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Enhancing our understanding of the role of environmental policy in environmental innovation: adoption explained by the accumulation of policy instruments and agent-based factors

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ABSTRACT

The empirical literature reports conflicting findings on the relation between environmental policy and environmental innovation: environmental policy both encourages and impedes environmental innovation, resulting in competing theoretical explanations. To find a way out of this counterproductive debate requires new and complementary insights into the effects of different policy instruments. This research therefore advances an approach in which a set of specific policy instruments as well as firms' behavior regarding CHP (cogeneration of heat and power) adoption are considered as two distinct factors explaining environmental innovation in the Dutch paper and board industry. Using a longitudinal research design, the focus was not on any single policy instrument but on the accumulation of policy instruments. In addition, we studied intra-organizational factors influencing the adoption decision.

Overall, we can conclude that paper and board factories perceive governmental environmental policies to be relevant, but that this constitutes just one of the factors influencing adoption processes, next to intra-organizational factors. The relative importance of such policies varies over time and per adoption process. The role of top-down regulation appears to be limited, whereas interactive regulation turned out to be important for several factories in the latest period of adoption. Positive economic instruments were important in almost all adoption processes, but were not and will never be the most important reason for adoption. The most important reason for CHP adoption appears to be high energy prices in combination with cost price reduction or the threat of additional regulation. For future policies, we recommend the implementation of 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 behavior.

1. Introduction

Different and sometimes even conflicting theoretical and empirical findings on the relation between environmental policy and environmental innovation exist in the literature (Sanchez, 1997). There is ambiguity about the effects of environmental policy on innovation, as it may both encourage and impede environmental innovation. The

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literature also presents different explanations for this ambiguity, as outlined in more detail in the next section. We believe that there are some further reasons for these ambiguities. In the case of environmental policies, there are two reasons why we cannot simply attribute environmental impact reductions to governmental environmental policies. First, we are dealing with an accumulation of policy instruments, which implies that, in relatively short time periods, multiple policy instruments are implemented with the aim of achieving related policy goals. One can therefore not simply attribute impact reductions to any 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, eco-friendly behavior by firms is not just influenced by policies but also by intra-organizational factors such as operational strategies. For instance, firms innovate in order to beat the competition or they launch a new eco-friendly product to improve their corporate image. To gain broader insight into the effects of different policy instruments on innovation and to incorporate policy accumulation and intra-organizational factors, we advance an alternative approach that not only evaluates specific policy instruments, but also evaluates firms' behavior regarding the adoption of eco-friendly technologies.

As to the environmental innovation, we focus on the adoption of CHP-installations (cogeneration of heat and power) in the Dutch paper and board industry. The simultaneous generation of electricity and heat is more efficient than separate generation, resulting in an increase of energy efficiency (defined as primary energy use/sales) and a decrease of CO_2 emissions. Over the last decades, the adoption and implementation of CHP-installations has been an important means to increasing energy efficiency in the industry (VNP, 1986; Koopman et al., 2004).[1] Over the course of years, the Dutch government developed an elaborate series of policy initiatives aimed at improving industrial energy efficiency. These governmental policy objectives have been attained (VNP, 2003; Koopman et al., 2004). It is specifically the serial and simultaneous nature of implemented policy initiatives that makes it difficult to attribute effects to particular measures. We are therefore curious to see how paper and board factories perceive the role of policy instruments compared to intra-organizational factors in the adoption process.

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

The next section starts with the literature review on the relation between environmental policy and innovation. After that, the theoretical framework is explained in more detail. The research approach is outlined in Section 4, and Section 5 presents the results. A conclusion and discussion follow in the final section.

2. Literature review: environmental policy induces innovation?

Table 1 presents a short overview of a number of studies to demonstrate the inconsistency of findings regarding the impact of environmental policies on environmental innovation. In their theoretical review of environmental innovation (especially of energy-efficient technologies) and environmental policy, Grubb and Ulph (2002) 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 is weak, and that the most significant effects appear in the long term through learning-by-doing (Grubb and Ulph, 2002). Other studies present opposing conclusions. With regard to the generation of innovation, it has been observed empirically that environmental policy, operationalized as pollution abatement costs and pollution abatement expenditures, results in an increase in innovation, measured through the number of patents (Lanjouw and Mody, 1996; Brunnermeier and Cohen, 2003). By contrast, Jaffe and Palmer (1997) did not find a statistically significant relationship between regulation compliance expenditure and patenting activity. They did however find a significant positive relationship between regulation compliance expenditure and R&D expenditure (controlled for industry) (Jaffe and Palmer, 1997). A final conflicting finding in the Dutch industry is that innovation intensity was influenced negatively by compliance with environmental regulations and environmental demands (CBS, 1998).

