

This long list of incidents needed to be coded. One incident can yield more than one code. This coding was done according to the coding scheme, given in Table 7.1. This resulted in 824 codes. Table 7.2 below presents the number of codes for each working group.

3. Check coding

In order to check for subjectivity of the coding, three other coders were involved. Each of them coded a different subset of the database, consisting of 48, 51, and 68 codings, respectively. In general there was a large agreement among the research and the coders. Differences in coding were discussed and when necessary accommodated. Table 7.3 presents the interrater reliability. Appendix 7-I shows the calculation. The Cohen's Kappa is in all cases above 0.8, which suggest a reasonable interrater agreement (Poole et al., 2000) (p. 166).

4. Time series construction

On the basis of the coded database, different time series of all variables have been created. We compared four types of time series: time series consisting of the dates of incidents, time series aggregated over 1 month, time series aggregated over 2 months, and time series aggregated over 3 months. The time series of 2 months provided us with a maximum number of data points and a minimum number of missing values. Therefore, we use these 2 months time series.

Such an aggregation results in discrete count data, whereas ordinary least squares and two stage least squares analyses requires continuous data. To check if we are allowed to apply regression analyses (OLS and TSLS) to our time series, we made a comparison of discrete ordinal Kendalls-Tau B and continuous interval Pearson's correlations for the variables of the model. See also the Box. No systematic deviations between Pearson's correlations and Kendalls-Tau B appeared. Thus, as the estimated Kendalls-Tau B and Pearson's correlation do not differ structurally from each other, i.e. no structural bias is present, the time series data are conceived as continuous data allowing Times Series Analyses by means of OLS and TSLS methods.

Pearson versus Kendall's tau-b

210 correlations were calculated with each correlation measure
12 times Pearson correlation coefficient was significant in cases where Kendall's tau-b correlation coefficient was not
20 times Kendall's tau-b correlation coefficient was significant in cases where Pearson correlation coefficient was not
Pearson correlation coefficient was 51 times higher than Kendall's tau-b correlation coefficient in the case of significant correlations
Kendall's tau-b correlation coefficient was 35 times higher than Pearson correlation coefficient in the case of significant correlations

For all working groups time series were created. However, for working group D the concept of network dynamics of the working group (participation and volatility in working group D) could not be used due to a lack of data[31].

5. Time Series Analysis by means of Ordinary Least Squares Analysis (OLS)
Next, we conducted ordinary least squares (OLS) analyses to check which relations in our conceptual model are statistically significant. In these OLS analyses we tested the following set of 10 relations for each working group. Table 7.4 shows the variable names and their meaning. In appendix 7-II a short list of abbreviation is given as well.

(1) AC conti T = AC conti T-1 + Opos T + Opos T-1 + HR pos T + HR pos T-1 + HR neg T + HR neg T-1 + MIp T + MIg T + NDp + NDv + TNDv
(2) AC modi T = AC modi T-1 + Opos T + Opos T-1 + Oneg T + Oneg T-1 + HR pos T + HR pos T-1 + HR neg T + HR neg T-1 + MIp T + MIg T + NDp T + NDv T + TNDv T
(3) Opos T = AC conti T + AC conti T-1 + AC modi T + AC modi T-1 + Opos T-1+ PP pos T + PP pos T-1 + NDp T + NDv T + TNDv T
(4) Oneg T = AC modi T + AC modi T-1 + Oneg T-1 + PP neg T + PP neg T-1 + NDp T + NDv T + TNDv T
(5) HR pos T = Opos T + Opos T-1 + Oneg T + Oneg T-1 + HR pos T-1 + MIg T + NDp T + NDv T + TNDv T
(6) HR neg T = Opos T + Opos T-1 + Oneg T + Oneg T-1 + HR neg T-1 + MIg T + NDp T + NDv T + TNDv T
(7) PP pos T = Opos T + Opos T-1 + PP pos T-1 + NDp T + NDv T + TNDv T
(8) PP neg T = Opos T + Opos T-1 + Oneg T + Oneg T-1 + PP neg T-1 + NDp T + NDv T + TNDv T
(9) Mip T = PP neg T + PP neg T-1 + NDp T + NDv T + TNDv T
(10) MIg T = Opos T + Opos T-1 + Oneg T + Oneg T-1 + NDp T + NDv T + TNDv T

Lagged variables are specified in order to control for:
1. Lagged Effects over time

Table 7.4 Variables names and their meaning

Variable name	Meaning
AC conti T	Action Course continuation at time t 0
AC conti T-1	Action Course continuation at time t-1
AC modi T	Action Course modification at time t 0
AC modi T-1	Action Course modification at time t-1
Opos T	Outcome positive at time t 0
Opos T-1	Outcome positive at time t -1
Oneg T	Outcome negative at time t 0
Oneg T-1	Outcome negative at time t -1
HR pos T	Availability Human Resources positive at time t 0
HR pos T-1	Availability Human Resources positive at time t -1
HR neg T	Availability Human Resources negative at time t 0
HR neg T-1	Availability Human Resources negative at time t -1
PP pos T	Performance of Partners positive at time t 0
PP pos T-1	Performance of Partners positive at time t -1
PP neg T	Performance of Partners negative at time t 0
PP neg T-1	Performance of Partners negative at time t -1
Mip T	Management Intervention with regard to partners at time t 0
MIg T	General Management Intervention at time t 0
NDp T	Network Dynamics participation (per working group) at t
NDv T	Network Dynamics volatility (per working group) at t
TNDv T	Network Dynamics volatility total project at t

2. Time dependency of regression errors

In order to check for time dependency of regression errors we conducted the Durbin-Watson test. Additionally, we also conducted a test of multi-colliniarity.

We conducted stepwise OLS analyses. This implies that we run the regression analysis and the most insignificant variable was removed from each equation. With this new equation a new regression analysis was conducted. Again the most insignificant variable was removed. This procedure has been repeated until every equation contained only significant independent variables; i.e. the best fitting model. The outcome of these OLS analyses was a set of simultaneous equations for each working group.

In a set of simultaneous equations, dependent variables are specified as independent variables in other equations. We know that in such a situation independent variables correlate with the error terms of dependent variables, while independency is assumed. This results in biased estimates of unknown constant regression coefficients. This has been solved by applying a two stage least square analysis[29] of these sets of simultaneous equations.

6. Time Series Analysis by means of Two Stage Least Squares Analysis (2SLS)

As the name suggests, this analysis consists of two stages. In the first stage, for every equation the non-specified independent variables are used as instrumental variables to predict the values of the dependent variable. These predicted values are used in the second stage for obtaining minimum variance unbiased estimates of the unknown constant regression coefficients of the specified independent variables. The syntax of our analyses can be found in Appendix 7-III.

7.4 Results

Before we discuss the results of the ordinary least squares and the two stage least squares analyses, we will first discuss some descriptive measures and results concerning the case and network dynamics.

7.4.1 The case

The project we focus on in this chapter, is a knowledge generation project of the Centre of Competence Paper and Board (Kenniscentrum Papier en Karton in Dutch). The aim of the project is to develop technology for sustainable pretreatment and use of fibre raw material. The project consists of two main parts, of four years each. The emphasis in the first part is on the generation of fundamental knowledge, whereas the second part is focused on development of that knowledge into practical use. We focus on the first four years: the generation of fundamental knowledge. This part of the research project ran from 2000 to 2003. After realisation of the first part of the project, they continued with the second part of the project, the development phase.

This project consists of four sub-projects, working groups (A-D). Each working group has its own specific objective. But these working groups also need to collaborate and share knowledge. Furthermore a steering group and project management team have been formed. At the start of the project 12 partners (organisations) were involved. Different types of organisations were represented by these partners, such as universities, research institutes, industry suppliers, paper and board mills. Hence, it is a network project.

7.4.2 Network dynamics

We already explained that the different working groups need to collaborate. They need to share knowledge. Some project members are part of more working groups at the same time and can therefore act as brokers between the working groups. Figure 7.6 shows per year the extent to which project members, representing one or more working group(s), are connected. Together, they form a network. These four figures are composed of the attendance of project members during meetings in a specific year. Appendix 7-IV gives enlargements of these networks.

The position of the projects members (the nodes) reflect their membership of working group(s). If someone is part of WG A they are positioned in the upper left corner of the Figure 7.6. A member of WGB is positioned in the upper right corner, whereas the right lower corner is reserved for members of WG C. And in the final corner, the lower left one, members of WGD are positioned. Members who are part of different working groups, are placed in between. See also the explanation at the bottom of the Figure 7.6.

The different colours of the nodes represent the type of organisations of the project members. The shape of these nodes shows the amount of subsidy the organisation of the project member received for this project. Some organisations did not receive any subsidy money, whereas others received more than 500.000 euros. The size of the nodes indicates the attendance in meetings of the project member during the year. The more meetings a member attended in a year, the bigger the node. The lines are also different in size. Hence, we have valued graphs. The thickness of the lines indicates the number of times these persons were together in meetings: a thicker line between two project members (nodes) indicates that these two project members were more often attending the same meeting. But what can we conclude on the basis of these four pictures?

If we compare the different organisations we observe some differences. The project members from the paper and board factories have central positions in the network and a large attendance (the nodes are big). These project members are all part of most or all working groups. Research institutes are also represented in all working groups. The universities are only represented in

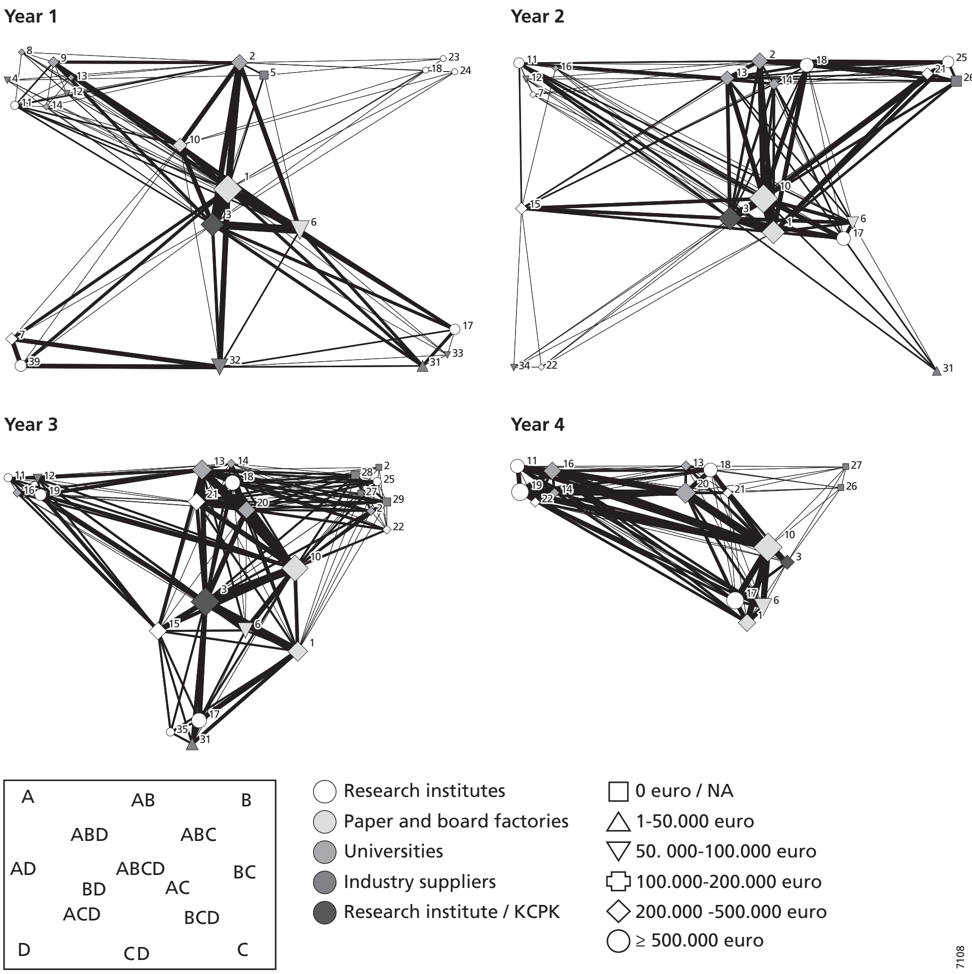


Figure 7.6 The presence of the project members per year. The nodes represent the different project members. Each project members has a unique number. The lines represent attendance of the same meeting(s). The color of the nodes represents the organisation, the shape the budget and the size the attendance. The position of the nodes indicates the membership of (different) working group(s)

working group A or AB. Industry suppliers were present in all working groups at the start of the project. However, in the final year they are only present in working group B. Moreover, these project members have a small attendance. This can be explained by the fact that the companies of these members were located abroad.

As to the budget (the subsidy the organisations received in this project), we observe that more budget does not automatically imply a larger attendance. Thus, one could conclude that the commitment of project members, in terms of participation in meetings, is not a direct reflection of the amount of subsidy. This is probably also related to the fact that several partners are located abroad.

If we compare the networks over time, we see that working group D is active in the first year. However, after about the first year the working group leader changed and relatively soon after that, the steering group decided to stop the activities of this working group. Year 2 is characterised by a closely linked network for working group B and AB. In year 3 this is the case for working group AB. In the final year we see that mainly members of working groups A and AB are active. Finally, we observe a stronger collaboration between working group A and working group B and between working group A and working group C over time. These working groups obtain more linking nodes.

Table 7.5 also gives some descriptive measures of the different networks over time. In the final year we see a relative large decrease in the number of nodes (column B) and linkages (column C). In the second and third year the number of linkages was largest. Not only in absolute sense (column C), but also relatively (column D). This implies that in those years project members were more often present during meetings. However, in those years also more meetings took place compared to year 1 and 4 (N.B. this can not be observed in Table 7.5 or Figure 7.6). Hence, in that sense it is likely that there are more linkages per nodes.

The density of the total network, which in this case (valued graph) "measures the average strength of the lines" (Wasserman et al., 2005) (p.143), (column E) is largest in year 2 and year 4.

A final observation is that the network seems to become more stable over time (column G). The relative shift in nodes becomes smaller (relative more nodes are present in subsequent years). In this project 9 members were participant during all four years (column H).

Table 7.5 Descriptive measures of networks over time

Year	# nodes	# linkages	# linkages/ # nodes	Density valued graph = $\Delta = \Sigma v_k/g(g-1)$ (v_k = value of link k; g = actors)	# nodes same T0 and T1	# nodes same T0 and T1/# nodes T1	# nodes present in all four years
A	B	C	D = B/C	E	F	G = F/B	H
1	22	197	9	0.43	–	–	9
2	20	281	14	0.74	13	13/20 = 0.65	
3	25	312	12	0.52	18	18/25 = 0.72	
4	16	172	11	0.71	16	16/16 = 1	

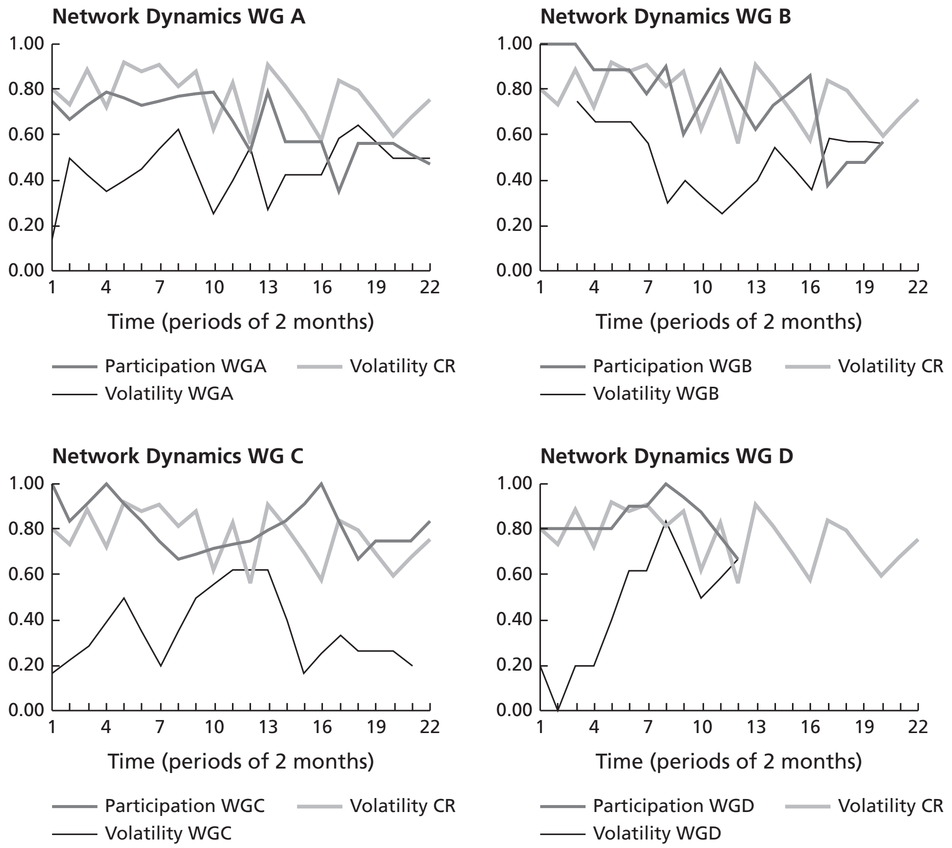


Figure 7.7 Network Dynamics

Figure 7.7 gives the time series for the different network dynamics variables: the participation and volatility of the working group and the volatility of the project as a whole.

For working group A we observe a high participation in the beginning, but later on participation decreases. The volatility of the network of working group A fluctuates during the period of observation. For working group B we also observe a decrease in participation over time. As to the volatility of the network of working group B we observe a relative high volatile network in the beginning as well as in the end. In the middle of the time period the volatility is less. The network dynamics of working group C are characterised by a lower participation and a higher volatility in the middle of the time period. For working group D we observe a high participation during the time this working group existed. But we also observe a large increase in volatility. In this working group several members left and new members entered. This explain the high volatility. However, the members that should be present were almost all present during the meetings. This explains the high participation.

With regard to the total network dynamics volatility (volatility CR in figures) we observe a relative high volatility. This is not surprising because not everyone is part of more working groups. However, in the beginning of the project we observe less fluctuations than in the end of the project.

7.4.3 Time Series Analysis by means of Ordinary Least Squares Analysis (OLS)

The main results obtained from the Ordinary Least Squares Analysis are given below. Appendix 7-V gives more detailed information. These outcomes were used as an input for the two stage least square analyses. As was explained in the methodology section we tested for time dependency in the data (Durbin-Watson test) and multi-colliniarity. The tests for multi-colliniarity showed that multi-colliniarity poses no problem. The Tolerance[30] of all equations was above 0.1. With regard to time dependency there was only one equation in which the Durbin-Watson test unambiguously showed that there was time dependency. Therefore we specified the lagged dependent variable in this equation, even though it was not significant. The problem of time dependency was solved then.

			Adjusted R square
WGA			
AC conti T	=	7.08 + 0.68 Opos T + 0.28 HR pos T-1 – 0.3 HR neg T – 0.5 NDv	0.880
AC modi T	=	10.8 + 0.33 Opos T-1 + 0.81 Oneg T + 0.33 HR neg T-1 + 0.33 MIp T – 0.53NDp – 0.46 NDv – 0.42 TNDv	0.651
Opos T	=	-3.69 +1.04 AC conti T + 0.49 NDv	0.646
Oneg T	=	- 2.37 + 0.68 AC modi T + 0.35 PP neg T + 0.35 NDv	0.635
HR pos T	=	0.71 +0.57 Opos T-1 + 0.69 Oneg T – 0.68 HR pos T-1	0.452
HR neg T	=	-3.38 + 0.55 Oneg T + 0.59 TNDv	0.492
PP neg T	=	0.39 Opos T + 0.36 Opos T-1 + 0.50 PP neg T-1	0.497
MIg T	=	0.53 +0.45 Oneg T-1	0.205
WGB			
AC conti T	=	2.29 – 0.36 Opos T-1 + 0.56 HR pos T + 0.45 HR neg T-1 – 0.39 NDp	0.355
AC modi T	=	1.31 + 0.59 HR pos T – 0.44 NDv	0.438
Opos T	=	0.75 + 0.39 AC modi T-1 + 0.41 PP pos T	0.245
HR pos T	=	0.84+ 0.35 Oneg T – 0.34 HR pos T-1	0.189
HR neg T	=	- 0.50 Opos T-1 + 0.48 TNDv	0.387
PP pos T	=	0.41 Opos T	0.124
PP neg T	=	- 0.40 Oneg T-1 + 0.49 TNDv	0.331
MIp T	=	0.39 TNDv	0.109
WGC			
AC conti T	=	-0.42 AC conti T-1 + 0.39 Opos T + 0.43 HR neg T	0.571
AC modi T	=	-3.53 + 0.59 Opos T + 0.44 HR pos T-1 + 0.22 NDp + 0.31 NDv	0.757
Opos T	=	2.07 – 0.37 AC conti T-1 + 0.53 AC modi T	0.516
Oneg T	=	0.89 + 0.72 AC modi T – 0.22 Oneg T-1 + 0.33 PP neg T-1	0.773

		Adjusted R square
HR neg T	= 0.41 – 0.43 Opos T + 0.51 Oneg T	0.149
PP neg T	= -2.61 +0.54 Oneg T + 0.49 Oneg T-1 + 0.38 TNDv	0.504
MIg T	= 0.89 – 0.42 Opos T	0.141
WGD		
AC conti T	= 0.18 AC conti T-1 + 0.41 Opos T	0.125
AC modi T	= 1.89 + 0.93 Oneg T – 0.53 MIp T – 0.38 TNDv	0.645
Opos T	= 0.37 AC conti T + 0.48 AC modi T	0.334
Oneg T	= 0.54 AC modi T + 0.63 PP neg T	0.741
PP neg T	= -2.83 + 0.62 Oneg T + 0.40 TNDv	0.594
MIg T	= 0.51 Opos T-1	0.221

7.4.4 Time Series Analysis by means of Two Stage Least Squares Analysis (TSLS)

The results obtained from the two stage least squares analyses are presented below and in more detail in Appendix 7-VI. These results will be discussed in further details. First, the results on the dynamics of each working group will be presented in Section 7.4.5. After that the sub questions derived from the main research question in Section 7.1, will be addressed in Section 7.4.6.