Van Soest (2005) focused on the impact of environmental policy instruments on the timing of the adoption. Using a simulation model, he concluded that there is no clear 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 these instruments (Requate and Unold, 2003; Tarui and Polasky, 2005).

These examples clearly show the ambiguity surrounding 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 and Zegveld, 1981; Rothwell, 1992; Braun and Wield, 1994; Hitchens et al., 1998; Marcus et al., 2002). This reduces the 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 available to seek an optimal solution (Rothwell and Zegveld, 1981; Rothwell, 1992), to decrease the freedom to innovate, and to increase the bureaucracy (Braun and Wield, 1994). Finally, it is argued that firm managers are uncertain about the regulations (Marcus, 1981; Rothwell, 1992; Meijer et al., 2007) and the behavior of regulators (Marcus, 1981; Rothwell and Zegveld, 1981; Gunningham and Sinclair,

[1] Contribution of CHP to energy efficiency improvement: >50% in period 1979–1984; 42.2% in period 1989–2001 (VNP, 1986; Koopman et al., 2004).

Table 1 – An overview of studies on the effects of environmental policy on environmental innovation.

Article	Focus	Operationalization	Conclusions
Lanjouw and Mody (1996)	Generation	Pollution abatement costs; number of patents	Positive relation between pollution abatement costs and number of patents
Jaffe and Palmer (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 and Cohen (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 and Unold (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 and Polasky (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 and Ulph (2002)	Review theoretical and 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

1998; Meijer et al., 2007). Consequently, companies develop risk-avoiding behavior that results in less environmental innovation.

Other authors argue the reverse, claiming that environmental regulation saves money since environmental innovations can reduce the variable or fixed costs through 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 boosting demand and opportunities (Braun and Wield, 1994) and steering technical change (Ashford, 2002). They add that a threat from outside is required to draw attention to a problem. Without such a threat – as for instance environmental regulations – there will be no behavioral change (Van de Ven, 1986; Van de Ven and Polley, 1992; Van de Ven et al., 1999). The argument is that environmental innovation will not occur in the absence of environmental regulation.

We can furthermore identify several limitations of the empirical studies discussed above. First, these studies often use indirect measures to operationalize the concepts. For instance, policy pressure is operationalized in several studies by means of policy abatement expenditures. Another example is a focus on patents in general, instead of concentrating on patents relating to environmental innovation. In addition, policy accumulation is neglected or not properly taken into account, and the studies only focus on a short time period. Finally, with the exception of some control variables, other factors such as intra-organizational aspects are ignored. With these results in mind, we now present our theoretical framework.

3. Theoretical framework

It is striking how most of these explanations treat the adopting firm as a black box and ignore behavioral and intra-organizational explanations, other than resource-based impacts of environmental policies. Moreover, the studies could have

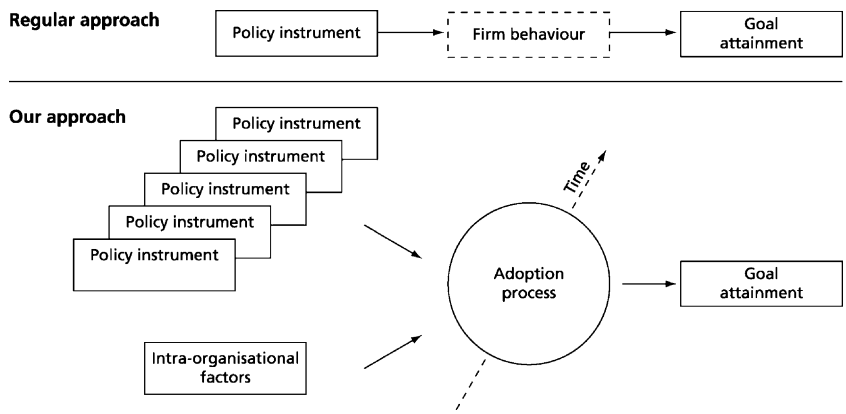

Fig. 1 – Our approach compared to regular evaluations.

devoted more attention to the complexities caused by the fact that so many policy measures with related environmental targets have been implemented simultaneously. Our theoretical framework (Fig. 1) attempts to incorporate these issues. Fig. 1 also shows how this research complements regular effect evaluations, which primarily focus on goal attainment. As these normal evaluations often do not take firm behavior into account, it has been placed in the dotted framework in the top half of Fig. 1. In this research we shift towards an agency perspective.