		Adjusted R square
WGA		
AC conti T	= 7.41 + 0.63 Opos T + 0.30 HR pos T-1 – 0.32 HR neg T – 0.51 NDv	0.832
AC modi T	= 9.87 +0.76 Oneg T + 0.32 HR neg T-1 – 0.48 NDp – 0.42 NDv – 0.37 TNDv	0.480
Opos T	= 1.03 AC conti T + 0.48 NDv	0.441
Oneg T	= -2.29 + 0.73 AC modi T + 0.34 NDv	0.382
HR neg T	= -3.54 + 0.68 Oneg T + 0.61 TNDv	0.453
PP neg T	= 0.50 PP neg T-1	0.355
MIg T	= 0.56 + 0.44 Oneg T-1	0.155
WGB		
AC conti T	= - 0.61 Opos T-1 + 1.52 HR pos T + 0.94 HR neg T-1 – 0.49 NDp	0.208
AC modi T	= 1.62 – 0.42 NDv	0.184
HR neg T	= - 0.46 Opos T-1 + 0.49 TNDv	0.300
PP neg T	= - 0.52 Oneg T-1 + 0.57 TNDv	0.450
MIp T	= 0.42 TNDv	0.125
WGC		
AC modi T	= -3.68 + 0.64 Opos T + 0.41 HR pos T-1 + 0.21 NDp + 0.31 NDv	0.734
Opos T	= 2.76 – 0.48 AC conti T-1	0.397
Oneg T	= 1.05 + 0.76 AC modi T – 0.22 Oneg T-1 + 0.27 PP neg T-1	0.722
PP neg T	= -2.78 + 0.60 Oneg T + 0.49 Oneg T-1 + 0.42 TNDv	0.429

			Adjusted R square
WGD			
AC modi T	=	1.95 – 0.39 TNDv	0.098
Oneg T	=	0.72 PP neg T	0.279
PP neg T	=	-2.83 + 0.65 Oneg T + 0.39 TNDv	0.448
MIg T	=	0.32 + 0.50 Opos T-1	0.208

7.4.5 The dynamics of the working groups

Working group A

Figures 7.8 shows the results of the two stage least square analyses for Working Group A. Only the statistically significant effects are depicted.

Figure 7.8 shows that positive outcomes result in a continuation of the action course and the other way around. This is in line with what we expected. This reciprocal relation indicates that learning takes place.

Both positive outcomes and the continuation of the action course are influenced by the volatility of the working group (NDv). A higher volatility results in more positive outcomes, although it also decreases the likelihood of continuation of the action course. The volatility of a network reflects the possibility of knowledge spill-over. In case of a low volatility, in other

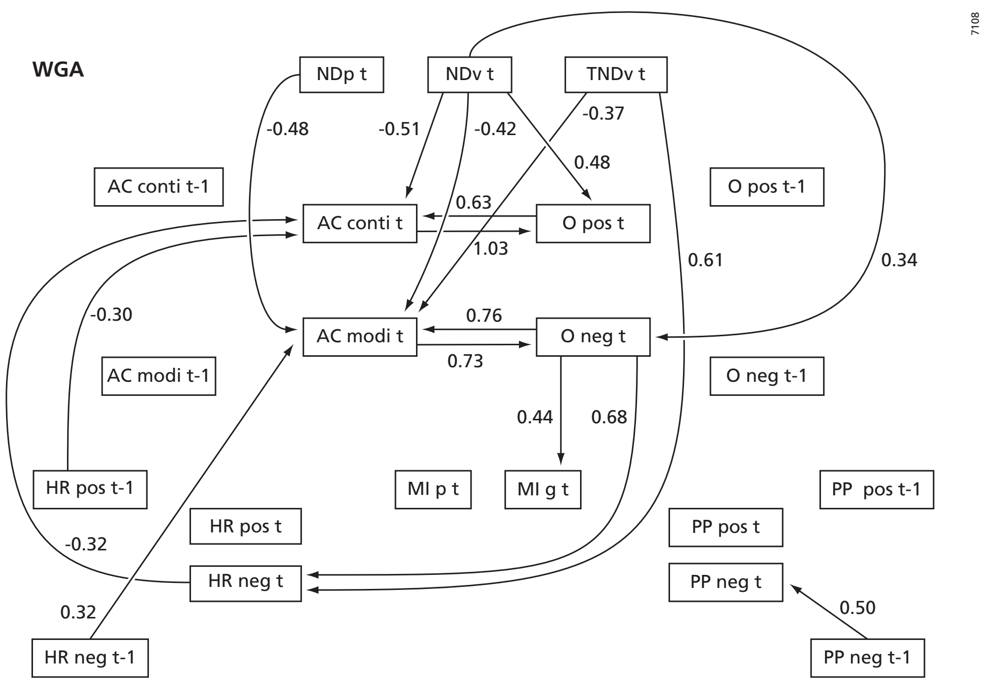


Figure 7.8 Significant results of two stage least square analysis for working group A

words a stable network, more knowledge spill-over is possible. Logically, in situations of high volatility less knowledge spill-over is possible, which may result in unawareness of project members about the current action course and decisions made in previous meetings. This may result in less continuation of the action course. However, these changing compositions of the working group in meetings (high volatility) also result in more positive outcomes. Similar to the fact that turnover of members may result in positive outcomes, differences in the composition during meetings can also turn out to be positive.

The relation between modification of the action course and negative outcomes is reciprocal. They reinforce each other: negative outcomes stimulate a modification of the action course and a modification of the action course mostly results in negative outcomes. We did expect a modification of the action course as a result of negative outcomes. Ideally, this change in the action course should eventually result in positive outcomes. However, this is not the case. Hence, it seems that if they start to modify (trial-and-error) the action course, a successful action course, i.e. resulting in positive outcomes, is not found. Thus, learning is in this sense limited to knowing that these new action courses were not resulting in positive outcomes.

Similar to the observations of positive outcomes and continuation of the action course, a high volatility of the working group results in more negative outcomes, although it also decreases the likelihood of modification of the action course. The high volatility may lead to indecision of the project members. In that case, they do not dare to change the action course. Remarkably, a high volatility decreases the likelihood of continuation as well as of modification of the action course and thereby increases the likelihood of positive as well as negative outcomes. So, volatility results in paralyzing of decision-making on the action course. However, the effect of the volatility of the working group on positive outcomes and the continuation of the action course is somewhat stronger that on negative outcomes and the modification of the action course. A high participation of the working group and high volatility within the total project also decreases the likelihood of modification. It seems that a high participation stimulates a natural resistance to change.

The volatility within the total project also influences the negative availability of human resources. This volatility of the total project can be seen as a kind of reflection of the progress of the total project. If this volatility is high, less feedback from other working groups will be received by each working group and less knowledge spill-over takes place. This may work discouraging for the project members and may result in the exit of project members. This negative availability of human resources is also caused by negative outcomes. Negative outcomes result in a negative change in available human resources, because there might be less willingness to invest, resulting in less human resources. Moreover, it may be necessary that members leave, when they are held responsible for the negative outcomes or when members get frustrated with the outcomes. A negative change in the available human resources in its turn leads to lagged modification of the action course (in the next period) and immediately leads to less continuation of the action course. Whereas a positive change in the available human resources results in a continuation of the action course. Thus, the entry of human resources leads to a continuation of the action course, whereas project members leaving the project or unavailability of new project members result in a modification of the action course.

Negative outcomes stimulate management intervention as expected. Although, these management interventions do not result in a change of the action course. Hence, the management intervenes when things are going wrong, but the working group is not changing its behaviour accordingly.

Finally, a suboptimal performance of partners leads to more suboptimal performance of the partners in the future. There is a self-reinforcing effect. However, suboptimal performance of partners is not significant related to any other variable.

Working group B

Working group B is a different story compared to working group A. For Working Group B we see in Figure 7.9 that positive outcomes result in less continuation of the action course the next period. This suggests that project members become satisfied with their achievements. Positive outcomes are achieved and there is less need to continue. With regard to trial-and-error learning, we do not observe further iterations between actions and outcomes. Therefore, it is difficult to identify learning.

Positive outcomes also stimulate project members not to leave the project, which we observe in the negative relation between positive outcomes and negative change in the available human resources in the next period.

However, if members do leave or if qualified new members are not available (negative availability of human resources), the working group tends to continue its action course in the next period. This is not surprising, because it may already be difficult to cope with personnel changes, which might stimulate them to keep the action course stable and therefore the working group continues its activities in the same direction. The entry of human resources (a positive

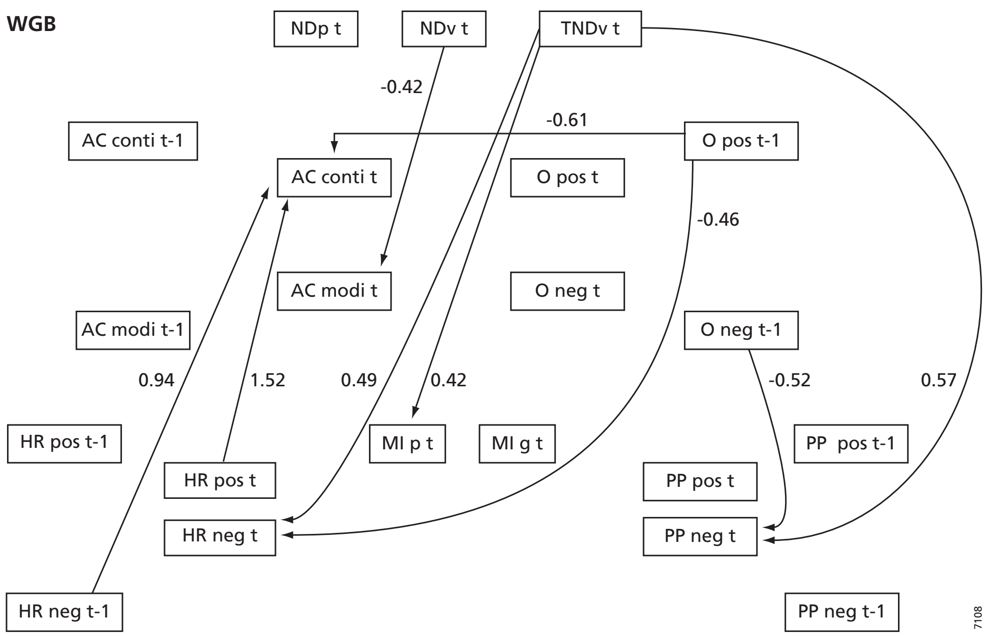


Figure 7.9 Significant results of two stage least square analysis for working group B

availability of human resources) on the other hand also results in a continuation of the action course (similar to our findings of working group A). So, changes in the human resources (positive and negative) result in a continuation of the action course.

Network dynamics also influence the learning process in this working group. A high volatility of the working group result in less modification (similar to working group A). Moreover, a high volatility of the total project results in management interventions. So, it seems that members of working group B are held responsible for the volatility of the total project. However, we do not observe evidence that these interventions result in a changed behaviour.

This volatility of the total project also results in negative availability of human resources. This is similar to findings for working group A. It seems that this high volatility of the project result in the exit of project members. Finally, a high volatility also results in suboptimal performance of partners. It may be possible that due to this high volatility, not enough knowledge spills over, which makes it impossible for partners to perform well. Moreover, partners continue this suboptimal performance, even though negative outcomes may decrease.

Working group C
For working group C we observe another learning mechanism of the trial-and-error learning process. We see in Figure 7.10 that continuation of the action course results in less positive outcomes. This fits our expectations. This can be explained by the fact that over time goals and criteria may change. What one first perceives as positive is less positive in later stages due to a dissatisfaction with results obtained. It suggests that infinite continuation of the action course is not optimal. In the end one needs to change its behaviour, the action course. We do observe this

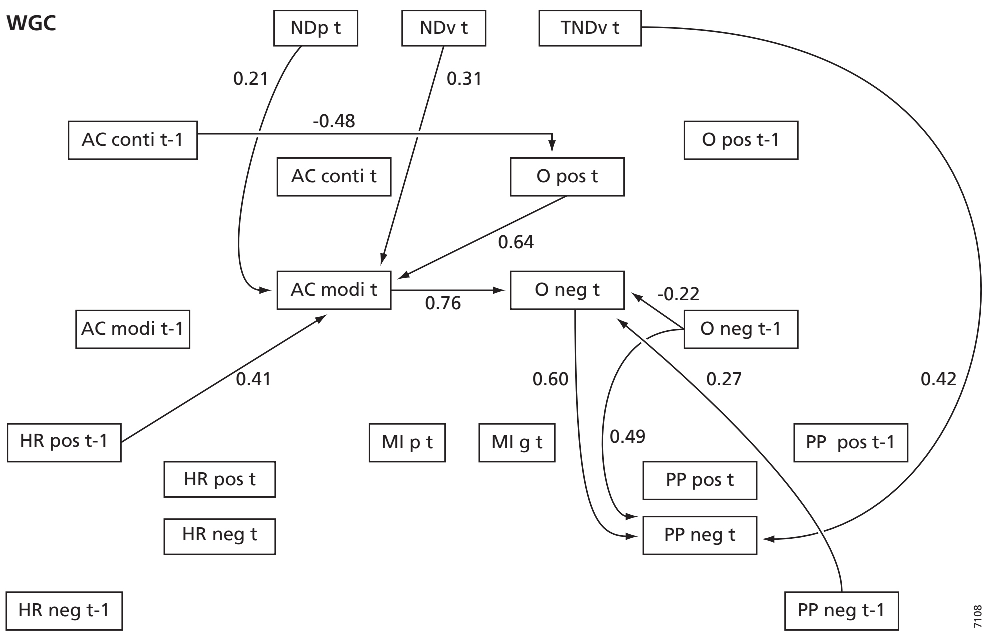


Figure 7.10 Significant results of two stage least square analysis for working group C

for working group C. Positive outcomes result in a modification of the action course. So, they aim to optimise. However, a modification of the action course has a large chance to result in negative outcomes. But negative outcomes are not self-reinforcing, which implies that they seem to die out in the end.

These negative outcomes (also the time lagged effect) in their turn stimulate suboptimal performance of the partners, which results in negative outcomes again in the next period. Hence, this is a reinforcing cycle between negative outcomes and suboptimal performance of partners. Suboptimal performance of partners is furthermore stimulated by a high volatility of the total project (similar to our observations for working group B).

Modification of the action course is, in addition to positive outcomes, also positively influenced by a high participation and a high volatility of the working group and positive change in available human resources. Here we see that new people produce stimuli to change and further optimisation. In contrast to working group A (and working group B) a high participation and volatility result in more modification by this working group. Apparently, they are not paralyzed. They are open to change and dare to take risks, although a modification of action course often lead to negative outcomes.

Working group D

For Working group D only a few relations appeared to be significant in the final model. See also Figure 7.11. We do not observe trial-and-error learning. There are two explanations. First, similar to the studies of Van de Ven (1992), trial-and-error learning did not take place in this stage of

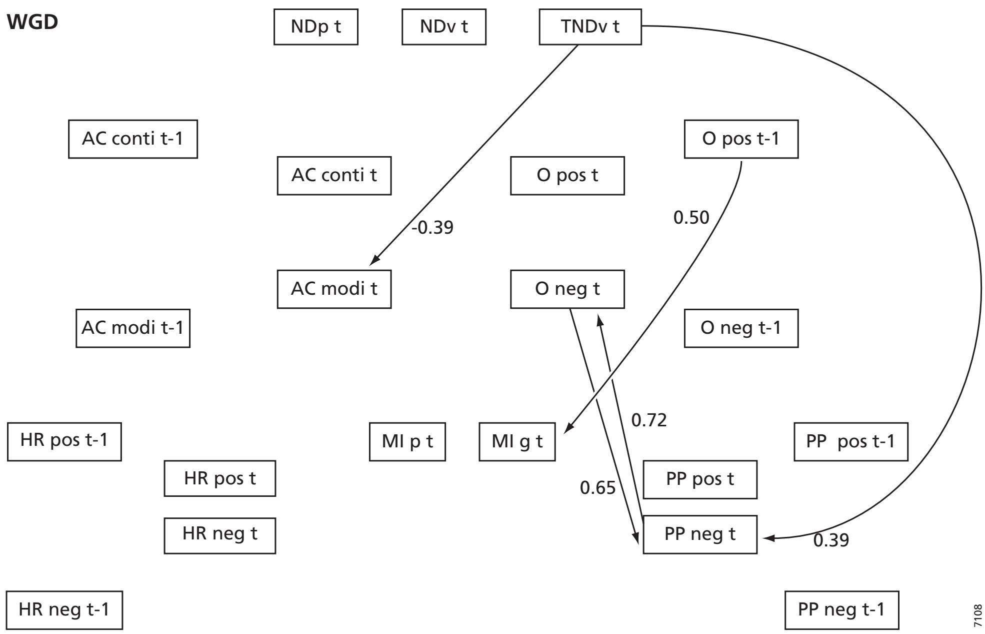


Figure 7.11 Significant results of two stage least square analysis for working group D

the innovation process. Second, for this working group there was a limited amount of data. This may result in relations that are not statistical significant.

There is a strong reciprocal effect between negative outcomes and suboptimal performance of partners (similar to working group C). This implies that negative outcomes result in suboptimal performance of partners, but also the other way around. Suboptimal performance of partners results in negative outcomes. This suboptimal performance of partners is also the result of the volatility of the network of the total project (similar to working group B and C)[31]. This same volatility also influences the modification of the action course. A high volatility results in less modification of the action course (also observed in working group A and B). As a consequence of this volatility the working group may become paralyzed and will not change its action course. A final observation is the intervention of the management after positive outcomes. So, positive outcomes stimulate management to intervene after a while (a time-lag effect). This suggests that the management strives for optimisation. Also for this working group, we observe that the interventions do not result in a change in the behaviour of the working group. However, we do know that the steering group intervened and stopped the activities of this working group. In the network pictures (Figure 7.6) we observed mainly activity in the first two years. Due to a limited amount of data for this working group relations will not be statistical significant.

7.4.6 General patterns: answering sub questions

In this final section of the result section we will reflect on the sub questions formulated in the introduction. Although results on the four working groups tell four completely different "stories" some findings are more general. These will be discussed. We start by reflecting on the trial-and-error learning process and continue with the influence of the performance of partners, the availability of human resources, and network dynamics, respectively.

Trial-and-error learning

For the relation between actions and outcomes we did observe (especially for Working Group A) positive outcomes resulting in a continuation of the action course. And negative outcomes resulting in a modification of the action course. We also observe optimising behaviour (modification of the action course after positive outcomes) and changing conditions and goals/criteria (less positive outcomes after continuation of the action course). However, we did not observe positive outcomes after modification of the action course. Van de Ven et al (1992) (p.95) argue that this is to be expected. On the basis of negative feedback you do know what is not working, but you do not know what to do to obtain success. Therefore, they expect "the propensity to obtain positive outcomes ….to decrease by changing the action course" (p.95). However, we kept negative and positive outcomes separated in the analysis. As a consequence, one expects to observe a certain effect on negative and positive outcomes after modifying the action course. However, we did not observe a positive effect on positive outcomes, which makes us conclude that the learning cycle is not completed. Hypotheses 1a, 1b, and 1c are confirmed but in different situations.

Finally, we observed some management interventions. In Working group A management intervened after negative outcomes, whereas it intervened in Working group D after positive outcomes. As we argued earlier, this latter might suggest that the management strives for optimisation. However, in both these working groups interventions did not result in changed behaviour. As a consequence Hypotheses 2 is also only partially confirmed for Working Group

A. Working Group D shows another stimulus for management interventions, i.e. optimisation, not considered before.

Performance of partners
With regard to the performance of partners, we observed a reciprocal relation between suboptimal performance and negative outcomes in two of the working groups. This implies that suboptimal performance of partners and negative outcomes reinforce each other. This is in line with our expectations. However, we did not observe this reciprocity for positive performance and positive outcomes in any of the working groups. Our results only confirm the negative spiral of suboptimal performance and negative outcomes, stated in hypothesis 3a. Thus, partners should perform positively, to avoid the vicious cycle between suboptimal performance and negative outcomes.

We also expected management interventions due to suboptimal performance. This was not observed. Hence, hypothesis 3b should be rejected.

Availability of human resources
We argued in the theoretical section that a change in human resources may result in a continuation as well as in a modification of the action course. Positive and negative consequences of changes of personnel are reported (Staw, 1980; Dalton et al., 1982). Indeed, we observed a continuation as well as a modification of the action course as a result of a negative as well as a positive change in available human resources but in different situations. Therefore, hypotheses 4a and 4b are not rejected but context dependent. We gave several explanations. On the one hand new people may be added to reinforce continuation of the action course (Working Group A and B). However, on the other hand members leaving the project may also stimulate the working group, to continue the action course (Working Group A and B). Although, the departure of project members can also result in a modification (Working Group A). On the one hand you may need to change your action course due to a loss of knowledge. On the other hand, it may be that you can finally modify your action course because paralyzing effects disappear. Finally, new members may modify the action course as a consequence of their new ideas and knowledge (Working Group C). Furthermore, new members are often more open to change the action course, because they are not necessarily committed to and hindered by earlier courses. Hence, on the basis of our results the effects of the entry and exit of human resources are not generic but context dependent. The results show that it is very case specific (differences per working group). Such context dependency may also explain the different findings in the literature (Faber et al., 2003).

We suggested that due to negative outcomes less will be invested and members can be held responsible for the negative outcomes. Eventually, some members will or need to leave. We indeed observed negative outcomes resulting in an exit human resources. However, the indirect effect of negative outcomes and the exit of human resources as a consequence of management interventions was not observed in our results. Therefore, the motivational part of hypothesis 4c is confirmed, but not its intervention part.

Network dynamics: participation and volatility
We distinguished two different types of network measures: participation and volatility. The observed effects of participation are limited and ambiguous. A high participation in working group A results in less modification of the action course, whereas it results in more modification of the action course in Working group C. We can think of two different explanations for these two different effects. On the one hand, a high participation, may work paralyzing, in the sense that a working group gets stuck with its own ideas (less modification). If only few members are present it will be easier to take decisions. On the other hand, a high participation reflects a certain level of representativity. If only a small number of the working group members are present in a meeting, decisions may be delayed because not enough support exists. So, hypothesis 5a is context dependent.

Although the effect of participation is relatively limited, the volatility of the network appears to have a relative large influence on the trial-and-error learning process. In several working groups we observed that a high volatility of the network results in less modification of the action course. We argued that in the case of a high volatility, less knowledge spill-over takes place leading to hesitation among the project members. As a consequence, they are not likely to change the course of action.

Moreover, this volatility also influences suboptimal performance of partners. Due to this high volatility, it is possible that the knowledge spill-over is not sufficient, which makes it impossible for partners to perform well. As we discussed above, this suboptimal performance in its turn may result in negative outcomes.

Finally, we observed several times that the volatility of the total project leads to the exit of human resources. We argued that this high volatility may result in less feedback of other working groups and less knowledge spill-over, which may discourage project members. This discouragement may result in the exit of project members. Hypothesis 5b is to large extent confirmed but not in one working group but in different situations.

In sum, the confirmation of the hypotheses is context specific:
Hypothesis 1a: Partially confirmed for WG A and C.
Hypothesis 1b: Confirmed for WG C and partially confirmed for WG B.
Hypothesis 1c: Partially confirmed for WG C.
Hypothesis 2: Partially confirmed for WG A.
Hypothesis 3a: Partially confirmed for WG C and D
Hypothesis 3b: Rejected
Hypothesis 4a: Partially confirmed for WG A, WG B and WG C
Hypothesis 4b: Confirmed for WG A and partially confirmed for WG A
Hypothesis 4c: Partially confirmed for WG A and WG B
Hypothesis 5a: Partially confirmed for WG A
Hypothesis 5b: Partially confirmed for WG A, WG B, WG C, and WG D

7.5 Conclusion and discussion

In this chapter we have elaborated on trial-and-error learning. We have taken the trial-and-error learning model of Van de Ven et al (1992; 1999) as a starting point. Our contribution aimed to be threefold: 1) testing the learning model of Van de Ven et al for a different type of case, namely a large multi-actor knowledge generation project concerning environmental innovation; 2) elaborating on the trial-and-error learning process by adding new variables: the availability (exit and entry) of human resources, the performance of partners, and incorporating multi-actor network dynamics into the model; 3) retaining dynamics by keeping different dimensions of variables separated.

We analysed a multi-actor research project of the Centre of Competence Paper and Board. The project consisted of four sub-projects, which we modelled separately. Hence, actually we studied four projects. These four working groups each have a specific dynamic. If we had treated it as one large project, this would have given an wrong picture. This is a first important conclusion. Each working group has it own context and story. The confirmation of hypothesis also appeared to be context dependent. Therefore, aggregation of the data over the working groups is not preferred.

The main research question was: *In what way are elements of the trial-and-error learning process interrelated to the volatility of inputs?*

We can conclude that trial-and-error learning processes takes place. Positive outcomes resulted in a continuation of the action course, and negative outcomes resulted in a modification of the action course. Furthermore, we observed optimising behaviour. However, we did not observe positive outcomes after the modification of the action course. In other words, there is no convergence towards a successful action course, in terms of an action course resulting in positive outcomes, after modification of the action course. On the basis of these results one would conclude that modification of the action course should be avoided. But of course we do know that this is not valid in innovation projects in which it is over time often necessary to alter an action course. An explanation for this observation is that the time period might be to limited to observe this convergence.

With regard to the elaboration on the trial-and-error learning model, the results showed that suboptimal performance should be avoided because this will result in negative outcomes and the other way around. Although positive performance is not directly resulting in positive outcomes it is necessary to avoid the vicious cycle of negative outcomes and suboptimal performance.

The study does not enable us to solve the ambiguity in the effects of turnover of personnel. As stated in the literature, we observed different effects of turnover on the continuation and modification of the action course in this study as well. We can conclude that the effects are case specific and thus management should try to detect which of these effects occur in their projects.

The results of the network dynamics were impressive. The volatility of the network, which we defined as the number of project members that attended two meetings in a row, has a relative large impact on the learning process. A high volatility results in less modification of the action course, suboptimal performance and the exit of project members. The main argument is that a high volatility makes it difficult to spill over knowledge sufficiently, leads to indecision, results in unawareness of progress, and in discouragement of project members. We conclude that volatility should be avoided, at least in projects with such a large number of participants. It would be interesting to study this effect in smaller projects as well.

Whereas, we observed some management interventions, these interventions did not result in changed behaviour. Due to the high importance of the network dynamics and the volatility therein specifically, it may be suggested that in this type of projects (collective knowledge generation projects) management better dedicates itself to team building, instead of supervising and trying to steer by means of interventions as they appears to have no effect.

In contrast to Van de Ven et al (1992; 1999) we kept action course continuation and modification as well as positive and negative outcomes separated, in order to retain more dynamics. We can conclude that this was useful. In this way we were able to test hypotheses on these different dimensions simultaneously. A remaining challenge is the weighting of events. In this research we coded the events with the nominal categories 0-1, counted them, and treated them all equally. However, it is possible that some events are more important than others. Similar, to Chapter 3, it would be interesting to develop a measure for the "importance" of events.

Overall, we can conclude that trial-and-error learning is observed. But we observed different aspects of the trial-and-error learning process and it turns out to be context specific. Hence, the trial-and-error learning pattern in knowledge generation is not completely robust and these results should therefore be handled with caution. Finally, adding these variables resulted in a in-depth insight of the trial-and-error learning. Although the effect of turnover of personnel is still unclear, the effect of the performance of partners and the volatility of the network provide us with interesting conclusions.

8 Conclusion and discussion

In the introduction of this thesis we argued that there is a need to open the black box of environmental innovation. Insight into underlying organisational and behavioural processes affecting environmental innovation (both positively and negatively) is needed. We argued that the role of government is likely to be important in the case of environmental innovation, given that the environment is a public good. However, the literature presents conflicting views of the relation between environmental policy and environmental innovation. Since negative as well as positive effects are reported, this calls for additional insight into this relation. Furthermore, we made clear that we conceive innovation as a learning process. Little is known about the structuring of these learning processes in the case of environmental innovation. Who is involved and why? And to what extent does this depend on the internal resource base and complexity?

To open the black box of environmental innovation, the aim of this thesis is twofold: first, we pursue a better understanding of how an industry interacts with government, and second we aim at a better understanding of how underlying learning processes for environmental innovation are structured and the interactions that occur within these learning processes. These aims resulted in the following four research questions, which we have addressed in the empirical Chapters 3 to 7 of this thesis.

RQ 1: To what extent is the industry association of the Dutch paper and board industry involved in the policy-making processes of distinct types of instruments?

RQ 2: What is the relative role of distinct environmental policy instruments in the case of environmental innovation in the Dutch paper and board industry with regard to energy, waste water, and waste?

RQ 3: To what extent does the Dutch paper and board industry involve external actors in their learning processes in the case of environmental innovation?

RQ 4: To what extent can (the development of) these learning processes be explained from a resource based view of the innovating firm(s)?

The first two research questions are discussed in Chapters 3, 4 and 5. Research questions 3 and 4 are addressed in Chapters 6 and 7. Chapter 2 contains a short introduction to the Dutch paper and board industry, its production process and important partners. We will now briefly discuss the findings of the empirical chapters, draw conclusions and highlight the implications. We will end this chapter with a methodological reflection and some concluding remarks.

8.1 Environmental policy and environmental innovation

8.1.1 The role of the industry association in the policy-making process

The first objective of this thesis was to obtain insight into the relative role of an industry association in the policy-making processes of different policy instruments. Three issues concerning the Dutch paper and board industry were analysed: waste water, waste, and energy. For each of these issues, we studied the specific policy instruments implemented in the period 1980-2004. The different types of instruments in this thesis are: top-down regulation, interactive regulation, positive economic instruments, and negative economic instruments. The Dutch government has implemented a wide range of policy instruments (Rothwell, 1992; Skea, 1994; Keijzers, 2000b; Keijzers, 2002; Vermeulen, 2002; Zito et al., 2003; Vermeulen, 2007). However, per issue some instruments have been more dominant than others. With regard to waste water, levies (negative economic instrument) for discharges are dominant, whereas in the case of waste, the top-down regulation is dominant. In the case of energy, interactive regulation is dominant. As to the policy-making process, we distinguished four steps, namely policy formulation, decision, implementation, and evaluation. We hypothesised a proactive industry association in the policy-making processes of interactive regulation and positive economic instruments, and a reactive industry association in the policy-making processes of top-down regulation and negative economic instruments. On the basis of the findings we can conclude that this was the case. Furthermore, compared to the government we expected the role of the industry association to be different for the policy-making processes of distinct instruments. We hypothesised that most activities of the industry association would be in the policy-making process of interactive regulation. The relative role, i.e. the role of the industry association compared to the government, was indeed largest in the case of interactive regulation. With regard to this interactive regulation, the industry association participated in the policy formulation, the decision, and implementation of instruments. In the case of top-down regulation the industry association only participated in the implementation phase. The relative role of the industry association was smallest in the case of top-down regulation, as we hypothesised. The relative role of the industry association in the case of economic instruments (positive and negative) was moderate.

Considering research question 1 (To what extent is the industry association of the Dutch paper and board industry involved in the policy-making processes of distinct types of instruments?), we can conclude that the role the industry association plays is clearly different. We observed reactive versus proactive behaviour and different levels of involvement for distinct policy instruments. The involvement of the industry is largest in the case of interactive regulation, (represented by the industry association) and smallest in the case of top-down regulation. Following the shift in Dutch governmental policy towards more interactive regulation, the intermediaries have achieved a stronger function. Whereas the roles of intermediary organisations are assumed to be quite static in the existing literature (cf. (Van Lente et al., 2003)), the findings in this thesis show a more detailed picture of intermediaries' behaviour.

8.1.2 The effect of environmental policy on environmental innovation

Although Chapter 3 provides a more extensive description of the roles of the intermediary organisation, it does not show whether differences in the role of the industry association for different types of instruments also result in a change of policy effectiveness. This issue is addressed in Chapter 4, which investigates these same sets of instruments to gain more insight into how the accumulation of policy measures affects research activities and eco-efficiency (RQ2). In this chapter we identified trends in policy pressure (implementation of policy instruments), research activities (number of collective research projects), and eco-efficiency (environmental impact per sales) concerning the issues of waste water, waste and energy.

We hypothesised that after an increase in policy pressure, i.e. the implementation of policy instruments, research activities will increase if existing knowledge and solutions are not sufficient, which is then followed by an increase in eco-efficiency. However, if valid solutions are available, eco-efficiency may increase in immediately. On the other hand, we also hypothesised the possibility that, even though knowledge is available, eco-efficiency does not directly increase. This can be the consequence of competition between policy instruments. If several instruments are implemented simultaneously, or sequentially but shortly after each other, firms have to decide how to prioritise eco-efficiency goals and how to divide their attention, time and resources across activities given the time and budget available. Furthermore, if firms are confronted with too many initiatives, their motivation to comply with policy measures can decrease. As a result, the increase in research activities (if existing knowledge is not sufficient) and eco-efficiency may be smoothed and delayed.

For waste water and waste, a time lag was observed between the increase in policy pressure and the increase in eco-efficiency. For both issues, research activities did not increase following the increase in policy pressure. This time lag may be the consequence of the problems that policy pressure can create in terms of prioritising goals, resulting in a delay in the increase in eco-efficiency. It may also be the consequence of the possibility that firms were conducting research themselves, whereas in this study only collective research projects were taken into account. On the basis of this analysis it is not possible to determine which of these effects actually occured. With regard to the third issue of energy, we observed an increase in policy pressure followed by an increase in research activities and an increase in eco-efficiency. In contrast to the results for the other environmental issues (waste water and waste), no delay between the different indicators of policy pressure, research activities and eco-efficiency was observed. An increase in the energy efficiency of the production process has benefits in economic as well as in environmental terms. This is a possible explanation for the observation that eco-efficiency with regard to energy has increased relatively fast in the Dutch paper and board industry.

These findings prompt the conclusion that, in general, an increase in policy pressure results in an improvement of eco-efficiency, with or without a time-lag. However, these results do not enable us to determine the extent to which and the way in which different policy measures influence innovation. To obtain more insight into the effect of different policy instruments and possible prioritising problems (see above), in Chapter 5 we shifted towards an agency perspective. Here we analysed the adoption processes of CHP-installations, as an energy efficiency measure within the Dutch paper and board industry. At the time of our study, 17 paper and board factories were using a CHP-installation. The adoption of these installations covers a time period of about forty years. The oldest of the current installations was already adopted in 1959. Ten installations were adopted between 1977 and 1986 and six installations were adopted between 1992 and 1997. Since this latter installation of 1997, no new adoption has taken place.

In contrast to the former chapter, this chapter takes the perspective of companies as to policies and their effect on the companies' behaviour as its focal issue. Companies were asked to indicate how and to what extent policy pressures derive from distinct types of regulations and what intra-organisational considerations made them adopt CHP. This approach enabled us to capture the weight attributed to policy pressures as compared to intra-organisational considerations for adopting CHP. Overall, we found that policy pressures as such are relevant, although the most important reason appeared to be the high energy prices combined with the cost price reduction. Further, pressures deriving from a threat of additional environmental regulation turned out to have a major impact on the adoption of CHP. These finding differ from the results of Dupuy (1997), as policy was the most important reason for adoption in his study.

The understanding of policy impact can be refined further by taking temporal aspects and types of instruments into account. The results show different effects for distinct types of policy instruments. The role of top-down regulation was perceived as limited in the adoption processes, whereas interactive regulation turned out to be important for several factories[32]. Negative economic instruments were not observed, whereas the role of positive economic instruments turned out to be large. Although positive economic instruments were important for almost all of the adoption processes (it was not mentioned in just three out of seventeen cases), it was never and, according to the respondents, will never be the most important reason for adoption.

This chapter (5) also gives a nice indication of the possible effects of the accumulation of policy instruments. We observed instruments positively reinforcing each other. For instance, different subsidies all stimulate the diffusion of CHP. These measures thus reinforced each other. We additionally observed that the implementation of instruments disturbed situations originating from earlier policy instruments. Finally, we observed that the implementation of several instruments in a short time span resulted in negative behaviour, namely risk-averse behaviour. This latter effect of policy accumulation is similar to the one discussed in Chapter 4, where a time-lag was observed between policy-pressure and an increase in eco-efficiency. We believe that this complex interaction of policy effects on firms' innovative behaviour may also explain why some researchers that study the effects of isolated policy instruments find negative impacts (CBS, 1998), whereas others (also) find positive impacts (Lanjouw et al., 1996; Brunnermeier et al., 2003). These findings may therefore have been an unintended effect caused by the research design. If policy instruments are analysed as if they are implemented as a 'stand alone' measure, this simply ignores the fact that policy measures interact with other policy measures, which might lead to counteracting effects of measures. Of course this counteracting effect is more likely when policy accumulation occurs. Imagine, for instance, that positive policy instruments stimulating environmental innovation are simultaneously (or shortly thereafter) accompanied by other negative instruments penalizing substandard environmental performance; clearly, those measures counteract each other's effect. If one focuses only on the positive policy instrument and is unaware of other instruments, one might conclude that it has no effect. Whereas in other situations in which, for instance, positive policy instruments reinforce each other, one would find positive effects for positive policy instruments. Neglecting other policy instruments and focusing on just one instrument may therefore cause allocation problems. On the basis of the literature review in Chapter 5 we furthermore discussed how indicators often used to operationalise environmental innovation (number of patents in general) as well as indicators used to operationalise environmental policy (policy abatement expenditures) are not always adequate.

With respect to RQ2, we can therefore conclude that, per issue, some instruments are applied more frequently than others. With regard to waste water, levies (negative economic instrument) for discharges have been dominant, whereas in the case of waste, the top-down regulation has been dominant. In the case of energy, interactive regulation has been dominant. However, the accumulation of policy instruments makes it difficult (if not impossible) to attribute effects to specific instruments even though goals are attained, if one studies a policy instrument. Furthermore, other factors, such as intra-organisational factors, can play a role in (environmental) innovation processes. However, if the focus shifts to the firm's perspective, paper and board factories in our case, environmental policy instruments only partially explain the adoption. In the case of the adoption of CHP-installations, the most important reason appeared to be the high energy price combined with the cost price reduction or the threat of regulation. With regard to policy instruments, interactive regulations have had the largest impact on CHP adoption, while positive economic instruments have been important as a stimulus.

8.1.3 Implications

Theoretical contribution

These first three empirical chapters mainly focused on environmental policy and the relation between environmental policy instruments and environmental innovation. This has resulted in a better understanding of distinct policy instruments with regard to the policy-making processes, specifically regarding the role of the industry association, as well as of the behavioural mechanisms of these instruments. Furthermore, it has resulted in a better understanding of the possible accumulation effects, which are often said to be neglected in previous research (Schuddeboom, 1990; Rennings, 2000; Dieperink et al., 2004; Vollebergh, 2007). As to the approach chosen in Chapter 5, i.e. start from an company perspective, it helps to dispel the ambiguities in the effects and explanations of environmental policies on innovation. It also enabled us to focus on the accumulation of policy measures and on intra-organisational factors over a longer time period. Had we neglected the non-policy factors in this approach, we would have missed important explanations. On the other hand, just focusing on the most important factor for each factory would have resulted in a very low significance of environmental policies in adoption of CHP-installations. This would also have been the conclusion if we had focused on one group of instruments only or on one policy instrument only. However, we do know on the basis of our study that policies have been relevant. This implies that, to develop a more fully fledged approach to explaining the impact of environmental policies on environmental innovation, analytical models should combine intra-organisational factors, and policy pressures, and finally market factors. As this research was only a first attempt, for future research we recommend the investigation of different technologies/technological trajectories and of the same technologies/technological trajectories in different industries.

Policy implications

What can we learn from these results for policy-making? On the basis of these chapters we can conclude that the relative role of the industry is largest in the policy-making process of interactive regulation. This interactive regulation also seems to have the largest effects on the adoption processes of CHP-installations. These findings suggest support for the argument that the involvement of stakeholders in policy-making processes results in more effective regulation (Rennings, 2000).

However, one should not forget that firms also have other reasons (such as cost price reduction) for innovating. We discovered that it is naïve to neglect such intra-organisational factors and to think that policy is effective if policy goals are achieved. In the case of energy efficiency, for example, policy goals were achieved, yet from the stakeholders' perspective policy was just one of the factors influencing the adoption process of CHP-installations.

We further found that, while the accumulation of policy instruments can result in positive effects (reinforcement of instruments), it can also result in negative situations in which firms become risk-avoiding or discouraged. Policy makers should be aware that different instruments are based on different behavioural mechanisms. Having insight into the industry, its behaviour, production processes, hot topics, problems, etc. before policies are implemented can result in a better alignment of aims of both government and industry. The involvement of the industry is a relatively easy way of achieving this, which again hints at interactive regulation.

8.2 Learning processes in the case of environmental innovation

In addition to the relation between environmental policy and environmental innovation, we were interested in the learning processes implied in environmental innovation. In this thesis we have taken a look at adoption and implementation as well as at generation. Adoption was analysed in Chapter 6 and generation in Chapter 7.

8.2.1 Adoption

In Chapter 6 the aim was to gain insight into interactive learning processes in the adoption of CHP-installations. Whereas Chapter 5 centred on the reasons why firms adopt CHP-installations, this chapter focused on the *process* of how these firms adopt CHP-installations. First, we identified temporal patterns in the use of different compositions of learning structures, and second we looked into the effects of the strength of the internal resource base and technological complexity on the differentiated use of learning structures. Whereas previous studies on interactive learning (cf. Meeus and colleagues 2001a and 2004, and Nooteboom et al. 2007) start from a dyadic perspective, we broadened the analysis of interactive learning processes to a community of potential participants in the adoption process. More specifically, we adapted the notion of interactive learning by including the configuration of partners, which reflects a variety of learning structures. Based on literature about knowledge acquisition (Powell et al., 1996; Meeus et al., 2000; Gherardi, 2001; Zahra et al., 2002), we developed a typology of six learning structures. We distinguished three main dimensions of learning structures: 1) reliance on own versus external knowledge, 2) entrance into knowledge-based relationships, and 3) outsourcing. Furthermore, each of these structures also offers the possibility of hiring new personnel (recruit bearers of knowledge). This results in six different learning structures (see Table 6.1).

It appeared difficult to identify robust temporal patterns over the whole time period. But we did observe that most factories (9) relied on supplier relations only in addition to their own knowledge, whereas six factories collaborated with consultancy firms or other knowledge relations. Outsourcing was only observed twice. Considering that CHP is an environmental innovation, these finding are remarkable. In the case of environmental innovation it would be more likely that the acquisition of external knowledge would be necessary in addition to supplier relations (Ehrenfeld, 1999; Marcus et al., 1999). As was observed in Chapter 4, energy efficiency has a significant economic impact on the competitiveness of the Dutch paper and board industry, besides having major environmental significance as well. For these reasons, energy efficiency has been on the innovation agenda for a long time in this industry. This explains why the paper and board factories want to control energy costs and energy provision themselves as far as possible. These factors also account for the relatively large number of adoptions with just supplier relations and the use of own knowledge.

In this study on CHP in the Dutch paper and board industry, we observed a typical innovation champion mainly at the end of the seventies and first half of the eighties. An innovation champion has a strong belief in an innovation (Buswick, 1990) and will perform promotional activities for this innovation (Howell et al., 2004). This innovation champion was part of larger company and was involved in the adoption processes of all five factories within this company. He conducted an extensive study to design the optimal installation, founded a user club, and disseminated his knowledge to other paper and board factories and also other industries. He successfully promoted this technology and supported the (building of a) knowledge infrastructure.

We were also interested in the influence of technological complexity and the strength of the internal resource base of the innovating firm on the choice for specific learning structures over time. We found that firms with a stronger internal resource base more often rely on their own knowledge in addition to supplier relations, whereas firms with weaker internal resource bases acquired external knowledge in addition to their own knowledge and supplier relations. This supports the resource deficits argument (Teece, 1986; Meeus et al., 2000; Nooteboom, 2000) stating that in case of sufficient internal resources, innovating firms have no incentive to look for external partners with the exception of supplier relations, whereas a lack of resources results in interactive learning.

We also hypothesised that complexity would be positively related to the level of interaction with partners to obtain external resources. However, we did not find support for this hypothesis. Some innovating firms may prefer to involve external knowledge resources in the case of non-core innovating activities, even though the installation is relatively simple.

However, technological complexity did have an effect, when one looks at the interaction effect of technological complexity and the strength of the internal resource base. A high complexity requires skills, capabilities and/or knowledge, which most innovating firms do not have internally (Zahra et al., 2002). As a consequence, these innovating firms will acquire external resources and search for partners other than just suppliers. On the basis of the results we can conclude that we have found support for this hypothesis.

Finally, we expected time to act as a moderating variable. More specifically, we expected accumulation of knowledge over time. As said, the oldest CHP-installation that we studied was already adopted in 1959, and the most recent one in 1997. This study thus covers a relatively large time period, so we expected an accumulation of knowledge over time. We can conclude for two reasons that we did observe this accumulation of knowledge. First, new employees were hired only in the earlier periods. These new employees were all former employees in the shipping industry that used similar technologies. In later adoptions, it was no longer necessary to hire new personnel. Second, knowledge accumulation was observed in the fact that firms in later periods did not acquire external knowledge for the adoption of installations with a similar complexity, due to a stronger internal resource base. Moreover, in later periods more complex installations were adopted and implemented without external knowledge acquisition. We therefore infer that time is a moderating variable (compare Waarts and colleagues (2002)).

With respect to RQ 3, we found that several actors were involved in the adoption and implementation of CHP-installations. In addition to suppliers of components of the CHP-installations, several firms involved external actors to obtain knowledge. These other actors were: consultancy firms, electricity and/or natural gas companies, the industry organisation, a financial, a validation, and/or juridical agency, an outsourcing partner, a maintenance company, and finally a joint venture partner. The absence of the government in this list is remarkable. Whereas the government induced adoption by exerting policy pressures, in this interactive learning process and the selection of partners the government does not play a direct role.