3.1. *Intra-organizational factors*

We know that adoption, that is, the decision to incorporate an innovation, depends on many different factors besides environmental policies (Rogers, 2003). In Section 1 we already pointed out that neglecting these additional factors makes it difficult to determine the effectiveness of a policy instrument. Regarding 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), which can generally be summarized as follows: innovation characteristics, characteristics of innovators, and context characteristics. In the first group of 'innovation characteristics', five factors mentioned often are relative advantage, complexity, compatibility, triability, and observability (Rogers, 2003).

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

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

There are several studies substantiating the model we advance in Fig. 1. Dupuy's study on the Province of Ontario's Municipal Industrial Strategy for Abatement (MISA) (1997), for instance, considers factors such as cost savings or material savings in addition to environmental policy. Here it emerged that governmental 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.[2] However, despite gaining general insight into factors that did or did not play a role, they were unable to establish a ranking for the different factors. They also concluded that the role of environmental policies in the adoption process has received insufficient attention so far. The studies they analyzed moreover focus on one set of variables from one perspective only, and they recommend that future studies integrate different perspectives and take even more factors into account. Although more factors are indeed considered by some of these studies, the accumulation of policy measures is nevertheless neglected in these studies.

3.2. *Policy accumulation and time*

Let us therefore turn to the accumulation of instruments. In previous literature, it is acknowledged that this accumulation of policy instruments deserves more attention (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 to achieve related policy goals in relatively short time periods. This policy accumulation often implies a mixture of policy instruments with a variety of underlying mechanisms to enable the achievement of policy goals. We discern several dimensions to policy accumulation: growing variety of types of instruments, (in)consistencies between the

[2] 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 and Turkenburg, 1994; Blok and Farla, 1996), as well as several other studies (Boonekamp and Van Hilten, 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.

policy mechanisms, and the temporal aspect, that is clustering of instruments into policy regimes. All these aspects are subsequently dealt with. In the time period covered in this study, the Dutch government applied a variety of policy instruments to induce specific behavior of firms (Rothwell, 1992; Skea, 1994; Keijzers, 2000; Keijzers, 2002; Vermeulen, 2002; Zito et al., 2003). In our research (Chappin et al., 2007, 2008), we distinguished 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 paper as well. The mechanisms with which these instruments evoke, or inhibit certain behaviors are different: coercion, consent, and incentives are applied to achieve policy goals. In top-down regulation, 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'', coercion is the main mechanism. 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 organization and a representative of the private sector with the intent of achieving national environmental policy aims on a voluntary basis'', builds on consent as mechanism. The relationship between these two parties tends to be more cooperative with interactive regulation than with top-down regulation (Sunnevag, 2000). Finally, economic instruments use incentives as mechanisms to promote allocative efficiency through monetary rewards, or sanctions (Rothwell, 1992). We distinguish between negative economic instruments that result in higher costs, and positive economic instruments that result in cost reduction (Vermeulen, 1989).

Throughout the time period covered in this study, multiple policy instruments are implemented simultaneously, and they apply all mechanisms mentioned above. The shorter the time span in which related policy instruments are implemented, the higher the policy pressure for target groups. If implemented in too short a time span, policies will create pressure that may trigger behavioral 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 top-down regulation, interactive regulation, or subsidies. Another example is the exemption of paper and board factories from eco-tax (a tax imposed on natural gas and electricity that are not ''green'') if they participate in the ''Convenant Benchmarking'' (interactive regulation) (see Chappin et al., 2007). However, it can also happen that the mechanisms of the instruments are related yet inconsistent, 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 into fuel pellets in order to save energy (Koninklijke VNP, 2004). In the end it turned out that Dutch legislation at that time prohibited burning these pellets. 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. For this reason, it is also worthwhile exploring how policies develop over time.

Policy accumulation does not only refer to the number of policy instruments implemented. The accumulation of measures can also result in the presence of a cluster of policy instruments. On the basis of the mix of policy instruments based on (un-)related mechanisms, we refer to these clusters of measures as policy regimes. As it is relevant to figure out to what extent different regimes replace each other over time, time should feature as an important aspect in adoption research (Jaffe et al., 2002). Moreover, not only policy instruments accumulate and change over time but intra-organizational factors may also vary across different time periods. For that reason, Waarts et al. (2002) propose to take time into account as a significant factor. Indeed, they observe a shift in the explanatory factors over a period of time (Waarts et al., 2002). The accumulation of policy instruments as well as intra-organizational factors are thus deliberately taken into account, and both within the context of time. This is a first attempt to determine the relative influence of environmental policies on environmental innovation in this way.