In this specific case (CHP adoption in the Dutch paper and board industry), a relatively large number of firms did involve suppliers only. The option to outsource the project was not chosen very often. Paper and board factories want to have the energy provision in their own hands as much as possible.

With regard to the final research question (RQ 4), we conclude that learning structures with a focus on the acquisition of external knowledge in addition to supplier relations are more likely if the internal resource base is weak and therefore insufficient, and if the complexity is larger. The resource deficits and the large complexity determine the acquisition of external knowledge.

8.2.2 Generation

As part of the research on the generation of innovation and new knowledge, we studied a multi-actor research project. This project was part of a larger programme of the Competence Centre Paper and Board (KCPK), dedicated to developing technology for the sustainable production of fibre raw material. This research project, performed between 1999-2003, mainly focused on the generation of fundamental knowledge. The aim of Chapter 7 was to test to what extent the trial-and-error learning process occurred in the case of environmental innovation and to what extent actions-outcomes are interrelated to the volatility of inputs. This volatility of inputs is differentiated into three different aspects. First, the availability of human resources, meaning the entry and exit of project members. Second, the quality of human resources, in other words the performance of project partners. Third, the interactions between the project members, that is the network dynamics. Similar to Van de Ven and colleagues, we modelled the trial-and-error learning process by means of a process approach. We used Event Time Series Regression Analysis to test the model (Poole et al., 2000).

The project consisted of four sub-projects, which we analysed separately. Thus, we actually studied four projects. The dynamics of these four projects appeared to be different. We can conclude that each project has it own story. However, some findings were more general, in the sense that they were observed in different working groups. Concerning the effect of the entry and exit of human resources on the trial-and-error learning process, literature is ambiguous. Both negative effects of entry and exit and positive effects are reported in the empirical literature. New employees may have new ideas resulting in positive outcomes, whereas the exit of employees implies exit of knowledge. Our results are inconclusive as well. The entry of human resources resulted in some cases in a change of the action course, whereas it resulted in a modification of the action course in other cases. The same applies to the exit of human resources. It resulted in a change of the action course in one working group and a modification of the action course in another working group.

With regard to the performance of partners, a reciprocal relation between substandard performance and negative outcomes was observed in two of the working groups. We did not observe this reciprocity for standard performance and positive outcomes in any of the working groups. These results indicate that, in this case, positive performance does not positively influence the outcomes, but that substandard performance does negatively influence the outcomes. One can conclude that partners' performance should remain constant, although this in itself does not always result in positive outcomes. Otherwise, if project members' performance is substandard, a vicious cycle is created between substandard performance and negative outcomes.

The results of the network dynamics were interesting. The volatility of the network, which we defined as the number of project members that attended two meetings in a row, has a relatively large impact on the learning process. We observed several effects. We argued that in the case of high volatility, less knowledge spill-over takes place. First, this may lead to indecisiveness among project members. As a consequence, they will not alter the course of action. Indeed, several times we observed that a high volatility of the network resulted in less modification of the action course. Second, a high volatility may cause substandard performance of partners. If knowledge spill-over is sufficient, it is possible for partners to function properly. As we discussed above, this substandard performance in turn may result in negative outcomes.

Finally, several times volatility led to the exit of human resources. A high volatility may result in less feedback from other working groups and less knowledge spill-over, which may discourage project members. This discouragement may result in the exit of members.

Finally, it was remarkable to observe how management interventions did not have a direct effect in the sense that management interventions did not result in a change of the action course. This suggests that in the case of such multi-actor projects, it might be more fruitful to focus on teambuilding.

Concerning RQ 4, we can conclude that adding variables, such as the availability, quality and volatility of human resources, resulted in an in-depth insight into trial-and-error learning. The study does not enable us to solve the ambiguity in the effects of personnel turnover. As reported in the literature, in this study we also observed different effects of turnover on the continuation and modification of the action course. Furthermore, the results showed that substandard performance should be avoided because this will result in negative outcomes. Although standard performance does not directly result in positive outcomes, it is necessary to avoid the vicious cycle of negative outcomes and substandard performance. A high volatility results in less modification, substandard performance and the exit of project members. The main reasons are that a high volatility makes it difficult to spill over knowledge sufficiently, leads to indecision, results in a lack of awareness of progress, and in a general discouragement of project members. We would therefore suggest that volatility should be avoided. In sum, although the effect of personnel turnover is still unclear, the effect of partners' performance and the effect of volatility of the network provide us with interesting conclusions.

8.2.3 Implications

Theoretical contributions

In Chapter 6 we reworked the notion of interactive learning (Lundvall, 1988; Meeus et al., 2001a; Meeus et al., 2001b; Meeus et al., 2004; Nooteboom et al., 2007) by including a variety of partner configurations, thus capturing several learning structures that serve to solve knowledge deficits encountered in the adoption and implementation of CHP-installations. This operationalisation in network configurations appeared to be a fruitful approach, as this resulted in a more fully fledged picture of the interactive learning process. The focus on a relatively long time period enabled us to observe knowledge accumulation. It would be interesting to test this approach for other technologies and/or more industries.

In Chapter 7 we elaborated on the trial-and-error learning model of Van de Ven et al. (1992, 1999). In their model they do not systematically deal with the effects of volatility in inputs in the analysis of the learning process. In this study we have modelled these effects (availability, quality and volatility of human resources). This has resulted in valuable outcomes, but the challenge remains to further study personnel turnover and network dynamics. The volatility of the network especially appeared to impact upon trial-and-error learning, in both a positive and a negative manner. The fact that the project we study consisted of a diverse network of members, i.e. different specialisations, originating from a large number of different partners, can explain the importance of a stable network. The competences of these members are difficult to replace by other members during meetings and if members are not present during meetings, valuable knowledge will not be transferred. Further research on this topic is required to gain insight into the effect of network dynamics in smaller and less diverse teams as well.

Managerial implications

What is the usefulness of such results for managers? In the analysis in Chapter 6, it appeared that different actors are involved in learning processes. One can therefore conclude that it is important for a firm to know about the different actors in their respective contexts; especially in the case of environmental innovation, which is not the core process of the firms we studied. If you are not aware of the competences of the actors in the field, you will not be able to collaborate.

One specific actor in the case of CHP was an innovation champion. If such a champion exists, it is useful to know since firms can learn a lot from such an actor. Besides for firms, it is also useful for the government to know of the existence of an innovation champion. Governments can benefit from the champion's competence, and the champion can help promote the innovation.

On the basis of the results of Chapter 7, several lessons can be learned. The importance of network dynamics, and specifically the volatility of the network, suggest that the management of such multi-actor and multi-disciplinary projects should avoid high volatility. The complexity of a multi-actor project requires strong commitment. It is important to be aware of each other and to keep each other informed. Thus, communication is crucial. Furthermore, substandard performance by partners should be avoided, as this may result in a vicious cycle between substandard performance and negative outcomes.

The results are not only relevant to the management of the project, but also to a subsidising authority. In this specific example, the subsidising authority had already mentioned beforehand that the project would be difficult due to the large number of partners, and that they would monitor this. The project management specifically concentrated on this aspect, which paid off well since the project was considered a success. Several governmental subsidised programmes are geared to such multi-actor and multi-disciplinary projects. Such "exotic" projects demand a lot from the participants. It is important that both project participants and policy makers take this into account.

8.3 Methodological considerations

In Chapter 1, the introduction, we also highlighted the methodological aim of this thesis, which was the study of the concept of environmental innovation at different levels of analysis, starting from different perspectives, and using a longitudinal approach as much as possible.

The focus on different perspectives and levels appeared to be useful. It enabled a detailed analysis of the subject and produced complementary explanations that can be tested and observed on one level but not on the other level. The topic of environmental innovation is understood better and better, step by step. The industry level analyses in the first two empirical chapters yielded insight into the history of policy accumulation and made explicit what has been achieved over time regarding various issues. The shift to the project level resulted in a better understanding of the effects of environmental policy on environmental innovation (Chapter 5) on the one hand, and insight into the learning process on the other hand (Chapter 6). The shift to the intra-project level made it possible to conduct a process approach and created a better understanding of the dynamics within such a project. We believe that all these levels and approaches truly help to enhance our understanding of this thing called environmental innovation.

The use of longitudinal data also proved valuable. In the first two empirical chapters it was necessary to address such a long time period to understand what happened over the past few decades. We thereby realised that, within such a time period, many different (types of) instruments can be implemented.

In Chapters 5 and 6 it was important to notice that adoption and implementation within an industry are different over time, and that conditions can be very different for the adopting firms. Both these chapters provide good examples of the moderating effect of time. Not only the role of policies appears to be different in the various time periods, but also the effect of technological complexity and the strength of the internal resource base on the learning structure. In addition, we observed knowledge accumulation in Chapter 6. These observations were made possible by focusing on a longer time period instead of one short time period. In Chapter 7 we applied a process approach, which requires longitudinal data. In contrast to Van de Ven et al. (1992, 1999), we kept action course continuation and modification as well as positive and negative outcomes separate, in order to retain more dynamics. We can conclude that this was useful. In this way we were able to test hypotheses on these different dimensions simultaneously.

In the study of the role of the industry association in Chapter 3, the study of the research activities in Chapter 4, and the study of the knowledge generation project in Chapter 7, events were coded and counted. A deficit of this unweighted counting of events is that it ignores the fact that some events can be more important than others. In the case of the policy-making process and research projects, some activities may have had more impact than others. And in the case of the collective research projects it also applies that some projects may have had more effect in terms of knowledge diffusion. Therefore, in future research it would be interesting to focus on differences between events by developing a measure for the 'intensity of events'. Our approach (a long time period and/or a retrospective analysis), made this impossible. However, a real-time analysis over a short time period might enable this.

Focusing on a single industry has some advantages as well as disadvantages. The main advantage is that we were able to obtain a complete picture. In Chapters 3 and 4 we were able to study three topics over a long time period. In the study on CHP we had a response rate of 100%. In Chapter 7 we used several data sources for the study of one project, which made it possible to conduct a very detailed analysis. Moreover, we had the advantage that this industry is relatively active and has to deal with several environmental issues, making it an interesting object of study. The main disadvantage of focusing on a single industry is that it is difficult to generalise the outcomes. Nevertheless, we are convinced that these insights into the process of environmental innovations are also valuable for other industries and policy makers; especially since we obtained such comprehensive overviews/studies and because of the richness of the data. Of course, when applying the results to a different situation, one should bear the case-specifics in mind.

8.4 Concluding remarks

I think that most people would agree that that environmental innovation is necessary in the process towards achieving a sustainable society. I do think there is a challenge for policy-making and industry here. This very final section of my thesis offers some reflections on the outcomes and some ideas concerning these challenges.

With regard to policy making, I suggest that it is important to involve stakeholders. Before policies are implemented, obtaining insight into the industry, its behaviour, production processes, hot topics, problems etc. can contribute to a better alignment of the aims of government and industry. This seems to be more effective. Firms are heard, while it can be difficult for a government to completely understand the production process of a specific industry. Intermediary organisations such as industry associations can play an important role in this process. It also important to realise that different instruments are based on different behavioural mechanisms, and that an accumulation of policy measures can have both desirable and undesirable effects. I would suggest a clear set of instruments, with clear objectives and a measure of flexibility for the firms in pursuing these objectives, but also stringent action by the government if goals are not reached. In that way we all know what we can expect of each other.

At the same time, it is important for firms and industries to be aware of current policy and to anticipate future policy, in order to avoid surprises at the end of the day. Furthermore, I think that it is important for firms and industries to be aware of technological developments. Especially where it concerns non-core innovation, it is important to pay close attention to technological developments, as it is not self-evident to pursue these in a field that is not your own. In addition to technological developments, it is important for firms to know which actors are involved and what competences and knowledge they possess. I believe that organisations such as an industry association can also play an important supporting role in this process.

Thus, after opening the black box of environmental innovation, we may conclude that environmental innovation is a challenge: for industry, politics and innovation science alike!

Notes

1 Sustainable development has been defined by the Brundtland Commission in 1987 as development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs". (WCED, 1987) (p.43)

2 Non-rival implies that a public good "once produced can be consumed by an additional consumer at no additional costs " (p.1) (i.e. consumption of the good by one individual does not reduce the amount of the good available for consumption by others) (Holcombe, 1997). Non-excludable implies that consumers cannot be excluded from consuming the public good (Holcombe, 1997).

3 More information about the Dutch paper and board industry and the production process is given in Chapter 2.

4 The literature offers several other definitions on steering. The use of policy instruments can be defined as anything that an actor can use to promote the realisation of one or more objectives ((Hoogerwerf, 2003)). Steering can be seen as the attempts of a government to direct a target group to behave in specific ways, which it otherwise would not do of its own accord ((Van de Peppel, 1995)).

5 For the learning process, different types of knowledge can be necessary. The following distinction can be used ((Lundvall, 1996)
Know-why, refers to the scientific background; the knowledge about the principles and laws of motion in nature, in the human mind and in society.
Know-what, refers to the knowledge of 'facts'. This knowledge looks like information.
Know-how, refers to skills; the ability to do something.
Know-who, refers to social skills: information about who knows what and who knows to do what.

6 An earlier version has been presented at the 11th Annual International Sustainable Development Research Conference 2005 in Helsinki, Finland.

7 On 28 May 2004, the Netherlands' Paper and Board Association (VNP) celebrated its centennial, receiving the designation "Royal" from the queen, thus becoming the Royal Netherlands' Paper and Board Association (Koninklijke VNP).

8 An earlier version has been presented at the 11th Annual International Sustainable Development Research Conference 2005 in Helsinki, Finland.

9 Ideally, we would also want to identify a trend of individual research and innovation projects of all firms. However, these data are not available for two reasons. First of all, we take into account a very long period and therefore information has been lost over the years. Secondly, not all firms make these overviews.

10 The use of production numbers instead of sales would be preferred; If one uses the production numbers all indicators will originate from the same year. However, if one uses the sales, it may possible that part of the sales of $year_X$ was already produced in $year_{X-1}$. Unfortunately, these numbers are not available for the whole period and therefore it was decided to use sales.

11 The annual report for 1980 was not available. As a consequence, the annual reports of 1981-2003 were used.

12 Not all minutes were available for the whole period.

13 Not all minutes were available for the whole period.

14 Not all overviews were available for the whole period

15 When substitution takes place the new measure replaces an old one and it is not implemented next to the other measure.

16 Objectives of policy: the aims to reduce in 2000 and 2010. Zinc: 65%; 80%.Copper: 50%; 80%. Nitrogen: 70%; 75%. Phosphorus: 75%; 95%.

17 Submitted as: Chappin, M. M. H., W. J. V. Vermeulen, M. T. H. Meeus and M. P. Hekkert. "Enlarging Understanding of the Role of Environmental Policy in Environmental Innovation: Adoption explained by the Accumulation of Policy Instruments and Agent-based Factors."
An earlier version of this chapter has been presented at Technology, Policy and Management Graduate Consortium Annual Meeting, 2006 in Lisboa, Portugal.

18 Contribution of CHP to energy efficiency improvement: >50% in period 1979-1984; 42,2% in period 1989-2001 (VNP, 1986; Koopman et al., 2004)).

19 The diffusion of heat pumps, combined heat and power, and high-efficiency boilers was researched more thoroughly. With regard to CHP, several studies of Blok and colleagues appeared to be useful, (Blok, 1993; Blok et al., 1994; Blok et al., 1996) as well as several other studies (Boonekamp et al., 1995) Brand and colleagues observed that the number of studies in which the diffusion of such energy-saving technologies was actually explained was lower than they had expected.

20 Recently, three factories have been closed. Two of these factories had a CHP-installation.

21 The key events mentioned here are: the oil crisis of 1973, the establishment of "Projectbureau Warmtekracht" (Project Bureau which support cogeneration of heat and power) in 1987, and the moratorium of EnergieNed en SEP in 1994 (for a period of 8 months, plans for new installations > 2 MW were stopped or cancelled).

22 This is a covenant between the industry and the Ministry of Economic Affairs (VNP, 1993). The objective was to increase the energy efficiency with 14% in the period 1989-1995 (Koopman et al., 2004).

23 Submitted as: Chappin, M. M. H. and M. T. H. Meeus. "Explaining compositions of learning structures in the adoption and implementation of CHP-installations."

24 Especially, when it recently appeared that energy costs of the sector have been doubled in the last two years (Koninklijke VNP, 2006)

25 The joint ventures, which are meant here, were collaborations between a paper and board factory and an electricity company. These joint venture were formed after the first Electricity Law of 1989. Due to this law, production and distribution of electricity were separated. The only way for the distribution companies to "produce" electricity was to form a joint venture with industry. This resulted in large CHP-installations.

26 In this picture only the most recent installations are visible. If a factory also adopted an installation before (for instance in the sixties) this is not shown

27 An earlier version of this chapter has been presented at Sunbelt XXVII International Sunbelt Social Science Network Conference 2007, Corfu Island, Greece.

28 Similar to Van de Ven et al. (1992) we take context events and goal/criteria shifts into account. Where we are especially interested in the role of inputs on the trial-and-error learning process, we will not explicitly model these variables, but use them as an explanation for the relation between continuation of the action course and the likelihood of negative outcomes (Hypothesis 1c).

29 Full-Information Maximum Likelihood and Generalized Least Squares methods could not be applied because de input covariance matrix was not positive definite.

30 Tolerance = $1 - R^2$

31 For working group D it was not possible to use the time series for network dynamics of the working group, participation and volatility (see also method section). There have not been enough meetings within working group D to get suitable time series for these two variables. As to network dynamics, only the volatility of the total project is used for working group D

32 This was only observed for factories that adopted a CHP-installation after the eighties, since this type of regulation was not present before.

Appendices

Appendix 3-I: Overview of observed events in the policy-making processes

Table A.1 Observed events in top-down regulation

Year	Actor	Step	Content of event	Source
Top-down regulation				
Waste water				
1991	G	I	A written communication of the Ministry of Housing, Spatial Planning and the Environment (VROM) about industrial discharges of nitrogen en phosphate	1
1991	IA	I	A written and reserved reaction of the paper and board industry to VROM: the paper and board industry is a small discharger	1
1995	J	I	Negotiations with RIZA (Institute for Inland Water Management and Waste Water Treatment) about a model that RIZA wants to include in the permit. An internal commission of the VNP need to make a proposal	2
1995	IA	I	A note of the RTM (research unit of VNP) to the Ministry of Economic Affairs about water control	3
1996	G	I	A report of the government on the method to link environmental care to Water Pollution Control Act (WVO) permits	4
1997	G	I	A report of RIZA with a list of possible measures for the industry to reduce emissions	5
1997	G	E	An investigation commissioned by the government with the aim to identify bottlenecks in the procedure of the WVO-permits	6
Waste				
1983	IA	I	Due to a limitation of possibilities to dispose and a rise of dispose expenditure the waste from recovered paper becomes a big problem. This has been mentioned by the industry association in a consultation with the government.	7
1988	G	I	Note on the collection, prevention and reuse of waste	8
1995	G	PF	The AAO (Waste Consultation Organ) has suggested to have a accelerated introduction of the prohibition to landfill and to close the boarders with regard to waste in order to prevent a overcapacity of waste incineration installations	2
1996	G	D	Prohibition to landfill collected paper and board	9
2001	G	D	Prohibition to landfill all waste streams	10
Energy				
1989	G	D	First electricity law	11
1990	G	D	BEES-directive: Decision Emission Demands Heating Installations	15
1994	G	I	A written communication of the government about how to handle energy use and the long term agreement in the environmental permits	12
1995	G	I	A tutorial about energy in the environmental permit	13
1996	G	PF	A design of the new electricity law	14
1998	G	D	New Electricity Law	

Top-down regulation				
Year	**Actor**	**Step**	**Content of event**	**Source**
1999	G	I	A written communication of the government about how to handle energy in the environmental permits	13
2000	G	I	Report of the Inter-provincial Consultation (IPO): Energy with authority; energy in the provincial environmental permit	16

IA = industry association; G = government; J = Joint; PF = Policy Formulation; D = Decision; I = Implementation; E = Evaluation
1:(Board RTM, 1991), 2:(Board RTM, 1995a), 3:(Executive board RTM, 1995a), 4:(Twijnstra Gudde, 1996), 5:(Wagemaker et al., 1997), 6:(Bruin de et al., 1997), 7:(VNP, 1983), 8:(RIVM et al., 2000), 9:(VROM, 1996), 10:(VNP, 1998), 11:(VNP, 2003a), 12:(VROM, 1994), 13:(VROM et al., 1999); 14:(EZ, 1996), 15:(Nederlandse Emissie Richtlijnen Lucht, 1991), 16: (IPO, 2000)

Table A.2 Observed events in interactive regulation

Interactive regulation				
Year	**Actor**	**Step**	**Content of event**	**Source**
Target group policy				
1990	G	PF	Note of the government on the approach for the Target Group Policy	1
1991	G	PF	Note on the implementation of the Target Group Policy: deals with the question what the implementation brings along	1
1993	G	PF	Meeting VNO/BRMO	2
1993	IA	PF	Preparation for Target Group Policy by the industry association	2
1993	G	PF	Guide by Ministry of Housing, Spatial Planning and the Environment (VROM) for the formulation of the company environmental plans	3
1993	J	PF	Start negotiations of Target Group Policy	4
1994	IA	PF	Informative meeting for the environmental coordinators	2
1994	IA	PF	Start research with the aim to investigate possibilities in the industry	2
1995	G	PF	Research commissioned by the Ministry of Housing, Spatial Planning and the Environment (VROM)	5
1995	IA	PF	A concept version of the integral environmental target plan is ready by the working group integral environmental target plan (IETP)	6
1996	J	D	Singing intention statement	7, 8
1996	J	I	Formulation of Company Environmental Plans (CEPs): Start meetings with government	9
1996	IA	I	Support by VNP by means of meeting environmental coordinators	9
1996	IA	I	Industry association asked for integration of the environmental reporting	9
1997	IA	I	Preparation of CEPs	10
1997	G	I	The approval of these CEPs	10
1997	G	I	Government developed a standard design for the yearly progress report	10
1999	J	D	Second cycle of the Intention statement	11
1999	IA	I	Preparation of the second round of CEPs	11
2003	J	D	Agreement on the third round of CEPs	12
Energy				
1991	J	PF	VNP and Ministry of Economic Affairs signed intention statement. VNP will investigate possibilities to save 20% of energy in 2000.	13, 14
1993	J	D	Signing of Long Term Agreement (LTA)	4
1994	IA	I	Progress report industry LTA 1989-1993	41
1994	G	E	The state of affairs with regard to environmental and energy-saving covenants	15

Interactive regulation

Year	Actor	Step	Content of event	Source
1994	J	PF	The industry association and the Ministry of Economic Affairs negotiate again about the extent to which the LTA needed to be adjusted	16
1995	IA	I	Progress report industry LTA 1989-1994	17
1995	G	E	An evaluation study of the government about the Long Term Agreement and energy saving	18
1995	G	I	First results of the LTA by the government	19
1995	IA	PF	LTA: a questionnaire among the members about the new LTA	6, 20
1995	J	PF	A meeting about a new Long Term Agreement	21
1995	G	PF	The Ministry of Economic Affairs made a proposal for continuation of the LTA. In principle the industry association will agree	22
1996	IA	I	Progress report industry LTA 1989-1995	23
1996	J	D	Signing Long Term Agreement 2. Alignment Long Term Agreement with Target Group Policy	9/24
1996	G	I	Progress report government LTA 1995	25
1997	IA	I	Progress report industry LTA 1989-1996	26
1997	G	I	Progress report government LTA 1996	27
1997	G	E	Evaluation of the Long Term Agreements by Utrecht University commissioned by the Ministry of Economic Affairs	28
1998	IA	I	Progress report industry LTA 1989-1997	29
1998	J	PF	Negotiation of VNP and Ministry of Economic Affairs with regard to the benchmark	30
1998	J	PF	Negotiation of Ministry of Housing, Spatial Planning and the Environment (VROM) and Ministry of Economic Affairs and industry with regard to the benchmark	30
1999	IA	I	Progress report industry LTA 1989-1998	31
1999	J	D	Signing Convenant Benchmarking Energy-efficiency	11
1999	G	I	Progress report government LTA 1998	32
2000	G	I	Progress report government LTA 1999	33
2000	IA	I	Report on the implementation of the Benchmark: approach and method	34
2000	IA	I	Progress report industry LTA 1989-1999 Progress report industry LTA	35
2001	G	I	Annual report Benchmark 2000	36
2001	G	I	Progress report government LTA 1 until 2000	37
2001	G	I	Progress report government LTA 2001	38
2002	G	I	"Score" Convenant Benchmarking	39
2002	IA	I	Energy-efficiency plans finished	40
2003	G	I	Annual report Benchmark 2002	42
2003	G	E	Evaluation of the first round of the Convenant Benchmarking	12

IA = industry association; G = government; J = Joint; PF = Policy Formulation; D = Decision; I = Implementation; E = Evaluation
1: (VROM, 1991), 2: (RTM, 1994), 3: (VROM, 1995), 4:(VNP, 1993), 5:(Hooimeijer et al., 1995), 6:(Executive board RTM, 1995a); 7:(VNP, 1995), 8:(1996), 9:(VNP, 1996) 10:(VNP, 1997), 11:(VNP, 1999), 12:(VNP, 2003b), 13:(TNO, 1993), 14:(VNP, 1992), 15:(VNO NCW, 1994), 16:(VNP, 1994), 17:(Koopman et al., 1995), 18:(Kelfkens, 1995), 19:(EZ, 1995), 20:(Executive board RTM, 1995b), 21:(Board RTM, 1995b), 22:(VNP, 1995), 23:(Koopman et al., 1996), 24:(EZ et al., 1996b), 25:(EZ, 1996c), 26:(Koopman et al., 2004), 27:(EZ, 1997), 28:(Das et al., 1997), 29:(Koopman et al., 1998), 30:(VNP et al., 1998b), 31:(Koopman et al., 1999), 32:(EZ, 1999), 33:(EZ, 2000), 34:(KPMG Milieu et al., 2000), 35:(Koopman et al., 2000), 36:(Commissie Benchmarking, 2001), 37:(EZ, 2001a), 38:(EZ, 2001b), 39:(Commissie Benchmarking, 2002), 40:(VNP, 2002); 41:(Koopman et al., 1994), 42:(Commissie Benchmarking, 2003)

Table A.3 Observed events for negative economic instruments

Negative economic instruments				
Year	**Actor**	**Step**	**Content of event**	**Source**
Waste water				
1980	G	PF	The government wrote a report in which quite drastic changes to the levy system were proposed. The discussion is ongoing.	1
1981	G	PF	Point of view of Ministry Transport, Public Works and Water Management about the design of the levy system.	2
1981	G	D	A new calculation system for levies has been introduced. (Increase of 20% and some installations did no longer meet requirements)	2
1983	IA	I	Objections of the VNP against levy system.	3
1983	G	I	A continuation of levy. This in reaction to the objections of the VNP	3
1985	G	PF	Note in parliament on drastic proposals with regard to correction arrangements, levies, etc.	4
1985	IA	PF	In reaction the VNP wrote a letter to the government in which they set out their objections.	5
1992	G	I	The government wrote a report in which they propose a compromise with regards to remainders of levies	6
1994	G	E	A research on the competitive position of the Dutch paper and board industry as a consequence of the WVO-levies	7
Waste				
1993	G	PF	The introduction of a public bill in the parliament. It concerns a Tax on Environmental Ground (Wbm)	8
1993	IA	PF	The VNP together with de-inkers published their concerns. They wrote letters to the government: the tax make a shift from recovered paper to virgin paper economic feasible. They see as a disproportionate increase in the financial burden	8, 9
1994	G	D	The de-inking sludge will be temporarily exempted	10
1995	J	I	Consultation with VROM about alternative use of the de-inking sludge	11
1995	G	D	Execution Act Tax on Environmental Ground (Wbm)	12, 13
1995	G	PF	The government communicated that it considers a continuation of the exemption if this appears necessary for the concretizing of research projects	11
1996	G	E	Evaluation Act Tax on Environmental Ground	14
1996	IA	PF	In view of the evaluation, the VNP asked for an exemption for coarse rejects	14
1997	IA	PF	A letter of the industry association towards the government to plea for the continuation of the exemption for de-inking sludge	12
1997	IA	PF	A letter to the government for the introduction of the exemption for coarse rejects	12
1997	G	PF	On the basis of the evaluation of Tax on Environmental Ground, it was recommend to the government to not exempt coarse rejects	12
1997	G	D	Continuation of exemption. In the evaluation of the Wbm it has been shown that the tax is indeed an extra burden for the industry and that the industry has successfully implement solutions with regard to secondary resources.	15
2000	G	D	Large increase in tax on land filled waste (contrary to the earlier arrangements)	16
Energy				
1991	G	D	Fuel tax: exemption if Cogeneration Heat and Power (CHP) has an efficiency of 30%	17
~1996	IA	PF	VNP asked for exemption of levy for firms that participate in the Long Term Agreement	15

Negative economic instruments				
Year	**Actor**	**Step**	**Content of event**	**Source**
~1996	G	PF	This was not accepted by the government. According to VNP, the indirect compensations are not enough and they continue to resist against further levies.	15
1996	G	D	Eco-tax: regulating energy tax	17
2002	IA	PF	VNP asked for exemption for small CHP for fuel tax	18

IA = industry association; G = government; J = Joint; PF = Policy Formulation; D = Decision; I = Implementation; E = Evaluation
1:(RNP, 1980), 2:(VNP, 1981), 3:(VNP, 1983), 4:(Board RNP, 1985), 5:(VNP, 1985), 6:(Board RTM, 1992), 7:(Board RTM, 1994), 8:(VNP, 1993), 9:(Board RTM, 1993), 10:(VNP, 1994), 11:(VNP, 1995), 12:(Ministerie van Financien, 1997), 13:(Tubbing, 1997), 14:(VNP, 1996), 15:(VNP, 1997), 16:(VNP, 1999), 17:(VNP, 2003a) 18:(VNP, 2002)

Table A.4 Observed events for positive economic instruments

Positive economic instruments				
Year	**Actor**	**Step**	**Content of event**	**Source**
Energy				
1980	G	D	Energy Bonus of 10%	1
1981	G	PF	The government seeks a general solution for stimulation arrangement and financing method. According to the VNP this resulted in a delay.	2
1982	G	D	Three stimulation instruments for CHP: -energy bonus increased; arrangement large-scale consumers; – investment credits	1,2
1982	G	E	Evaluation of arrangement large-scale consumers to solve possible bottle necks	2
1982	IA	I	VNP plea for extension of the stimulation instrument	2
1994	G	PF	Rumours about possible changes in the available means of the Ministry of Economic Affairs for subsidisation of energy-saving measures	3
1994	J	PF	Negotiation about cut backs in subsidies.	4
1994	IA	PF	The industry association has made a draft report for the Ministry of Economic Affairs for a new negotiation	4
2001	G	D	Reduction on remittance	5
2003	G	D	Introduction of the environmental quality of power production act (MEP)	6

IA = industry association; G = government; J = Joint; PF = Policy Formulation; D = Decision; I = Implementation; E = Evaluation
1:(Blok, 1993), 2:(VNP, 1982), 3:(VNP, 1994), 4:(Board RTM, 1994), 5:(VNP, 2003a), 6:(VNP, 2002)

Appendix 4-I: Environmental policy for the Dutch paper and board industry

Before turning to the overview of environmental policy measures for all three topics, an instrument that is important for each topic, will be discussed.

Target group policy
In the current environmental policy an important instrument is the target group negotiation. In 1993 the Dutch paper and board industry and government started the Target Group Negotiations

(VNP, 1990). In 1996 the industry and government signed the integral environmental target plan (IETP). In this integral environmental target plan targets are specified with regard to reducing air, water and soil pollution, saving energy, cleaning up contaminated soil and so forth. Firms are supposed to work out an Company Environmental Plan (CEP), in which the company set its own priorities. The CEPs of the companies need to be approved by an authority. The idea is that the sum of the individual contributions meets the objective for the sector (Glasbergen, 1998). Every four years the CEPs need to be revised. The second round of CEPs started in 1999 (VNP, 1999) and the third round in 2003 (VNP, 2003b). The firms are supposed to report annually on the results. The implementation of the target group policy is supported and supervised by an independent organisation, the FO-industry (FO-industrie, 2005).

Waste water

Waste water has become an important topic for the Dutch paper and board industry when the Water Pollution Control Act (WVO in Dutch) was executed in 1970 (VROM, 1999). The main instruments under the Water Pollution Control Act are the mix of permits and levies, which has proven to be effective (Bressers, 1983). In 1981 a new system for the collection of levies was introduced (VNP, 1981).

Waste

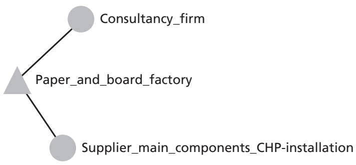
For the domain waste the limitation in landfill of waste and eventually the prohibition to landfill waste are important steps in regulations. Since 1996 it has been prohibited to landfill packaging waste (VROM, 1996) and since 2001 it is prohibited to landfill any kind of waste (VNP, 1998). Besides, levies are being used for waste: In 1995 the Act Tax on Environmental Ground (Wbm) was applied (Ministerie van Financien, 1997).

Energy

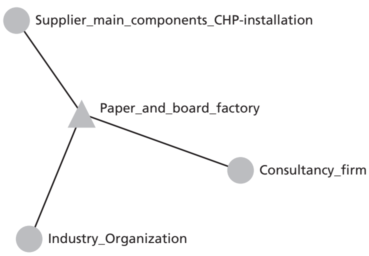
For this domain interactive regulation has been an important instrument. In 1993 the VNP and the Ministry of Economic Affairs signed a long term agreement (LTA) (VNP, 1993). The objective was to increase the energy efficiency with 14% in the period 1989-1995 (Koopman et al., 2004). As a consequence of the results of this LTA, a second LTA was signed in 1996. The objective was to realise an improvement of 20% in energy efficiency in 2000 compared to 1989 (Koopman et al., 2004). In 1999 the Dutch paper and board industry decided to take part in the Convenant Benchmarking Energy Efficiency (VNP, 1999). The aim is to be part of the world top with regard to energy efficiency in 2012, this means that a firm should belong to the best 10% of the world (VNP, 2003). The interactive regulation is supported by negative and positive economic instruments. Two important taxes are the eco-tax and the fuel tax. The eco-tax was executed in 1996 and is part of the Act Tax on Environmental Ground (Wmb) (RIVM et al., 2005). This tax is raised on natural gas and electricity that is not green. The fuel tax has been raised since 1991 and is since the execution of the Wmb in 1995 part of that act (RIVM et al., 2005). Firms that have their own combined heat power-installations (CHP-installations) are in certain cases exempted from the fuel tax. If firms participate in the Convenant Benchmarking they are now exempted from the eco-tax. With regard to the positive economic instruments, it needs to be remarked that these instruments are based on the use of CHP. In 1982 a regulation for self-generators of electricity was executed. As a consequence of this regulation self-generators got a reduction on the electricity prices. In 2001 regulation on the reduction on the remittance was executed (VNP, 2003). In 2003 the environmental quality of power production act (MEP) came into force (VNP, 2002). This act provides for the valuation of electricity produced by CHP plants (VNP, 2002). Some top-down regulation has been executed. In 1989 the Electricity Law (E-wet) was executed and in 1998 this act was renewed. This act deals with permits and rates of electricity among other things. In 1990 the Bees-directive (Decision Emission Demands Heating Installations = Besluit emissie-eisen stookinstallaties) has been executed.

Appendix 6-I: Factories and their learning structures

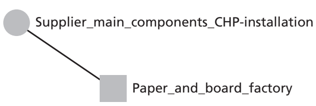
Legend
- ● alter
- ■ ego did not hire new personnel
- ▲ ego did hire new personnel



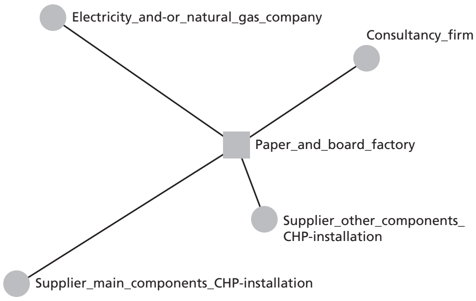
Factory A
In 1959 Factory A adopted a CHP-installation. It concerns a type 1 CHP-installation. The fit between competences and technology was moderately.
Learning structure: Factory A hired people and entered into relations for advice. The new employees came from the shipping industry.
The observed learning structure is type 2b



Factory B
In 1977 Factory B adopted a CHP-installation. It concerns a type 4 CHP-installation. The competences within the factory and the technology fitted reasonably. The gas-turbine was relatively new, but for this factory it was "a combination of what a steam-turbine (rotating parts) and a boiler do in which you put natural gas."
Learning structure: The factory used external advice and hired new people. Also for this factory applies that the new employees came from the shipping industry. Besides, industry organisations were involved in order to obtain information.
The observed learning structure is type 2b



Factory C
In 1979 this factory adopted a CHP-installation. It concerns a type 2a CHP-installation. The competences within the factory and the technology fitted reasonably.
Learning structure: The factory did not use external advice, because of the existence of the internal knowledge within the company (see box in Section 6.4.1). They did not hire new people because automation was an important structure for this company.
The observed learning structure is type 1a.

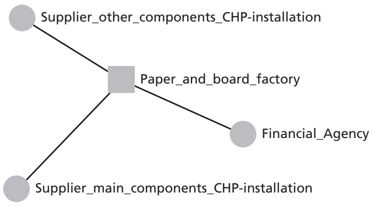


Factory D

In 1980 Factory D adopted a CHP-installation. It concerns a type 1 CHP-installation. The competences and the technology fitted reasonably. It is a relatively easy concept and the person in the organisation involved in the adoption originated from the boiler world.

Learning structure: The factory used external advice in their adoption process. The electricity and natural gas company were involved for information. They did not hire any new people.

The observed learning structure is type 2a

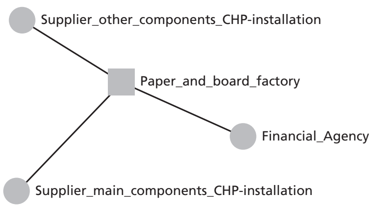


Factory E

In 1982 Factory E adopted three CHP modules. In 1985 its demand for electricity increased and the factory decided to adopt another, a fourth, module. These installations are all type 2a CHP-installations. The competences of the factory and the technology fitted reasonably.

Learning structure: The factory did not use external advice, because of the existence of the internal knowledge within the company (see box in Section 6.4.1). They did not hire new people because automation was an important strategy for this concern. The first three modules of 1982 were financed off balance. Therefore, there was a relationship with a financial agency.

The observed learning structure is type 1a

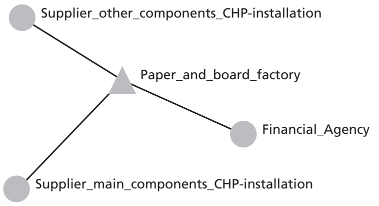


Factory F

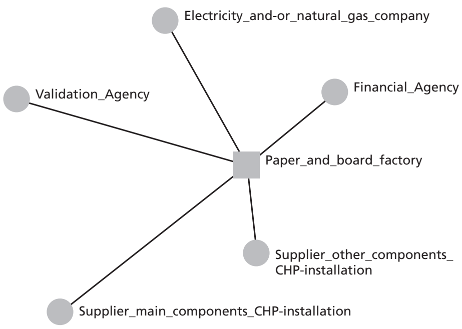
In 1982 Factory F adopted one CHP module. In 1985 their demand for electricity increased and they decided to adopt another module. In the early nineties one CHP-module of another factory of the company moved to this factory. These installations are all type 2a CHP-installations. The competences of the factory and the technology fitted reasonably.

Learning structure: The factory did not use external advice, because of the existence of the internal knowledge within the company (see box in Section 6.4.1). They did not hire new people because automation was an important strategy for this company. The module of 1982 was financed off balance. Therefore, there was a relationship with a financial agency.

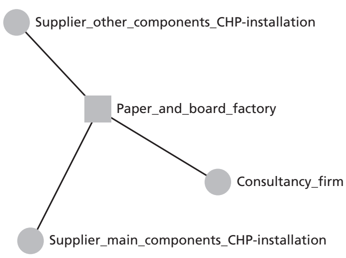
The observed learning structure is type 1a



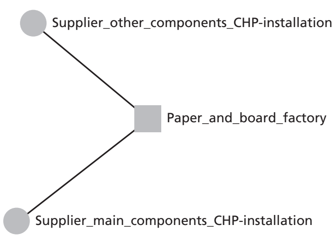
Factory G
In 1982 Factory G adopted a CHP-installation. It concerns a type 3a CHP-installation The competences and the technology did not fit at all. In this factory they were used to handle LD steam boilers. However, HD boilers and the CHP as a unit were new for them.
Learning structure: Factory G hired new people (from the shipping industry). However, no consultancy firm was involved because they were part of a company and they made use of the knowledge within the company (Factory K and N were part of the same company).
The observed learning structure is type 1b.



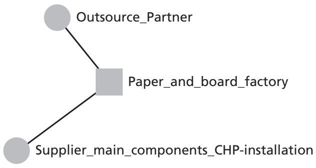
Factory H
In 1982 a complete new installation was adopted with feed back to the grid by Factory H. It concerns a type 3a CHP-installation. The competences and the technology fitted completely and they were able to design the installation self.
Learning structure: The factory did not use external knowledge relations and did not hire new people. The factory was in a situation of bankruptcy. A validation company was used to check if their plans were realistic and the existence of the company should be continued (with a smaller production). Besides, they were given the opportunity to get a granting of credit and therefore a relationship with the financial agency is displayed. The electricity company was involved for the feed back to the grid.
The observed learning structure is type 1a



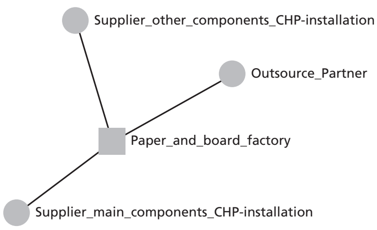
Factory I
In 1981-1982 Factory I adopted a new CHP-installation. It concerns a type 3a CHP-installation. The fit of the competences of the people in the factory and the technology was moderately, as a consequence of the new gas-turbine.
Learning structure: The factory used external advice in their adoption process, but they did not hire any new people.
The observed learning structure is type 2a



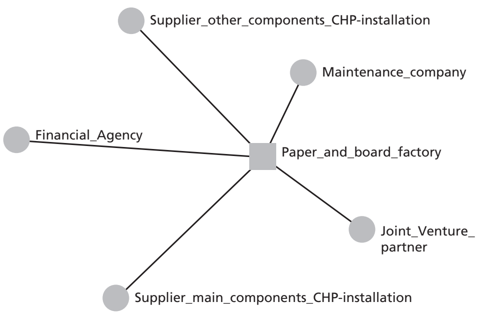
Factory J
In 1983 Factory J adopted a CHP-installation. It concerns a type 2a CHP-installation. The competences within the factory and the technology fitted reasonably.
Learning structure: The factory did not use external advice, because of the existence of the internal knowledge within the company (see box in Section 6.4.1). They did not hire new people because automation was an important strategy for this company.
The observed learning structure is type 1a



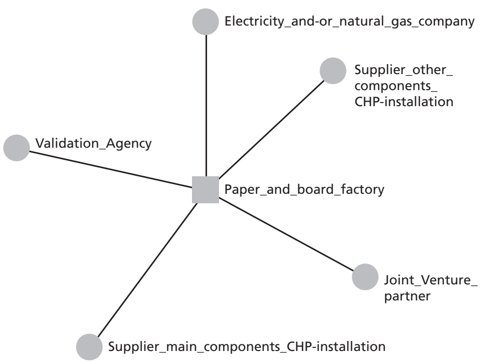
Factory K
In 1986 Factory K adopted a CHP-installation. It concerns a type 3a CHP-installation. The competences and the technology fitted moderately. The largest change was the gas-turbine and the required high-tech knowledge was not present in the firm.
Learning structure: Factory K did not hire new people. They outsourced the project and this outsource partner had the relation with the suppliers of the gas turbine and the boiler and was also responsible for maintenance etc.
The observed learning structure is type 3a



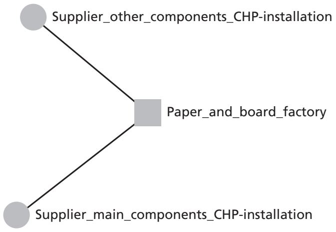
Factory L
This factory adopted a new CHP-installation in 1992. It concerns a type 3a CHP-installation. The competences fitted reasonably to the technology. The daily engineering was quite complex because the production was not continue.
Learning structure: They decided to outsource project, with the exception of the daily maintenance; that is their task. New people were not hired and new relation with external consultancy firms were not entered.
The observed learning structure is type 3a.



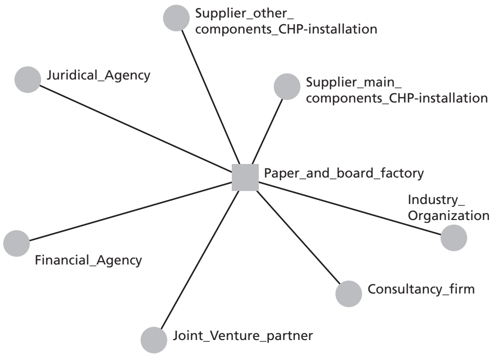
Factory M
In 1992 this factory adopted a new CHP-installation. It concerns a type 4 CHP-installation. The competences and technology fitted completely. They already had a CHP-installation. It was a matter of scaling-up.
Learning structure: They were able to design the installation their selves. It was not necessary to hire new people or to involve a consultancy firm. The (daily) maintenance is done by an external company and already during the implementation this company was approached. Besides, a financial agency was involved because of a financial loan.
The observed learning structure is type 1a.