4. Research approach

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 year we collected our data – the Dutch paper and board industry consisted of 27 factories.[3] During the time we gathered the data, 17 factories were using a CHP-installation.[33]

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

In preparation for the interviews, we consulted three experts in the field of CHP. Furthermore, by means of desktop research and these expert consultations we compiled a list of all policy instruments relevant to CHP that were implemented between 1977 and 2003 (see also Fig. 3).

During the interviews, which lasted between 1 and 2 h, the adoption and implementation processes were reconstructed with the interviewee. An important theme in this reconstruction was the role of governmental policies in the adoption process. We presented the interviewee with the overview of policy instruments and asked whether these instruments had influenced the decision. If this was the case, we asked whether and why it had either accelerated or delayed the decision. In addition to this list of policy measures, we probed other factors influencing the decision. First, we inquired about some key events and the need for cost price reduction. Second, the respondents were asked to indicate other factors that had affected their decision. For all events and factors listed, we

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

Table 2 – The ranking of influencing factors per factory per period.

Factors	Factory																						
	I[a]		II[a]												III[a]								
	A	Tot I[b]	B	C	D	E	F	G	H	I	J	K	Tot II	Mean[c]	L	M	N	O	P	Q	Tot III	Mean	Tot
Top-down regulation																×	6			4	3	4.17	3
Pos eco instruments			2	2	2	2	2	2	×	3	2	×	10	2.05	4	×	5		3		4	3.63	14
Interactive regulation															3	×	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		×	5	1.4	1	×	4		2	1	5	2.1	10
Capacity expansion										1			1	1			2		1		2	1.5	3
Replaced existing heat supply	1	1										×	1	1.2									2
Avoiding 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
Corporate survival									×				1	1.5									1
Winding up associated firm																		1			1	1	1

[a] Period.
[b] Total number of observations in a period or overall.
[c] Mean of relative influence of a factor in a period. If factories 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 $X = (1 + 2 + 3 + 4)/4 = 2.5$.