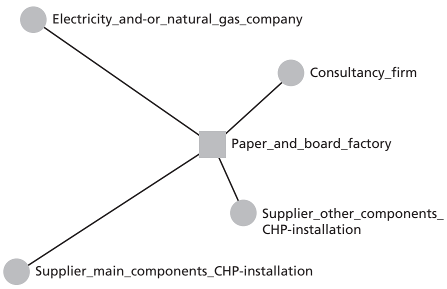
Factory N
This factory adopted a new CHP-installation in 1993. It concerns a type 3b CHP-installation. The competences and the technology fitted completely. They already used a CHP-installation before this new one.
Learning structure: It was not necessary to hire new people or to involve a consultancy firm. They run this CHP-installation together with their electricity company in a joint venture. A validation company was involved to perform some guarantee tests. The natural gas company was involved for information about and inspection of safety.
The observed learning structure is type 1a.



Factory O
The production of an associated factory stopped. In 1993 they moved the CHP-installation of that factory to this factory. It concerns a type 2a CHP-installation. The competences of the factory and the technology fitted reasonably.
Learning structure: The factory did not use external advice, because of the existence of the internal knowledge within the company (see box in Section 6.4.1). They did not hire new people because automation was an important strategy for this company.
The observed learning structure is type 1a



Factory P
Factory P decided to adopt a new CHP-installation in 1993. It concerns a type 4 CHP-installation. The competences and the technology fitted reasonably. Some work needed to be done, but this was relatively well doable, because of the presence of the old CHP-installation and the fact that this factory already shifted to a new operating system with that old CHP.
Learning structure: The internal knowledge was not sufficient to buy the equipment and design the installations without external advice. The firm entered into some relations to acquire various resources/ knowledge. First of all, two consultancy firms were involved. One firm for feasibility studies and the other to give a presentation towards stakeholders. Besides, juridical and financial advice were acquired. Finally, the industry association shared the information with regard to (changing) regulation. The firm did not hire new people.
The observed learning structure is type 2a



Factory Q
In 1995 this factory decided to adopt a CHP-installation. It concerns a type 2a CHP-installation. The competences and the technology fitted moderately. The production of steam was known, but CHP and the accessory control systems were new.
Learning structure: They did not hire new people, but they educated their own people and paid for external advice. The natural gas company was involved for information sharing.
The observed learning structure is type 2a

Appendix 7-I: interrater reliability

To calculate the interrater reliability a matrix can be used (Poole et al., 2000). The possible codes should be placed in first column as well as in the first row. The codes of coder 1 are placed along the rows and the one of coder 2 along the columns. The codes of the two coders are compared and placed in the correct cell (Poole et al., 2000). If Coder 1 and 2 give a similar code this will be placed on the diagonal.

The overall agreement between two coders can be calculated as follows:

Overall agreement: $\Sigma(r_i,c_i)/N$
(r_i, c_i) is the value of the cell row i and column i (the value on the diagonal)
N total number of codes

To correct for change one can apply Cohen's Kappa:
Cohen Kappa = (overall agreement – change agreement)/(1-change agreement)

Change agreement = $\Sigma(R_iC_i/N)/N$
R_i = sum of all codes in row i,
C_i = sum of all codes in column i,
N = total number of codes

See (Poole et al., 2000) (p 166).

Appendix 7-II: Abbreviations

AC = Action Course
O = Outcome
HR = Availability Human Resources
PP = Performance of Partners
MIg = Management Interventions General
MIp = Management Interventions Partner
NDp = Network Dynamics Participation Working group
NDv = Network Dynamics Volatility Working group
TNDv = Network Dynamics Volatility Total Project
Conti = Continuation
Modi = Modification
Pos = positive
Neg = negative
T = Point in time T
T-1 = Point in time T-1

Appendix 7-III: Syntax 2SLS analysis SPSS

```
WGA
2SLS A_ACconti_T WITH A_Opos_T A_HRpos_T_1 A_HRneg_T A_NWDv_T_1
/A_ACmodi_T WITH A_Opos_T_1 A_Oneg_T A_HRneg_T_1 A_MIp_T A_NWDp_T_1
    A_NWDv_T_1 CR_NWDs_T_1
/A_Opos_T WITH A_ACconti_T A_NWDv_T_1
```

```
/A_Oneg_T WITH A_ACmodi_T A_PPneg_T A_NWDv_T_1
/A_HRpos_T WITH A_Opos_T_1 A_Oneg_T A_HRpos_T_1
/A_HRneg_T WITH A_Oneg_T CR_NWDs_T_1
/A_PPneg_T WITH A_Opos_T A_Opos_T_1 A_PPneg_T_1
/A_MIg_T WITH A_Oneg_T_1
/INSTRUMENTS= A_Opos_T_1 A_Oneg_T_1 A_HRpos_T_1 A_HRneg_T_1 A_
    PPneg_T_1 A_MIp_T A_NWDp_T_1 A_NWDv_T_1 CR_NWDs_T_1.

WGB
2SLS B_ACconti_T WITH B_Opos_T_1 B_HRpos_T B_HRneg_T_1 B_NWDp_T_1
/B_ACmodi_T WITH B_HRpos_T B_NWDv_T_1
/B_Opos_T WITH B_ACmodi_T B_PPpos_T
/B_HRpos_T WITH B_Oneg_T B_HRpos_T_1
/B_HRneg_T WITH B_Opos_T_1 CR_NWDs_T_1
/B_PPpos_T WITH B_Opos_T
/B_PPneg_T WITH B_Oneg_T_1 CR_NWDs_T_1
/B_MIp_T WITH CR_NWDs_T_1
/INSTRUMENTS B_Opos_T_1 B_Oneg_T B_Oneg_T_1 B_HRpos_T_1 B_HRneg_T_1 B_
    NWDp_T_1 B_NWDv_T_1 CR_NWDs_T_1.

WGC
2SLS C_ACconti_T WITH C_ACconti_T_1 C_Opos_T C_HRneg_T
/C_ACmodi_T WITH C_Opos_T C_HRpos_T_1 C_NWPP_T_1 C_NWDv_T_1
/C_Opos_T WITH C_ACconti_T_1 C_ACmodi_T
/C_Oneg_T WITH C_ACmodi_T C_Oneg_T_1 C_PPneg_T_1
/C_HRneg_T WITH C_Opos_T C_Oneg_T
/C_PPneg_T WITH C_Oneg_T C_Oneg_T_1 CR_NWDs_T_1
/C_MIg_T WITH C_Opos_T
/INSTRUMENTS C_Oneg_T_1 C_HRpos_T_1 C_PPneg_T_1 C_NWPP_T_1 C_
    NWDv_T_1 CR_NWDs_T_1 C_ACconti_T_1.

WGD
2SLS D_ACconti_T WITH D_Opos_T
/D_ACmodi_T WITH D_Oneg_T D_MIp_T CR_NWDs_T_1
/D_Opos_T WITH D_ACconti_T D_ACmodi_T
/D_Oneg_T WITH D_ACmodi_T D_PPneg_T
/D_PPneg_T WITH D_Oneg_T CR_NWDs_T_1
/D_MIg_T WITH D_Opos_T_1
/INSTRUMENTS D_Opos_T_1 D_MIp_T CR_NWDs_T_1.
```

Appendix 7-IV: Close-up of networks over time

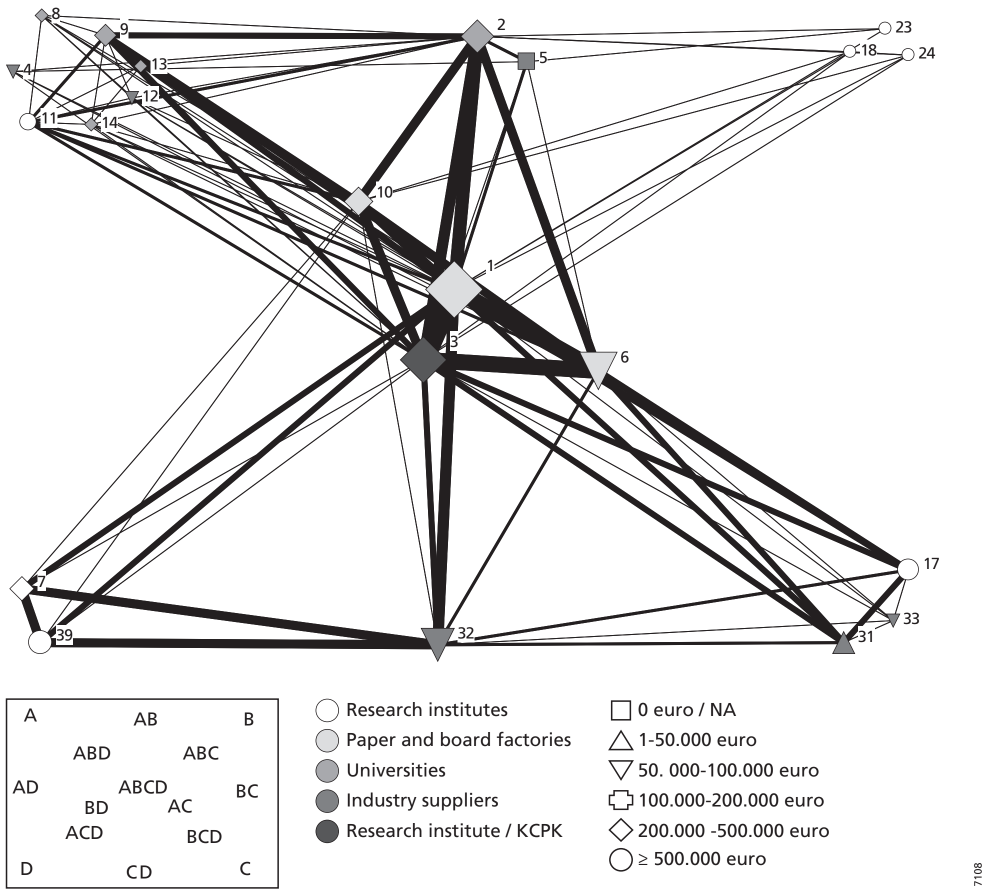


Figure A.1 Year 1 (see also figure 7-6)

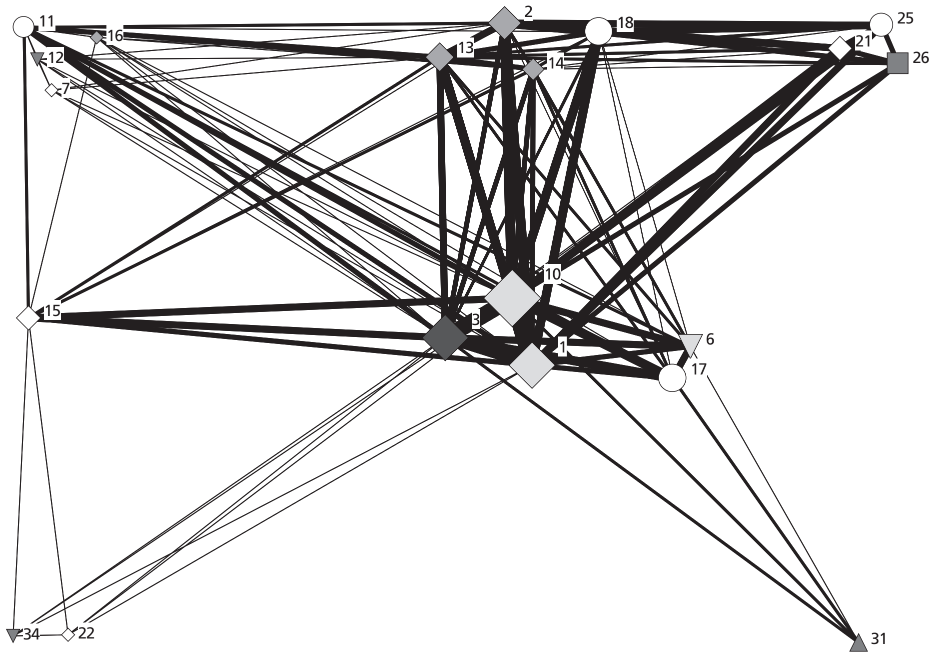


Figure A.2 Year 2 (see also figure 7-6)

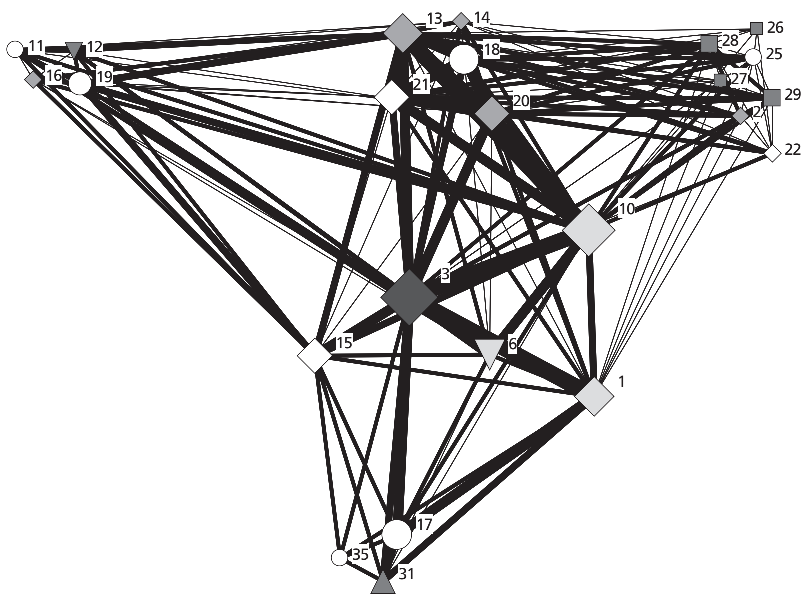


Figure A.3 Year 3 (see also figure 7-6)

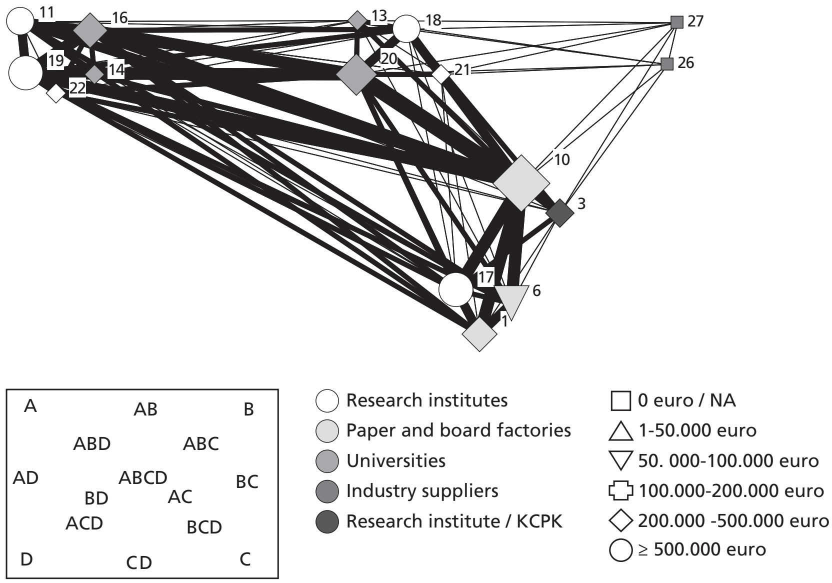


Figure A.4 Year 4 (see also figure 7-6)

Appendix 7-IV: Close-up of networks over time

Table A.5 Results Time Series Analysis by means of Ordinary Least Squares Analysis (OLS) for working group A

Results best fit explorative regression analysis working group A

	Independent variables																						
Dependent variable	**Constant**	**AC conti T**	**AC conti T-1**	**AC modi T**	**AC modi T-1**	**Opos T**	**Opos T-1**	**Oneg T**	**Oneg T-1**	**HR pos T**	**HR pos T-1**	**HR neg T**	**HR neg T-1**	**PP pos T**	**PP pos T-1**	**PP neg T**	**PP neg T-1**	**MIp T**	**MIg T**	**NDp**	**NDv**	**TNDv**	**Adjusted R square**
AC conti T	7.08a					0.68a					0.28a	-0.3a									-0.5a		0.880
AC modi T	10.8a						0.33c	0.81a					0.33c					0.33c		-0.53b	-0.46b	-0.42b	0.651
Opos T	-3.69b	1.04a																			0.49a		0.646
Oneg T	-2.37c			0.68a												0.35b					0.35b		0.635
HR pos T	0.71a						0.57a	0.69a			-0.68a												0.452
HR neg T	-3.38a							0.55a														0.59a	0.492
PP pos T																							
PP neg T						0.39b	0.36b										0.50a						0.497
MIp T																							
MIg T	0.53b								0.45b														0.205

a: Significant at the 0.01 level. b: Significant at the 0.05 level. c: Significant at the 0.10 level.

Table A.6 Results Time Series Analysis by means of Ordinary Least Squares Analysis (OLS) for working group B

Results best fit explorative regression analysis working group B

	Independent variables																					
Dependent variable	**Constant**	**AC conti T**	**AC conti T-1**	**AC modi T**	**AC modi T-1**	**Opos T**	**Opos T-1**	**Oneg T**	**Oneg T-1**	**HR pos T**	**HR pos T-1**	**HR neg T**	**HR neg T-1**	**PP pos T**	**PP pos T-1**	**PP neg T**	**PP neg T-1**	**MIp T**	**MIg T**	**NDp**	**NDv**	**TNDv**	**Adjusted R square**
AC conti T	2.29c						-0.36c			0.56b			0.45b							-0.39c			0.355
AC modi T	1.31c									0.59a											-0.44b		0.438
Opos T	0.75a				0.39c									0.41b									0.245
Oneg T																							
HR pos T	0.84b							0.35c			-0.34c												0.189
HR neg T							-0.50a															0.48b	0.387
PP pos T						0.41c																	0.124
PP neg T									-0.40b													0.49b	0.331
MIp T																						0.39c	0.109
MIg T																							

a: Significant at the 0.01 level. b: Significant at the 0.05 level. c: Significant at the 0.10 level.

Table A.7 Results Time Series Analysis by means of Ordinary Least Squares Analysis (OLS) for working group C

Results best fit explorative regression analysis working group C

	Independent variables																					
Dependent variables	**Constant**	**AC conti T**	**AC conti T-1**	**AC modi T**	**AC modi T-1**	**Opos T**	**Opos T-1**	**Oneg T**	**Oneg T-1**	**HR pos T**	**HR pos T-1**	**HR neg T**	**HR neg T-1**	**PP pos T**	**PP pos T-1**	**PP neg T**	**PP neg T-1**	**MIp T**	**MIg T**	**NDp**	**NDv**	**TNDv**	**Adjusted R square**
AC conti T			-0.42b			0.39b						0.43a											0.571
AC modi T	-3.53b					0.59a					0.44a									0.22c	0.31b		0.757
Opos T	2.07a		-0.37b	0.53a																			0.516
Oneg T	0.89b			0.72a					-0.22c								0.33b						0.773
HR pos T																							
HR neg T	0.41b					-0.43c		0.51b															0.149
PP pos T																							
PP neg T	-2.61b							0.54a	0.49a													0.38b	0.504
MIp T																							
MIg T	0.89a					-0.42b																	0.141

a: Significant at the 0.01 level. b: Significant at the 0.05 level. c: Significant at the 0.10 level.

Table A.8 Results Time Series Analysis by means of Ordinary Least Squares Analysis (OLS) for working group D

Results best fit explorative regression analysis working group D

Dependent variables	**Independent variables** Constant	AC conti T	AC conti T-1	AC modi T	AC modi T-1	Opos T	Opos T-1	Oneg T	Oneg T-1	HR pos T	HR pos T-1	HR neg T	HR neg T-1	PP pos T	PP pos T-1	PP neg T	PP neg T-1	MIp T	MIg T	NDp	NDv	TNDv	Adjusted R square
AC conti T			0.18d			0.41c																	0.125
AC modi T	1.89a							0.93a										-0.53a				-0.38b	0.645
Opos T		0.37b		0.48b																			0.334
Oneg T				0.54a												0.63a							0.741
HR pos T																							
HR neg T																							
PP pos T																							
PP neg T	-2.83b							0.62a														0.40b	0.594
MIp T																							
MIg T							0.51b																0.221

a: Significant at the 0.01 level. b: Significant at the 0.05 level. c: Significant at the 0.10 level. d: This variable was not significant, but we specified this lagged variable to overcome a problem of time dependency (see also method section).

Appendix 7-VI: Results Time Series Analysis by means of Two Stage Least Squares Analysis (TSLS)

Table A.9 Results Time Series Analysis by means of Two Stage Least Squares Analysis (TSLS) for working group A

Results 2SLS working group A

Dependent variables	Constant	AC conti T	AC conti T-1	AC modi T	AC modi T-1	Opos T	Opos T-1	Oneg T	Oneg T-1	HR pos T	HR pos T-1	HR neg T	HR neg T-1	PP pos T	PP pos T-1	PP neg T	PP neg T-1	MIp T	MIg T	NDp	NDv	TNDv	Adjustes R square
	Independent variables																						
AC conti T	7.41a					0.63a					0.30a	-0.32b									-0.51a		0.832
AC modi T	9.87a						0.29	0.76b					0.32c					0.20		-0.48c	-0.42c	-0.37c	0.480
Opos T	-3.573	1.03a																			0.48b		0.441
Oneg T	-2.29c			0.73a												0.30					0.34b		0.382
HR pos T	0.83a						0.29	-0.09			-0.20												0.004
HR neg T	-3.54a							0.68a														0.61a	0.453
PP pos T																							
PP neg T	0.10					0.13	0.32										0.50a						0.355
Mip T																							
Mig T	0.56b								0.44b														0.155

a: Significant at the 0.01 level. b: Significant at the 0.05 level. c: Significant at the 0.10 level.