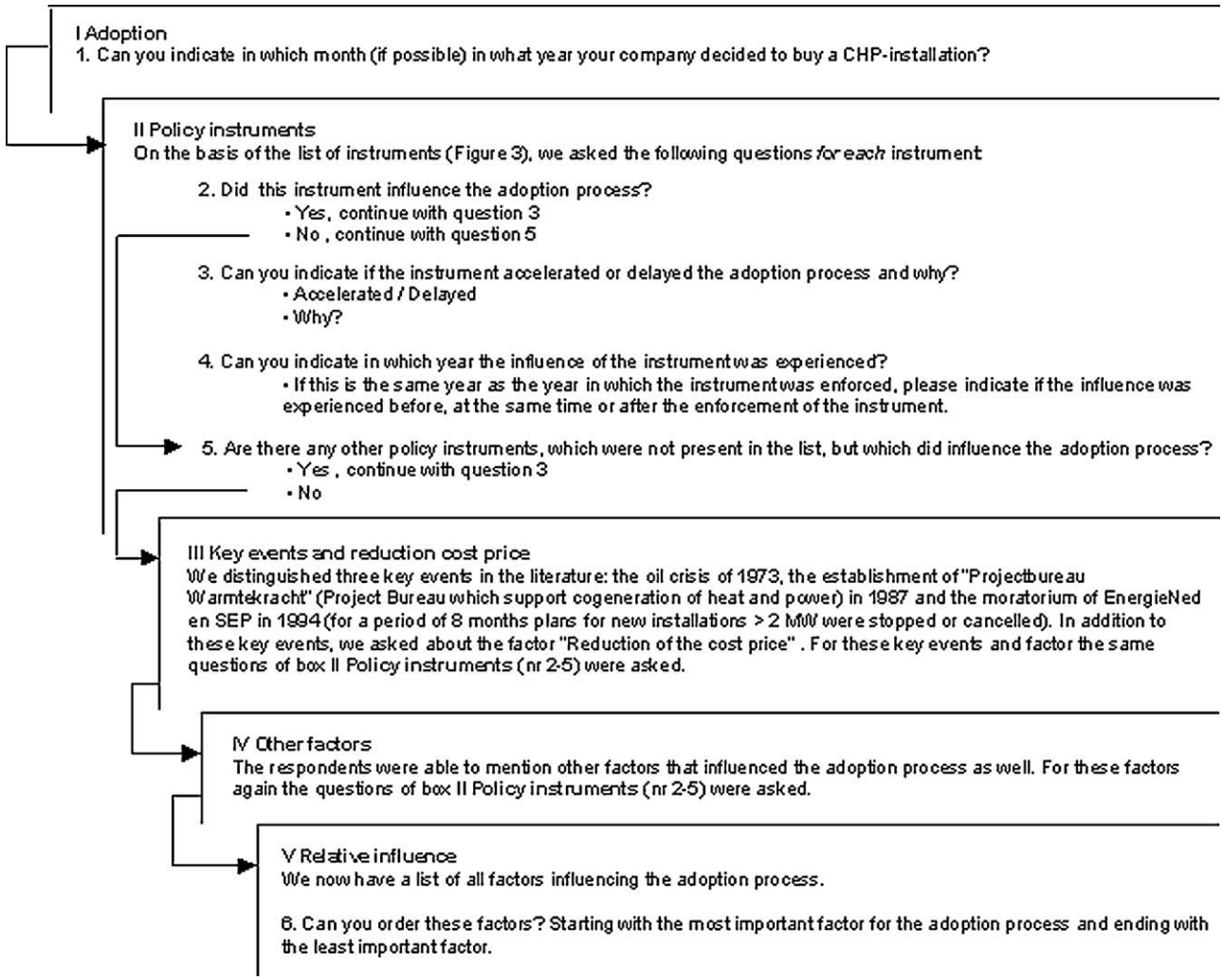

Fig. 2 – The reconstruction of the adoption process with the respondents.

asked whether and why they had either accelerated or delayed the decision. Finally, we asked the respondents to rank all the different factors that influenced the process. The important factors had previously emerged during the interview. We asked them to rank these from most influential to least influential in the adoption process and the reason(s) for this order. Most of the respondents were able to rank the different factors, though some respondents had trouble doing so. In these cases we treated all factors influencing that adoption process as equal (see also the explanation at the bottom of Table 2). See also Fig. 2 for an overview of the procedure of the interview.

In preparation for the analysis, the first step was to transcribe the interviews. The transcripts provide a basis for an overview of factors that influenced the adoption process, how they influenced the adoption process, and the relative weight compared to other factors for each factory. We conducted the analysis by comparing the adoption processes of the 17 factories. For this comparison we made an overview table (see Table 2 in the results).

Ideally, all possible influencing factors should be drawn up beforehand. However, since we were focusing on a relatively long time period, this was not possible due to data unavailability. We therefore identified factors that we were able to find and let the respondents indicate the remaining factors.

We are aware of the possible disadvantages of this approach, as some projects took place many years ago. This means that the decision-makers may have left the organization, leaving us to rely 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 presenting the overview of policy instruments, by discussing other key events, and by recalling the context with the respondents, we succeeded in reviving their memory. During the interviews, we had 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 at the time that the CHP-installation was implemented.

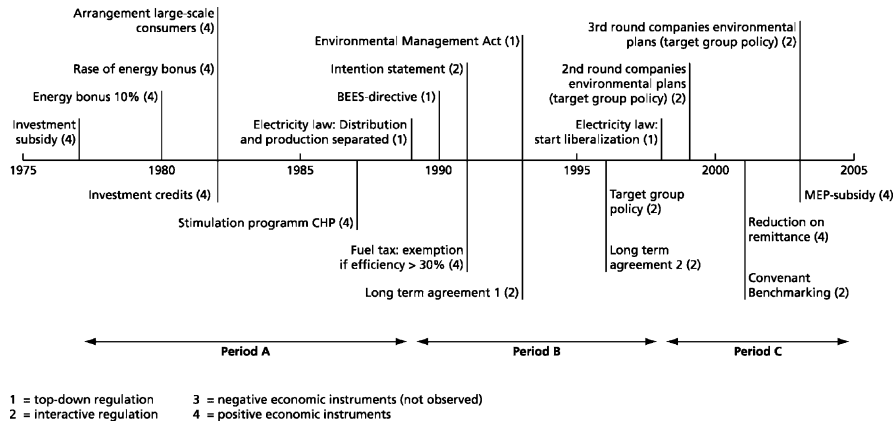

Fig. 3 – The accumulation of policy instruments with regard to CHP in the Dutch paper and board industry for the period 1977–2003.

5. Results

This section presents the results. First, we present the overview of policy instruments and discuss the accumulation of these instruments. We then give an overview of the adoption processes and the reasons why firms adopted CHP-installations. Finally, the role of policies after the adoption process will be discussed.

5.1. *The policy instruments*

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

These figures show that the government implemented a large number of instruments during this period. However, negative economic instruments were not observed. The figures also show the accumulation of policy instruments aimed at achieving related policy goals, over a relatively short period. 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.