Table A.10 Results Time Series Analysis by means of Two Stage Least Squares Analysis (TSLS) for working group B

Results 2SLS working group B

	Independent variables																						
Dependent variables	**Constant**	**AC conti T**	**AC conti T-1**	**AC modi T**	**AC modi T-1**	**Opos T**	**Opos T-1**	**Oneg T**	**Oneg T-1**	**HR pos T**	**HR pos T-1**	**HR neg T**	**HR neg T-1**	**PP pos T**	**PP pos T-1**	**PP neg T**	**PP neg T-1**	**MIp T**	**MIg T**	**NDp**	**NDv**	**TNDv**	**Adjustes R square**
AC conti T	1.26						-0.61c			1.52b			0.94c							-0.49			0.208
AC modi T	1.62b									0.36											-0.42b		0.184
Opos T	1.05a				-0.16									0.30									-0.024
Oneg T																							
HR pos T	0.89c							0.36			-0.28												0.144
HR neg T	-1.31						-0.46b															0.49b	0.300
PP pos T	-0.06					0.54																	0.103
PP neg T	-2.01								-0.52b													0.57a	0.450
Mip T	-2.12																					0.42c	0.125
Mig T																							

a: Significant at the 0.01 level. b: Significant at the 0.05 level. c: Significant at the 0.10 level.

Table A.11 Results Time Series Analysis by means of Two Stage Least Squares Analysis (TSLS) for working group C

Results 2SLS working group C

	Independent variables																						
Dependent variables	**Constant**	**AC conti T**	**AC conti T-1**	**AC modi T**	**AC modi T-1**	**Opos T**	**Opos T-1**	**Oneg T**	**Oneg T-1**	**HR pos T**	**HR pos T-1**	**HR neg T**	**HR neg T-1**	**PP pos T**	**PP pos T-1**	**PP neg T**	**PP neg T-1**	**MIp T**	**MIg T**	**NDp**	**NDv**	**TNDv**	**Adjustes R square**
AC conti T	-1.29		-0.08			1.03						0.64											0.392
AC modi T	-3.68b					0.64a					0.41a									0.21c	0.31b		0.734
Opos T	2.76a		-0.48b	0.28																			0.397
Oneg T	1.05b			0.76a					-0.22c								0.27b						0.722
HR pos T																							
HR neg T	0.60b					-0.54		0.35															-0.003
PP pos T																							
PP neg T	-2.78b							0.60b	0.49b													0.42b	0.429
Mip T																							
Mig T	0.83a					-0.32																	0.000

a: Significant at the 0.01 level. b: Significant at the 0.05 level. c: Significant at the 0.10 level.

Table A.12 Results Time Series Analysis by means of Two Stage Least Squares Analysis (TSLS) for working group D

Results 2SLS working group D

	Independent variables																					
Dependent variables	**Constant**	**AC conti T**	**AC conti T-1**	**AC modi T**	**AC modi T-1**	**Opos T**	**Opos T-1**	**Oneg T**	**Oneg T-1**	**HR pos T**	**HR pos T-1**	**HR neg T**	**HR neg T-1**	**PP pos T**	**PP pos T-1**	**PP neg T**	**PP neg T-1**	**MIp T**	**MIg T**	**NDp**	**NDv**	**TNDv**	**Adjustes R square**
AC conti T	1.45		0.58			-1.19																	-0.074
AC modi T	1.95b							0.97										-0.55				-0.39b	0.098
Opos T	0.47	0.52		0.02																			-0.067
Oneg T	0.11			0.23												0.72a							0.279
HR pos T																							
HR neg T																							
PP pos T																							
PP neg T	-2.83b							0.65b														0.39b	0.448
Mip T																							
Mig T	0.32c						0.50b																0.208

a: Significant at the 0.01 level. b: Significant at the 0.05 level. c: Significant at the 0.10 level.

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Summary

Opening the black box of environmental innovation

Governmental policy and learning in the Dutch paper and board industry

Introduction

Although climate change has always taken place, it has become clear that the recent changes in our climate are the result of human activities (IPCC, 2007). One important cause is the emission of greenhouse gases and in particular the emission of CO_2, which is mainly due to the use of fossil fuels. To reduce the risks of negative effects of climate change it is important to reduce the emissions of greenhouse gases. Despite the success of measures to reduce the environmental impact, we still face considerable environmental problems (European Environmental Agency, 2003; Elzen et al., 2005). In order to achieve a sustainable society, more fundamental changes in industrial processes are necessary (Hall et al., 2003; Geels et al., 2004). A way to realise this is environmental innovation. Environmental innovation is a special form of innovation and "consists of new or modified processes, techniques, practices, systems and products to avoid or reduce environmental harm" ((Beise et al., 2005) p6). There is a need for an improved understanding of these environmental innovation processes (Foster et al., 2000; Rennings, 2000; Hall, 2003). There is a need to open the black box of environmental innovation.

Similar to innovation in general, environmental innovation concerns something new for the innovating firm. Either innovation entails doing the same thing in a different way, or innovation entails doing new things. This means that learning needs to take place. The challenging aspect of environmental innovation is that these innovations are not part of the primary process of these innovating firms. But it is even more complex. Despite the fact that environmental innovation is not the core business of the innovating firm, one also has to deal with the fact that the environment is a public good. A public good can be characterised as non-rival and non-excludable. As a consequence, the cost-benefit ratio of environmental innovation is somewhat "awkward". While the benefits are for society as a whole, costs are mainly carried by the innovating firm and it is often difficult to appropriate the profits. This is referred to as the double-externality problem. This problem reduces the incentive for firms to invest in environmental innovation (Beise et al., 2005) and it suggests that this type of innovation (environmental innovation) will not be an autonomous development. This is often referred to as market failure. Therefore, governments are an important actor influencing environmental innovation. This makes it interesting to study the influence of governmental environmental policy on environmental innovation processes (Hardin, 1968; Foster et al., 2000; Rennings, 2000; Beise et al., 2005; Vollebergh, 2007).

In this thesis we focus on the Dutch paper and board industry. The reason for this is that the production process of paper and board is energy intensive. As a consequence, the Dutch paper and board industry has a long history in energy-saving activities. Moreover, this industry has two other environmental topics to deal with. In addition to energy, waste and waste water are important areas of concern in the production process of the Dutch paper and board industry. These two issues have also been on their innovation agenda for quite some time.

The aim of this thesis is twofold. We aim to achieve a better understanding, on the one hand of the structuring and the interactions taking place within these learning processes, and on the other hand of the interaction with the government. We have formulated the following four research questions:

RQ 1: To what extent is the industry association of the Dutch paper and board industry involved in the policy-making processes of distinct types of instruments?

RQ 2: What is the relative role of distinct environmental policy instruments in the case of environmental innovation of the Dutch paper and board industry with regard to energy, waste water, and waste?

RQ 3: To what extent does the Dutch paper and board industry involve external actors in their learning processes in the case of environmental innovation?

RQ 4: To what extent can (the development of) these learning processes be explained from a resource based view of the innovating firm(s)?

This thesis contains five empirical chapters in which these four research question are discussed. The first two research questions are discussed in Chapters 3, 4 and 5. Research questions 3 and 4 are addressed in Chapters 6 and 7. Chapter 2 contains a short introduction to the Dutch paper and board industry, its production process and important partners.

The empirical part

In the policy-making process concerning energy and environmental issues, cooperation between government and firms is a means to create a more efficient energy and environmental policy (Marcus et al., 2002). Intermediary organisations can play an important role in this policy-making process. The aim of Chapter 3 is to get insight into the role of one specific intermediary organisation: the industry association. The interests of the Dutch paper and board industry are represented by the Royal Netherlands' Paper and Board Association (Koninklijke VNP in Dutch). In this chapter, we focus on the three environmental topics, related to the production processes of this industry: waste water, waste, and energy. In this thesis we distinguish four types of governmental policy instruments: top-down regulation, interactive regulation, negative economic instruments, and positive economic instruments. The approach in this chapter (Chapter 3) is to map the activities of the industry association and the government in the development of these environmental policy instruments concerning waste water, waste and energy for the period 1980-2003.

The results offer interesting insights into the (relative) role of an industry association in policy-making processes for different policy instruments. It becomes clearly visible that the industry association plays a different role when different instruments are used. Similar to our expectations, the behaviour of the industry association was reactive in the case of top-down regulation and negative economic instruments, and proactive in the case of positive economic instruments and interactive regulation. Moreover, in the case of interactive regulation the involvement of the industry is largest (represented by the industry association) and smallest in the case of top-down regulation. Because of the shift in the Dutch governmental policy towards more interactive regulation the intermediaries have a stronger function. Whereas the roles of intermediary organisations are assumed to be quite static in the existing literature (c.f (Van Lente et al., 2003)) the findings in this thesis show a more detailed picture of intermediaries' behaviour.

While, Chapter 3 provides a more robust description of the roles of the intermediary organisation, it does not show if differences in the role of the industry association for different types of instruments also result in a change of policy effectiveness. Therefore in Chapter 4 we investigate these same sets of instruments to gain more insight into the way environmental policy affect environmental innovation.

The relation between environmental policy and environmental innovation is complex. Different and sometimes even conflicting theoretical and empirical findings on the relation between environmental policy and environmental innovation are found in the literature (Sanchez, 1997). Chapter 4 is an attempt to gain insight into the way the accumulation of policy measures, or in other words the increase of policy pressure, affects the innovative activities and affects the eco-efficiency of an industry. To study the effect of policy measures on research activities and eco-efficiency for each environmental topic (waste water, waste, and energy) the following trends are identified for the period 1980-2003: 1) Implementation of governmental environmental policy measures; 2) Collective research activities; 3) Eco-efficiency of the industry. The results of the waste water domain and waste domain show a time lag between the increase in policy pressure and the increase in eco-efficiency. For either domain research activities did not increase after the increase in the policy pressure. The results for the energy domain show an increase in policy pressure followed by an increase in research activities and an increase in the eco-efficiency. In contrast to results of the other environmental domains (waste water and waste), for this domain a delay between the different indicators policy pressure, research activities and eco-efficiency, was not observed. An increase in energy efficiency of the process has an obvious gain in economic as well as in environmental terms, which might explain the observation that the eco-efficiency with regard to energy increases relatively fast in the Dutch paper and board industry. Overall, this leads to the conclusion that in general an increase in policy pressure results in an improvement of eco-efficiency, with or without a time-lag.

However, these results do not enable us to determine the extent to which and the way in which different policy measures influence innovation. To obtain more insight into the effect of individual policy instruments we shift in Chapter 5 towards an agency perspective.

There are two reasons in the case of environmental policies, why we cannot simply attribute environmental impact reductions to governmental environmental policies. First, one is dealing with an accumulation of policy instruments, which implies that, in relatively short time periods, a number of policy instruments are implemented aiming at the achievement of related policy goals. Second, environmental friendly behaviour of firms is also influenced by other factors, such as intra-organisational factors. To gain a broader insight into the effect of different policy instruments on innovation and in order to incorporate policy accumulation and intra-organisational factors, we advance an alternative approach in Chapter 5, that instead of evaluating specific policy instruments solely also evaluates the behaviour of firms regarding the adoption of environmentally friendly technologies. In this chapter we look at the adoption of CHP-installations (cogeneration of heat and power) in the Dutch paper and board industry. By means of interviews adoption processes of current installations were reconstructed. The results show two main periods (Period II and III) in which most of these adoptions took place. Period II started at the end of the seventies and ended in the mid eighties. The other period (Period III) was the first half of the nineties. These periods (Period II and III) correspond with different periods of governmental policy instruments. In period II governmental policies were mainly based on subsidies stimulating the diffusion of CHP, whereas the period III was characterised by covenants between government and industry and the first Electricity Law of 1989. Around 1960, there was also a period (Period I) in which CHP-installations were adopted. However, most of these installations have now been replaced. The interviews revealed that in period II the high energy price, combined with the cost price reduction or the threat of regulation, were most influential in the decisions. Furthermore, positive economic instruments were important in all adoptions of Period II. The high energy prices/cost price reduction was also an important reason for adoption in Period III. Positive economic instruments were important in this period as well, although not as important as in Period II. In addition, interactive regulation was important in Period III. After Period III, no new adoptions took place. At that time, policies impeded innovation: due to governmental policies, the economic situation of CHP changed and due to frequent policy changes, firms became more risk-averse. Overall, we can conclude that policies are relevant, yet it is only one of the factors influencing the adoption process. Its relative importance varies over time and per adoption process. The results also show different effects of accumulation of policy instruments. We observed instruments positively reinforcing each other, as well as we observed that implementation of instruments disturbed situations originating from earlier policy instruments. Finally, we observed that the implementation of several instruments in a short time span resulted in negative behaviour, namely risk-averse behaviour.

In the first three empirical chapters we focus mainly on environmental policy and environmental innovation. From Chapter 6 onwards we focus on learning. Whereas in Chapter 5 the reasons why firms adopt CHP-installations are central, in Chapter 6 the process of engaging external partners during the adoption and implementation of these CHP-installations (i.e. how they organised their learning structure) is central. Chapter 6 aims at identifying temporal patterns in learning structures that are used, and getting insight into factors that explain the preference for a specific learning structure. In this chapter the explanation of the choice for specific learning structures is derived from the theory of interactive learning. We adapt the notion of interactive learning by including the configuration of partners, which reflects a variety of learning structures. So, our learning structures are operationalised as varying network configurations representing distinct ways of engaging external and internal partners in the adoption and implementation of CHP-installations. Based on literature on ways to acquire knowledge (Powell et al., 1996; Meeus et al., 2000; Gherardi, 2001; Zahra et al., 2002) we made a typology of six learning structures. We distinguished three main compositions of structures: rely on own knowledge, enter in knowledge based relationships, and outsourcing. Furthermore, for each of these structures there is also the possibility to hire new personnel (recruit bearers of knowledge). We expect the extent to which the adopting firm will elaborate the set of partners (select a different composition of learning structure) in the adoption and implementation processes to be a function of the strength of the internal resource base and the technological complexity. The focus on environmental innovation has some implications for the concepts and relations we study. The non-core element of environmental innovation suggests that more often than in the case of core innovation competences will be missing and new knowledge and routines will be more often required (Ehrenfeld, 1999; Marcus et al., 1999). In addition, if actors are to be involved, it is plausible, in the case of environmental innovation, that these actors are outside the "normal" network (value chain) of the firm (Ehrenfeld, 1999).

The results show that most factories (nine out of seventeen) relied on supplier relations only in addition to their own knowledge, whereas six factories collaborated with consultancy firms or other knowledge relations. Outsourcing was only observed twice. It was indicated that they want to have the energy provision in their own hands as far as possible. The results indeed show that firms with a stronger internal resource base more often rely on their own knowledge in addition to supplier relations, whereas firms with weaker internal resource bases acquired external knowledge in addition to their own knowledge and supplier relations. This supports the resource deficits argument (Teece, 1986; Meeus et al., 2000; Nooteboom, 2000). The results do not support that complexity is positive related to the level of interaction with partners to obtain external resources. However, technological complexity has an effect, when one takes the interaction term of technological complexity and the strength of the internal resource base. In sum, the results confirm the hypothesis that a high complexity requires skills, capabilities, and/or knowledge, which most innovating firms do not have internally (Zahra et al., 2002) and that these innovating firms as a consequence will acquire external resources and search for partners other than solely suppliers. Finally, we expected time to act as a moderating variable because of accumulation of knowledge over time. The results indeed show this accumulation of knowledge. In Chapter 6 we focus on learning on the project level. In Chapter 7 we shift to the intra-project level and study one knowledge generation project by means of a process approach.

In Chapter 7, we elaborate on trial-and-error learning as this trial-and-error learning has been extensively researched by Van de Ven et al (1992; 1999). Trial-and-error learning concerns the iterative sequence of actions and outcomes. The project we study in this chapter, a knowledge generation project of the Competence Centre Paper and Board in The Netherlands, is a collaboration of more than ten organisations. Although, it is often highlighted in literature that shared visions, similar aims and commitment of partners are necessary for successful collaboration (Doz, 1996; Draulans et al., 2003; Moors et al., 2007), effects of dynamics in the actor network on the evolution of innovation processes are not empirically investigated before. Moreover, in R&D-projects the acquisition of human resources and the availability and quality of such a resource is a trivial issue. In their analysis on learning processes, Van de Ven and colleagues do not deal with these effects systematically. The aim of Chapter 7 is to test the relation actions and outcomes and to test to what extent actions-outcomes are interrelated to the volatility of inputs. We decompose volatility of inputs into three different aspects. First, the availability of human resources, so the entry and exit of project members. The literature report positive as well as negative consequences of turnover of personnel (Staw, 1980; Dalton et al., 1982). Second, the quality of human resources, in other words the performance of project partners. Third, the interactions between the project members, in other words network dynamics. We distinguish two types of network dynamics: particpation and volatility. To facilitate knowledge exchange participation in meetings is important. In addition, a certain level of stability of the network is required. If in each meeting other persons turn up, which reflects a volatile network, it will be difficult to learn from earlier events. Similar to Van de Ven and colleagues we model trial-and-error learning by means of a process approach. We use event time series regression analysis to test the model (Poole et al., 2000). The project we study consist of four sub-projects, which we modelled separately. Each sub project has its own specific dynamic, although some findings are more general.

Concerning the effect of the entry and exit of human resources on the trial-and-error learning process our results are inconclusive. The entry of human resources results in some cases in a continuation of the action course, whereas it results in a modification of the action course in other cases. The same applies for the exit of human resources. With regard to the performance of partners, a reciprocal relation between substandard performance and negative outcomes is observed in two of the working groups. We do not observe this reciprocity for standard performance and positive outcomes. One can conclude that partners should perform standard, although this in itself does not always result in positive outcomes. Otherwise, if project members perform substandard a vicious cycle is started between substandard performance and negative outcomes. The results of the network dynamics are interesting. The volatility of the network, which we define as the number of project members that attended twice in two subsequent meetings, has a relative large impact on the learning process. We observe several effects. We argue that in the case of a high volatility, less knowledge spill-over takes place. First, this may lead to indecisiveness among project members. As a consequence, they will not alter the course of action. Indeed, several times we observe that a high volatility of the network resulted in less modification of the action course. Second, a high volatility, may cause substandard performance of partners. If knowledge spill-over is insufficient, it is more difficult for partners to function properly. As we discuss above, this substandard performance in its turn may result in negative outcomes. Finally, several times volatility leads to the exit of human resources. A high volatility may result in less feedback of other working groups and less knowledge spills over, which may discourage project members. This discouragement may result in the exit of members. Overall, we can conclude that adding these variables results in a in-depth insight of the trial-and-error learning. Although the effect of turnover of personnel is still unclear, the effect of the performance of partners and the volatility of the network provide us with interesting conclusions.

Conclusion and discussion

In the final chapter of the thesis conclusions are drawn and discussed. Moreover, I reflect on the outcomes. With regard to policy making, I suggest that it is important to involve stakeholders. Before policies are implemented, obtaining insight into the industry, its behaviour, production processes, hot topics, problems etc. can contribute to a better alignment of the aims of government and industry. This seems to be more effective. Firms are heard, while it can be difficult for a government to completely understand the production process of a specific industry. Intermediary organisations such as industry associations can play an important role in this process. It also important to realise that different instruments are based on different behavioural mechanisms, and that an accumulation of policy measures can have both desirable and undesirable effects. I would suggest a clear set of instruments, with clear objectives and a measure of flexibility for the firms in pursuing these objectives, but also stringent action by the government if goals are not reached. In that way we all know what we can expect of each other.

At the same time, it is important for firms and industries to be aware of current policy and to anticipate future policy, in order to avoid surprises at the end of the day. Furthermore, I think that it is important for firms and industries to be aware of technological developments. Especially where it concerns non-core innovation, it is important to pay close attention to technological developments, as it is not self-evident to pursue these in a field that is not your own. In addition to technological developments, it is important for firms to know which actors are involved and what competences and knowledge they possess. I believe that organisations such as an industry association can also play an important supporting role in this process.

Thus, after opening the black box of environmental innovation, we may conclude that environmental innovation is a challenge: for industry, politics and innovation science alike!

Samenvatting

Het openen van de zwarte doos van milieu-innovatie

Overheidsbeleid en leren in de Nederlandse papier- en kartonindustrie

Introductie

Hoewel klimaatverandering altijd al heeft plaatsgevonden, is het duidelijk dat de huidige veranderingen in ons klimaat het resultaat zijn van menselijke activiteiten (IPCC, 2007). Een belangrijke oorzaak is de uitstoot van broeikasassen, in het bijzonder de uitstoot van CO_2 als gevolg van het gebruik van fossiele brandstoffen. Om het risico van de negatieve gevolgen van klimaatverandering in te perken, is het belangrijk de uitstoot van broeikasgassen te verminderen. Ondanks het succes van eerdere maatregelen om de milieu-impact te verminderen, hebben we nog steeds te maken met aanzienlijke milieuproblemen (European Environmental Agency, 2003; Elzen et al., 2005). Fundamentele veranderingen in industriële processen zijn noodzakelijk om een duurzame samenleving te realiseren (Hall et al., 2003; Geels et al., 2004). Een manier om dit te bewerkstelligen is milieu-innovatie. Milieu-innovatie is een bijzondere vorm van innovatie en "bestaat uit nieuwe of gewijzigde processen, technieken, procedures, systemen en producten om milieu-impact te voorkomen of te reduceren" ((Beise et al., 2005) p6).

Een beter begrip van deze processen van milieu-innovatie is nodig (Foster et al., 2000; Rennings, 2000; Hall, 2003). Het is noodzakelijk om de zwarte doos van milieu-innovatie te openen.

Evenals bij "normale" innovatie is milieu-innovatie iets dat nieuw is voor de innoverende organisatie. Ofwel innovatie betreft het doen van hetzelfde op een andere manier, ofwel innovatie betreft het doen van nieuwe dingen. Dit houdt in dat er hoe dan ook geleerd moet worden. Het spannende aspect aan milieu-innovatie is dat deze innovaties geen onderdeel vormen van het primaire proces van de innoverende organisaties.

Maar het is nog complexer. Naast het feit dat milieu-innovatie niet het primaire proces is van de innoverende organisatie, hebben we ook te maken met het feit dat milieu een publiek goed is. Een publiek goed wordt gekarakteriseerd als niet-rivaliserend en niet-uitsluitbaar. Als gevolg hiervan is de kosten-batenverdeling scheef. Terwijl de baten in hun geheel voor de samenleving zijn, zijn de kosten voor de innoverende organisatie en is het bovendien in het geval van innovatie uberhaupt vaak moeilijk zich winsten toe te eigenen. Dit wordt het dubbele-externaliteiten probleem genoemd. Dit probleem vermindert de neiging te investeren in milieu-innovatie (Beise et al., 2005) en het veronderstelt dat dit type innovatie (milieu-innovatie) geen autonome ontwikkeling zal zijn. Dit wordt vaak aangeduid als marktfalen. Daarom is de overheid een belangrijke actor die milieu-innovatie beïnvloedt. Dit maakt het interessant om te onderzoeken wat de precieze invloed van overheidsbeleid is op milieu-innovatie processen (Hardin, 1968; Foster et al., 2000; Rennings, 2000; Beise et al., 2005; Vollebergh, 2007).