The first period (Period A) started in 1977 and lasted until 1989. In this period, governmental policies were based on stimulating the diffusion of CHP by means of positive economic instruments (e.g. various subsidies and a stimulation program). At that time the accumulation of policy instruments was such that these instruments reinforced each other. In this period, it was not worthwhile to produce more electricity than used by a factory, as there were no proper feed-in tariffs (the compensation a mill receives for delivering electricity to the grid). For that reason, 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.

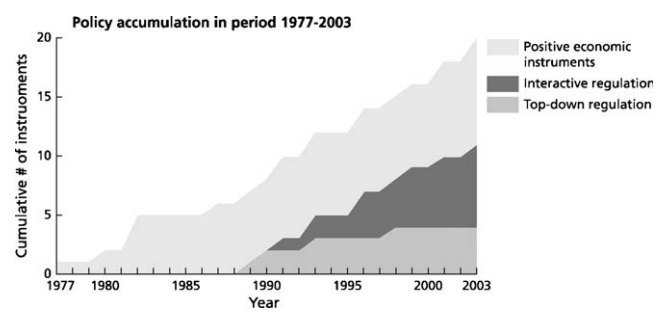

Fig. 4 – Policy accumulation: the cumulative number of instruments in the period 1977–2003.

This second period (Period B) started in 1989 with the implementation of the Electricity Act. As a consequence of this act, 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 consumed. This was economically feasible, for there now was a proper feed-in price as a result of the said act. 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 (*Besluit Emissie-Eisen Stookinstallaties*, directive on emission requirements of heating installations). This directive dealt with NOX-emissions, emitted by gas turbines. However, 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 had to be modified, as opposed to CHP-installations based on steam turbine technology. In this second period, several covenants (interactive regulation) between government and industry were concluded. Long Term Agreements 1 and 2 were signed,

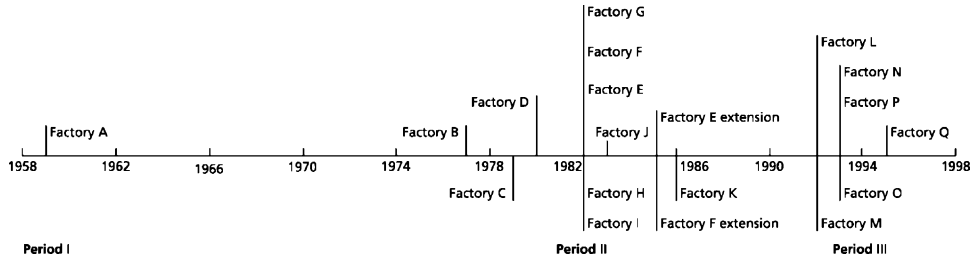

Fig. 5 – The adoption of the current CHP-installations in the Dutch paper and board industry.

which aimed to improve energy efficiency by 14% in 1995 and 20% in 2000, respectively, compared to 1989. The Target Group Policy, yet another interactive regulation instrument in this period, set targets 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 introduced: firms were exempted from fuel tax if the efficiency of the CHP-installation exceeded 30%. All these instruments were implemented in parallel over a relatively short time span. The top-down instruments sometimes caused problems. Installations just implemented before the introduction of the BEES-directive required modification. However, the interactive instruments were developed in cooperation with the industry, which generally resulted in a positive attitude of the industry towards these instruments.

The third and final period (Period C) began in 1998, when the first Electricity Act was replaced by the second Electricity Act. This second act resulted in the liberalization of the energy market. As a result of this liberalization, energy prices changed and the feed-in prices fell. 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 that 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 Act disrupted the situation. To offset negative effects for an industry like the Dutch paper and board industry, another instrument (a 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 to the grid. Finally, also in this period, covenants were concluded. After the expiry of Long Term Agreement 2, "Convenant Benchmarking Energy Efficiency" was signed in 1999. This covenant aims at being among the best 10% of the world as a firm in 2010. The Target Group Policy was extended in 1999 (2nd round of CEPs) and 2003 (3rd round of CEPs).

5.2. *The adoption processes*

Fig. 5 shows the time at which different factories (A–Q) adopted a CHP-installation. For each factory, only the most recent installation is shown.

Fig. 5 shows that there were two main periods during 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 Fig. 5). The other period was the first half of the nineties (Period III in Fig. 5). These two adoption periods correspond with the first two policy regimes (Periods A and B in Fig. 3). During the first policy regime (Period A: 1977–1989), firms B–K adopted their CHP-installations. Whereas governmental policies in this period were mainly based on subsidies to stimulate the diffusion of CHP, the other period was characterized by covenants between government and industry and by the first Electricity Act of 1989. Based on these observations – that an increase in policies results in an increase in adoption – one could easily conclude that policies are effective. Moreover, the government claims that for instance the Long Term Agreements proved 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 weight, or whether other factors were more important.

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

As mentioned in Section 4, 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) prompted 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 supply*.
- *Avoiding investment*: If the production of a factory increased and it required more electricity for its production process, two options were 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 supply (a CHP-installation). If this latter option turned out to be cheaper, this meant avoiding investment. Or in other words, if the adoption of CHP turned out to be a more efficient investment, other 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 encouraged several firms to adopt a CHP-installation.
- *Corporate survival*: Facing bankruptcy and needing to downsize its production, one firm (H) required a new and smaller CHP-installation.
- *Winding up of an associated firm*: The CHP-installation was moved from that firm.

Table 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 "×". 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. For the technical director, this was an opportunity to be innovative, and as a result, 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.

5.2.1. *Period II*

In period II, 10 factories adopted a CHP-installation. Two respondents were not able to rank the reasons. The two adoption processes concerned will therefore 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 was already using a CHP-installation. However, the factory was to 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. Aside from the need to survive, subsidies and a credit grand were conditional for the adoption. In sum, it was a combination of financial stimuli and the need to survive impending bankruptcy. Factory K had a high pressure boiler that performed poorly, often failing. This boiler therefore needed replacement. At the same time, an external party presented the possibility of financing the project and supplying the technological services. Reasons for Factory K to adopt the CHP-installation were the need to replace the existing heat supply, the availability of providers of capital, subsidy options, and energy savings (high energy prices/cost price reduction).

Regarding the other 8 factories of this period, we can observe from Table 2 that only a few factors were mentioned in this period: the attractiveness 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 expansion (Factory I).

For the 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 were positive economic instruments (subsidies). It was often said by the respondents that subsidies could 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 in the decision; it was ranked third place. For Factory D, avoided investments were the third factor influencing the adoption.

Overall in this period, the high energy price combined with cost price reduction and 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 economic instruments were in force simultaneously, thus reinforcing each other.

5.2.2. *Period III*

Six factories adopted a CHP-installation in this period. One respondent (Factory M) could not rank the factors, so we will first discuss 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 achieve the environmental policy goals of Long Term Agreement 1,[4] thereby obtaining subsidies. A final element influencing the decision was the Electricity Act of 1989. In 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 feed 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.

[4] 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).

Top-down regulation appeared to not 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 most influential factor. 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 in the way of causing some delay. On account of this act, they applied for a permit, but then the soil turned out to be polluted. This necessitated a new permit application, thus causing the delay. It was the fourth and final factor influencing the adoption process for 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 importantly as 3, 4, and 5.

Interactive regulation is important for some factories in this period. For Factory N, it was the most important reason for adoption. This factory was part of a large company. At that time, Factory K was also part of this company. The need to achieve 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 but not to the same extent, as it was ranked third place. We already mentioned the importance of Long Term Agreement 1 for Factory M.

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

Capacity expansion 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 supply) was worse, and adopting a new CHP-installation improved this position.

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 closure 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 efficiency 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 stems from 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 adoptions, these positive economic instruments were relevant as well. In that sense, these instruments (Long Term Agreement and positive economic instruments) reinforced each other.

5.2.3. *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 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). For Period II as well as for Period III, intra-organizational factors are more important than policy instruments. In both periods high energy prices, in combination with cost price reduction or in combination with the threat of regulation were the most important reasons.

5.2.4. *After Period III...*

Since 1995, no new adoptions have taken place. This slowdown after Period III was due in part to changes in the profitability of CHP. The liberalization of the energy market altered energy prices and feed-in tariffs. Consequently, some of the existing CHP-installations were no longer or hardly cost-effective. Some of the joint ventures, only just started in the third period, were already abandoned. Furthermore, it was economically no longer feasible to adopt a new CHP-installation. This became clear when, by the end of the nineties, some factories investigated the possibilities of a new CHP-installation. These projects were discontinued when the liberalization of the energy market came into view.