In dit proefschrift wordt gekeken naar de Nederlandse papier- en kartonindustrie. De reden hiervoor is dat het productieproces van papier en karton energie-intensief is. Als gevolg hiervan kent de Nederlandse papier- en kartonindustrie een lange geschiedenis van energiebesparende activiteiten. Bovendien heeft deze industrie te maken met twee andere milieukwesties. Naast energie zijn ook afval en afvalwater belangrijke aandachtspunten in het productieproces van de Nederlandse papier- en kartonindustrie. Deze kwesties staan ook al enige tijd op hun innovatieagenda.

Het doel van dit proefschrift is tweeledig. Het doel is het beter begrijpen van enerzijds de structurering van de leerprocessen en de interacties binnen deze leerprocessen en anderzijds de interactie met de overheid. De volgende vier onderzoeksvragen zijn geformuleerd:

RQ 1: In welke mate wordt de branchevereniging van de Nederlandse papier- en kartonindustrie betrokken in de ontwikkeling van verschillende typen van overheidsinstrumenten in het milieubeleid?

RQ 2: Wat is de relatieve rol van de verschillende milieubeleidsinstrumenten in het geval van milieu-innovatie in de Nederlandse papier- en kartonindustrie op het gebied van energie, afvalwater en afval?

RQ 3: In welke mate betrekt de Nederlandse papier- en kartonindustrie externe actoren in hun leerprocessen in het geval van milieu-innovatie?

RQ 4: In welke mate kunnen (de ontwikkelingen van) leerprocessen verklaard worden vanuit een "resource based view" van de organisatie?

Dit proefschrift bevat vijf empirische hoofdstukken waarin deze vier vragen worden bediscussieerd. De eerste twee onderzoeksvragen komen aan bod in Hoofdstuk 3, 4 en 5. Onderzoeksvragen 3 en 4 worden besproken in Hoofdstuk 6 en 7. Hoofdstuk 2 bevat een introductie in de Nederlandse papier- en kartonindustrie, haar productieproces en belangrijke partners.

Het empirische gedeelte

Samenwerking tussen overheid en bedrijfsleven in het beleidsproces is een manier om efficiënter energie- en milieubeleid te realiseren (Marcus et al., 2002). Intermediaire organisaties kunnen een belangrijke rol spelen bij de samenwerking in dit beleidsproces. Het doel van Hoofdstuk 3 is inzicht te verkrijgen in de rol van een specifieke intermediaire organisatie: de branchevereniging. De belangen van de Nederlandse papier- en kartonindustrie worden behartigd door de Koninklijke VNP. In dit hoofdstuk wordt gekeken naar de drie eerder genoemde milieukwesties, die gerelateerd zijn aan het productieproces van deze industrie: afvalwater, afval en energie. In dit proefschrift worden vier typen overheidsinstrumenten onderscheiden: top-down regulering, interactieve regulering, negatieve economische instrumenten en positieve economische instrumenten. De aanpak in dit hoofdstuk (Hoofdstuk 3) is het in kaart brengen van de activiteiten van de branchevereniging en de overheid in de ontwikkeling van milieubeleidsinstrumenten met betrekking tot afvalwater, afval en energie in de periode 1980-2003. De resultaten geven interessante inzichten in de rol van een branchevereniging in het beleidsproces voor de verschillende beleidsinstrumenten. Het wordt duidelijk dat de branchevereniging een andere rol speelt wanneer verschillende beleidsinstrumenten worden ingezet. In overeenstemming met onze verwachtingen is het gedrag van de branchevereniging reactief in het geval top-down regulering en negatieve economische instrumenten en proactief in het geval van interactieve regulering en positieve economische instrumenten. Bovendien is de betrokkenheid van de industrie, vertegenwoordigd door de branchevereniging, het grootst in het geval van interactieve regulering en het kleinst in het geval van top-down regulering. Vanwege een verschuiving in het Nederlands overheidsbeleid naar meer interactieve regulering krijgen intermediaire organisaties een belangrijkere functie. Hoewel de rollen van intermediaire organisaties in de bestaande literatuur (cf. (Van Lente et al., 2003)) als vrij statisch worden beschouwd, geven de resultaten in dit proefschrift een meer gedetailleerd beeld van het gedrag van intermediaire organisaties.

Terwijl Hoofdstuk 3 dus een meer robuuste beschrijving geeft van de rollen van een intermediaire organisatie, laat het niet zien of verschillen in die rol van de branchevereniging ook leiden tot een verandering in de effectiviteit van de betreffende beleidsinstrumenten. Daarom wordt in Hoofdstuk 4 dezelfde set van instrumenten bestudeerd om meer inzicht te verkrijgen in de manier waarop milieubeleid milieu-innovatie beïnvloedt.

De relatie tussen milieubeleid en milieu-innovatie is complex. Verschillende en soms conflicterende theoretische en empirische bevindingen ten aanzien van de relatie tussen milieubeleid en milieu-innovatie worden gevonden in de literatuur (Sanchez, 1997). Hoofdstuk 4 is een poging inzicht te verkrijgen in de manier waarop de stapeling van beleidsinstrumenten, of in andere woorden de stijging van beleidsdruk, innovatieve activiteiten en eco-efficiëntie van een industrie beïnvloedt. Om het effect van beleidinstrumenten op onderzoeksactiviteiten en eco-efficiëntie te bestuderen, worden voor de drie milieukwesties (afvalwater, afval en energie) de volgende trends geïdentificeerd voor de periode 1980-2003: 1) de implementatie van milieubeleidsinstrumenten; 2) collectieve onderzoeksprojecten; 3) eco-efficiëntie van de industrie. De resultaten voor afvalwater en afval laten zien dat er een tijdsvertraging zit tussen een stijging van de beleidsdruk en een stijging van de eco-efficiëntie. Voor beide milieukwesties vindt er geen stijging in de collectieve onderzoeksactiviteiten plaats nadat de beleidsdruk is gestegen. De resultaten voor energie laten zien dat een stijging van de beleidsdruk leidt tot een stijging van de onderzoeksactiviteiten èn een stijging van de eco-efficiëntie. In tegenstelling tot de resultaten van afvalwater en afval, wordt er in het geval van energie geen tijdsvertraging waargenomen. Een verbetering van de energie-efficiëntie van het proces heeft naast een reductie van milieu-impact ook een duidelijk economisch voordeel, hetgeen kan verklaren waarom de eco-efficiëntie in het geval van energie relatief snel stijgt. Over het geheel genomen leidt dit tot de conclusie dat in het algemeen een stijging van de beleidsdruk resulteert in een verbetering van de eco-efficiëntie met of zonder tijdsvertraging.

Maar deze resultaten stellen ons niet in staat om te bepalen wat de mate is waarin en de manier waarop verschillende beleidsinstrumenten milieu-innovatie beïnvloeden. Om meer inzicht te verkrijgen in het effect van individuele beleidsinstrumenten wordt het perspectief in Hoofdstuk 5 verschoven naar dat van de bedrijven.

Er zijn twee redenen waarom men niet eenvoudigweg reducties van milieu-impact kan toekennen aan milieubeleid van de overheid. Allereerst is er sprake van een stapeling van beleidsmaatregelen, wat impliceert dat in relatief korte tijdsperiodes een aantal beleidsinstrumenten worden geïmplementeerd met als doel het realiseren van gerelateerde overheidsdoelstellingen. Ten tweede wordt milieuvriendelijk gedrag van organisaties ook beïnvloed door andere factoren, zoals intra-organisatorische factoren. Om een beter inzicht te verwerven in het effect van verschillende beleidsmaatregelen op milieu-innovatie en om beleidsstapeling en intra-organisationele factoren mee te kunnen nemen, stellen we een andere aanpak voor in Hoofdstuk 5. Deze aanpak gaat naast het evalueren van specifieke beleidsinstrumenten ook in op het gedrag van organisaties ten aanzien van de adoptie van milieuvriendelijke technologieën. In dit hoofdstuk wordt gekeken naar de adoptie van wkk-installaties (warmtekracht koppeling) in de Nederlandse papier- en kartonindustrie. Met behulp van interviews zijn de adoptieprocessen van de hedendaagse wkk-installaties gereconstrueerd. De resultaten laten zien dat er twee periodes (Periode II en III) zijn waarin de meest adopties plaatsvonden. Periode II begon aan het eind van de jaren zeventig en eindigde in het midden van de jaren tachtig. Periode III bestrijkt de eerste helft van de jaren negentig. Deze twee periodes komen overeen met verschillende periodes van overheidsbeleid. In Periode II was het overheidsbeleid voornamelijk gericht op subsidies die de diffusie van wkk stimuleerden. Periode III echter kan gekarakteriseerd worden door convenanten tussen overheid en industrie en de Eerste Electriciteitswet van 1989. Rond de jaren zestig was er ook een periode (Periode I) waarin veel wkk-installaties zijn geadopteerd. Veel van deze installaties zijn echter vervangen. De interviews laten zien dat in Periode II de hoge energieprijs in samenhang met een kostprijsreductie of met de dreiging van regulering het meest belangrijk waren in de beslissingen. Bovendien speelden positieve economische instrumenten een rol in alle adopties. De hoge energieprijs in samenhang met een kostprijsreductie was ook een belangrijke reden voor de adopties in Periode III. Positieve economische instrumenten waren ook in deze periode belangrijk, maar niet zo belangrijk als in Periode II. Daarnaast was interactieve regulering belangrijk in Periode III. Na Periode III hebben er geen nieuwe adopties meer plaatsgevonden. Vanaf dat moment belemmerde het mileiubeleid eigenlijk milieu-innovatie: als gevolg van nieuw overheidsbeleid veranderde de economische situatie rondom wkk en als gevolg van veelvuldige veranderingen in het overheidsbeleid werden organisaties meer risicomijdend. Over het algemeen kunnen we concluderen dat overheidsbeleid relevant is, maar dat het maar één van de factoren is die de adoptie beïnvloeden. Het relatieve belang van overheidsbeleid varieert over de tijd en per adoptieproces. De resultaten laten ook de verschillende effecten van beleidsstapeling zien. Zo werd duidelijk dat bepaalde instrumenten elkaar op een positieve manier versterken, maar ook dat de implementatie van bepaalde instrumenten situaties kan verstoren die ontstaan waren door de implementatie van eerdere beleidsmaatregelen. Tot slot werd ook duidelijk dat de implementatie van verscheidene instrumenten in een relatief korte tijdsperiode kan leiden tot risicomijdend gedrag.

In de eerste drie empirische hoofdstukken stonden vooral overheidsbeleid en milieu-innovatie centraal, vanaf Hoofdstuk 6 komt leren centraal te staan. Terwijl in Hoofdstuk 5 is gekeken naar de redenen waarom organisaties wkk-installaties adopteren, staat in Hoofdstuk 6 het proces van het al dan niet betrekken van externe partijen tijdens deze adoptie- en implementatieprocessen (met andere woorden de structuur van het leerproces) centraal. Het doel van Hoofdstuk 6 is allereerst het identificeren van temporele patronen in de leerstructuren die gevolgd worden en daarnaast inzicht verkrijgen in de factoren die de voorkeur voor bepaalde leerstructuren verklaren. In dit hoofdstuk wordt de verklaring voor de keus van een bepaalde leerstructuur gehaald uit de theorie van interactief leren. Dit concept van interactief leren wordt door ons enigszins aangepast door, in tegenstelling tot eerdere literatuur, een configuratie van partners te bestuderen, welke een variëteit van leerstructuren oplevert. Kortom, in dit hoofdstuk worden leerstructuren geoperationaliseerd als variërende netwerkconfiguraties die verschillende manieren van het betrekken van partners in de adoptie en implementatie van wkk-installaties weerspiegelen. Op basis van literatuur die betrekking heeft op manieren om kennis te verwerven (Powell et al., 1996; Meeus et al., 2000; Gherardi, 2001; Zahra et al., 2002), is in dit hoofdstuk een typologie ontwikkeld van zes leerstructuren. Drie hoofdcomposities van structuren zijn onderscheiden: het bouwen op eigen kennis en toeleveranciers, het aangaan van kennisrelaties en het uitbesteden. Bovendien is er voor elke hoofdcompositie de mogelijkheid om nieuwe mensen aan te nemen. Het is onze verwachting dat de mate waarin een organisatie de set van partners uitbreidt (een andere compositie van een leerstructuur kiest) in een adoptie- en implementatie proces afhankelijk is van de sterkte van de interne kennisbasis en de technologische complexiteit. Het feit dat er in dit proefschrift naar milieu-innovatie wordt gekeken heeft implicaties voor de concepten en de relaties die bestudeerd worden. Het eerder genoemde aspect dat milieu-innovatie niet het primaire proces is, schept de verwachting dat vaker competenties ontbreken en nieuwe kennis en routines nodig zijn (Ehrenfeld, 1999; Marcus et al., 1999). Bovendien is de verwachting dat als er actoren betrokken zullen worden, dit andere actoren zijn dan uit het normale netwerk van de organisatie, andere actoren dan uit haar waardeketen (Ehrenfeld, 1999).

De resultaten laten zien dat de meeste fabrieken (negen van de zeventien) bouwden op hun eigen kennis en toeleverancierrelaties. Zes fabrieken werkten samen met adviesbureaus of andere kennisrelaties. Het uitbesteden is maar 2 keer waargenomen. Het blijkt dat men in de papierindustrie de energievoorziening zoveel mogelijk in eigen hand wil houden. De resultaten laten, in lijn met onze verwachtingen, zien dat organisaties met een sterkere interne kennisbasis vaker op hun eigen kennisbasis en toeleveranciers bouwen, terwijl organisaties met een zwakkere kennisbasis ook vaak externe kennis verwerven naast de eigen kennis en toeleverancierrelaties. Dit ondersteunt het "hulpbronnentekort" argument (Teece, 1986; Meeus et al., 2000; Nooteboom, 2000). De resultaten ondersteunen echter niet onze hypothese dat technologische complexiteit positief gerelateerd is aan de mate waarin samengewerkt wordt met partners voor het verkrijgen van externe hulpbronnen. Echter, technologische complexiteit heeft wel een effect waarneer gekeken wordt naar de interactieterm van technologische complexiteit en de sterkte van de interne kennisbasis. Kort samengevat: de resultaten bevestigen de hypothese dat een hoge complexiteit vraagt om vaardigheden, mogelijkheden en kennis die de meeste innoverende organisaties niet zelf in huis hebben (Zahra et al., 2002) en dat deze innoverende organisaties daarom externe hulpbronnen willen werven en dus op zoek gaan naar partners anders dan alleen toeleveranciers. Ten slotte verwachtten we dat tijd als een modererende variabele zou optreden als een gevolg van accumulatie van kennis over de tijd. De resultaten laten inderdaad zien dat er een accumulatie van kennis is. In Hoofdstuk 6 is de focus leren op projectniveau. In Hoofdstuk 7 verschuift de focus naar een intra-projectniveau en wordt een kennisgeneratieproject bestudeerd met behulp van een procesanalyse.

In Hoofdstuk 7 wordt trial-and-error leren bewerkt, wat door Van de Ven et al. (1992; 1999) zeer intensief onderzocht is. Trial-and-error leren is de iteratieve opeenvolging van acties en uitkomsten. Het project dat bestudeerd wordt in dit hoofdstuk is een kennisgeneratieproject van het Kenniscentrum Papier en Karton en is een samenwerking van meer dan tien organisaties. Hoewel vaak in de literatuur wordt aangekaart dat gedeelde visies, gelijke doelen en betrokkenheid van partners noodzakelijk zijn voor een succesvolle samenwerking (Doz, 1996; Draulans et al., 2003; Moors et al., 2007), zijn de effecten van netwerkdynamiek op het verloop van innovatieprocessen niet eerder empirisch onderzocht. Bovendien zijn het verwerven van menselijke hulpbronnen en de aanwezigheid en kwaliteit van zulke hulpbronnen in R&D-projecten duidelijk van belang. Van de Ven en collega's nemen deze effecten echter niet systematisch mee in hun analyse van leerprocessen. Het doel van Hoofdstuk 7 is het toetsen van de relatie tussen acties en uitkomsten en het toetsen van de mate waarin acties-uitkomsten in verband staan met de volatiliteit van input. Deze volatiliteit wordt in drie delen uiteengesplitst. Allereerst, de beschikbaarheid van menselijke hulpbronnen, met andere woorden het aantrekken en het vertrek van projectleden. In de literatuur worden zowel positieve als negatieve effecten beschreven als gevolg van het verloop van personeel (Staw, 1980; Dalton et al., 1982). Ten tweede, de kwaliteit van menselijke hulpbronnen, met andere woorden de prestaties van partners. Ten derde, de interacties tussen projectleden, met andere woorden netwerkdynamiek. Twee typen netwerkdynamiek worden onderscheiden in dit hoofdstuk: participatie en volatiliteit. Om kennisoverdracht te faciliteren is participatie in de vergaderingen belangrijk. Bovendien is een bepaalde mate van stabiliteit gewenst. Als namelijk in elke vergadering andere deelnemers verschijnen, hetgeen een volatiel netwerk weerspiegelt, zal het lastig zijn te leren van eerdere gebeurtenissen. In overeenstemming met Van de Ven en collega's wordt in dit hoofdstuk trial-and-error leren gemodelleerd met behulp van een procesaanpak. "Event Time Series Regression Analysis" wordt gebruikt om het model te toetsen (Poole et al., 2000). Het project dat geanalyseerd wordt, bestaat uit vier deelprojecten die apart gemodelleerd zijn. Het blijkt dat elk deelproject zijn eigen dynamiek kent, hoewel bepaalde bevindingen meer generiek zijn. Met betrekking tot het effect van het aantrekken en het vertrek van menselijke hulpbronnen op trial-and-error leren zijn de resultaten niet afdoende. Het aantrekken van menselijke hulpbronnen resulteert in sommige gevallen in een verandering van acties, terwijl het in andere gevallen juist leidt tot een continuering van de acties. Hetzelfde geldt voor het vertrek van menselijke hulpbronnen. Met betrekking tot de prestaties van partners wordt een wederkerige relatie geobserveerd tussen suboptimaal functioneren van partners en negatieve uitkomsten in twee werkgroepen. Deze wederkerigheid wordt echter niet waargenomen voor positieve prestaties en positieve uitkomsten. Op basis hiervan kan men concluderen dat partners het beste goed kunnen presteren, hoewel dit op zichzelf niet direct resulteert in positieve uitkomsten. Is dit namelijk niet het geval dan bestaat het gevaar in een vicieuze cirkel van negatieve uitkomsten en suboptimaal functioneren terecht te komen. De volatiliteit van het netwerk, gedefinieerd als het aantal projectleden dat aanwezig is bij twee opeenvolgende vergaderingen, heeft een relatief grote impact op het leerproces. Verschillende effecten zijn waargenomen. Het onderliggende argument is dat in het geval van een hoge volatiliteit minder kennis spillover zal plaatsvinden. Allereerst kan dit leiden tot besluiteloosheid onder de projectleden. Als gevolg daarvan zullen de acties niet gewijzigd worden. Inderdaad werd in verscheidene werkgroepen waargenomen dat een hoge volatiliteit resulteerde in minder wijzigingen van de acties. Ten tweede kan een hoge volatiliteit leiden tot suboptimaal functioneren van partners. Als de kennis spillover namelijk niet voldoende is, is het voor de partners moeilijker om goed te functioneren. Zoals hierboven al geschetst, kan het suboptimaal functioneren op zijn beurt weer leiden tot negatieve uitkomsten. Tot slot bleek een hoge volatiliteit in een aantal gevallen te leiden tot het vertrek van projectleden. In het geval van een hoge volatiliteit zal er minder feedback en spillover tussen de werkgroepen plaatsvinden. Dit kan leiden tot ontmoediging èn tot het vertrek van projectleden. Over het algemeen kan geconcludeerd worden dat het toevoegen van de variabelen resulteert in diepgaander inzicht in het trial-and-error leerproces. Hoewel het effect van het verloop van personeel nog steeds onduidelijk is, bieden de effecten van prestaties van partners en de volatiliteit van het netwerk interessante inzichten.

Conclusie en discussie

In het laatste hoofdstuk van dit proefschrift worden conclusies getrokken en bediscussieerd. Bovendien reflecteer ik daar op de resultaten. Met betrekking tot het maken van overheidsbeleid, ben ik van mening dat wanneer er inzicht verkregen wordt in de industrie, haar gedrag, productieprocessen, belangrijke zaken, problemen etc. voordat beleid wordt geïmplementeerd dit kan leiden tot een betere afstemming van de doelen van overheid en industrie. Dit blijkt effectiever te zijn. Organisaties worden namelijk gehoord en het is voor de overheid moeilijk het productieproces van verschillende industrieën volledig te begrijpen. Intermediaire organisaties, zoals een branchevereniging, kunnen een belangrijke rol spelen in dit proces. Bovendien is het ook belangrijk te beseffen dat verschillende instrumenten gebaseerd zijn op verschillende gedragmechanismen en dat een stapeling van beleidsinstrumenten zowel wenselijke als onwenselijke effecten met zich mee kan brengen. Daarvoor zou het overheidsbeleid volgens mij idealiter moeten bestaan uit een duidelijke set van instrumenten, met duidelijke doelen en een bepaalde mate van flexibiliteit voor organisaties met betrekking tot de wijze waarop deze doelen gerealiseerd moeten worden. Daarbij is het echter wel van belang dat de overheid streng optreedt wanneer doelen niet gerealiseerd worden. Op deze manier weet iedereen wat men aan elkaar heeft.

Tegelijkertijd is het belangrijk voor de industrie en organisaties op de hoogte te zijn van het huidige overheidsbeleid en te anticiperen op toekomstig overheidsbeleid om zo verrassingen te voorkomen. Bovendien is het mijns inziens belangrijk op de hoogte te zijn van technologische ontwikkelingen. In het bijzonder wanneer milieu-innovatie niet het primaire proces is, is het van belang extra aandachtig de technologische ontwikkelingen te volgen, omdat het niet vanzelfsprekend is deze te volgen als het niet het primaire proces betreft. Naast oog houden voor technologische ontwikkelingen, is het voor organisaties van belang te weten welke actoren betrokken zijn en welke competenties en kennis deze actoren bezitten. Ik denk dat een organisatie zoals een branchevereniging ook een belangrijke, ondersteunende rol kan spelen in dit proces.

Nadat de zwarte doos van milieu-innovatie geopend is, kunnen we concluderen dat milieu-innovatie een uitdaging is: voor de industrie, de politiek en innovatiewetenschap!

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Maryse Chappin
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Curriculum Vitae

Maryse Chappin was born in Zoetermeer, The Netherlands on 16 October 1980. She completed her secondary education at the 'Oranje Nassau College' in Zoetermeer in 1999. In this year she started studying Science & Innovation Management at Utrecht University. She specialized in Energy and Materials. She obtained her masters degree (with distinction) in 2003. In October 2003 she started working on her PhD project within the Copernicus Institute at the Department Innovation and Environmental Sciences at Utrecht University. Since October 2007, she has started working as a lecturer at the Department of Organization Studies at Tilburg University.

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