Moreover, most respondents indicated that governmental policies changed too often during the past 10 years, making them much more risk-averse with regard to energy efficiency. Only if the pay-back time is short will they adopt energy-saving measures, which is obviously not the case for CHP. Thus, after period III, the effect of environmental policies on environmental innovation was the reverse of what the government had intended: instead of stimulating environmental innovation it impeded environmental innovation. Explanations that emerged during the interviews were consistent with our theoretical claims. Uncertainty concerning regulations and the behavior of regulators resulted in risk-avoiding behavior by managers, consequently resulting in less environmental innovation (Marcus, 1981; Rothwell and Zegveld, 1981; Rothwell, 1992; Gunningham and Sinclair, 1998; Meijer et al., 2007). This is also in line with the findings of Mueller (2006). In their research on the adoption of CHP-installations, they conclude: "...firms abandon the adoption process due to concerns about the complexity of regulatory requirements" (Mueller, 2006). In our case firms became

stagnant due to these frequent changes resulting in uncertainty and due to the use of inconsistent mechanisms resulting in too much complexity. Whereas we observed a positive effect of policy accumulation in period II, this clearly indicates a possible negative effect of policy accumulation on environmental innovation.

6. Conclusion and discussion

In Sections 1 and 2, we highlighted the ambiguities in the effects of environmental policy on innovation, and in the explanations offered. The literature presents different and sometimes even conflicting theoretical and empirical findings on the relation between environmental policy and environmental innovation. We argued that previous policy evaluations have some limitations and that more insight into the effect of different policy instruments is desirable. Therefore, in this paper we shifted 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. Our study included intra-organizational 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 the adoption process of CHP-installations in the Dutch paper and board industry influenced by environmental policy instruments and intra-organizational factors, according to the perception of the paper and board factories? And to what extent are these results time-dependent?*

We already mentioned some drawbacks to this approach in Section 4. It would have been better if all factors had been identified objectively instead of some being identified by our respondents. As we explained, however, this was not feasible due to the long time period that we focused on. In our opinion, the advantage of focusing on a longer time period offsets the possible subjectivity of the identification of influencing factors. The second disadvantage was the fact that some of the processes under analysis occurred a long time ago. However, during the interviews we noticed that this time aspect in fact did 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 distinguished, 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 different time periods. In period II, the high energy price combined with the cost price reduction or combined with 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 also important in this period, though 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, next to intra-organizational factors. Its relative importance varies over time and per adoption process. This implies that a more fully-fledged approach to explaining environmental innovation is fertile soil for further research, and that assessments of the impact of environmental policies should be dealt with in tandem with intra-organizational and market factors. We believe that this might explain why previous studies, often operationalizing environmental policies and/or environmental innovation in a relatively simple way (see Table 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 combined with the threat of regulation. These findings differ from the results of Dupuy (1997), which identified policy as the most important reason for adoption.

However, our conclusion is only based on the direct effects of governmental policies. An important indirect effect of government interventions is the effect on the 'energy price', which is partly and 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 reveal the different effects of distinct types of policy instruments and of the accumulation of policy instruments. As explained in Section 3, each type of instrument applies a distinct behavioral 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 applied, while 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 3 out of 17 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 stimulating the diffusion of CHP. These measures thus reinforced one another. Furthermore, we observed that the implementation of instruments disturbed situations originating from earlier policy instruments. The implementation of the Second Electricity Act resulted in negative changes for CHP-owners in terms of energy prices and feed-in prices. Finally, we observed that the implementation of several instruments in a short time span resulted in negative, that is risk-averse behavior. This complex interaction of policy effects on firms' innovative behavior also explains why some researchers that do evaluate policies separately find negative impacts whereas others find positive impacts.

Policy makers should be aware of these effects. On the basis of our results, we can conclude that it would be naive to neglect intra-organizational 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 attained. In our case, policy goals concerning energy efficiency were achieved. Yet in the perception of the paper and board factories, policy was just one of the factors influencing the adoption process. As a matter of fact firms became quite policy-averse over time. Moreover, policy makers should be aware that different instruments are based on different behavioral mechanisms. Having insight into the industry, its behavior, production processes, topical issues, problems, etc. before policies are implemented can result in a better alignment of the aims of both government and industry. This can result in more effective policies. It is obvious that time horizons of firms and government are different. Firms' capital-intensive investments are based on long-term 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 behavior, which we saw occurring after Period III.

Finally, we are convinced of the usefulness of the approach to help solve the ambiguities in the effect of environmental policies on innovation and in the explanations offered. It enabled us to focus on the accumulation of policy measures and on intra-organizational factors over a longer 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 in each factory's adoption process had been taken into account, neglecting other factors, the importance of environmental policies would have appeared to be very low. This observation would also have been the case if we had 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, even though policies have indeed been relevant. The overview of policy instruments provides better insight into the role of policies. Finally, it can be concluded that the longitudinal approach is important, as more insight is gained compared to the focus on one short period. The role of policies turns out to be different in the different periods. As this research was just an initial attempt, for future research we recommend investigating different technologies/technological trajectories as well as the same technologies/technological trajectories in different industries.

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