
Dynamic perspective on the relation between environmental policy and eco-efficiency: the case of wastewater treatment, waste and energy efficiency in the Dutch paper and board industry

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Abstract: The relation between environmental policy and innovation is complex. This paper aims to gain insight into the way accumulation of policy measures, or in other words, the increase of policy pressure, affects research activities and eco-efficiency. Three environmental domains have been researched for the Dutch paper and board industry: wastewater, waste and energy. Three trends (1980–2003) are identified for these topics: (1) development of environmental policy; (2) number research projects started and (3) eco-efficiency.

We argue that if existing solutions and knowledge are not sufficient to reach the objectives, research activities will take place before eco-efficiency is improved. Moreover, we argue that an increase in policy pressure can cause competition between policy instruments. This may result in a smoothed and delayed increase in research activities (if existing knowledge is insufficient) and eco-efficiency improvement. This delayed eco-efficiency improvement was observed for wastewater and waste. It was not observed for energy efficiency.

Keywords: eco-efficiency; environmental policy; policy pressure; research activities; wastewater; waste; energy; Dutch paper; board industry.

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1 Introduction

The effect of environmental policy on industry is heavily debated in literature. Some articles 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 results in a reduction of money available for innovation in general. They also argue that environmental regulations limit the options for environmental innovation: environmental regulation is said to reduce the time to find 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 managers of firms are uncertain about the regulation (Meijer *et al.*, 2006; Marcus, 1981; Rothwell, 1992) and the behaviour of the regulators (Meijer *et al.*, 2006; Marcus, 1981; Rothwell and Zegveld, 1981; Gunningham and Sinclair, 1998). 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, as well as create demands and opportunities (Braun and Wield, 1994). They add that a threat from the outside is necessary to get attention to a problem.

Without such a threat, such as environmental regulation, the behaviour will not be changed (Van de Ven, 1986; Van de Ven and Polley, 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. It is remarkable 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 have not 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 and Wiczorek, 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 World Business Council for Sustainable Development (WBCSD) 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 and Bidwell, 2000). The aim of future policy is to stimulate eco-efficiency. Therefore, this paper 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 paper 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 of eco-efficiency?*

The Dutch paper and board industry is an interesting example on which different environmental policy instruments are aimed and where different environmental topics are important. Moreover, this industry was willing to participate, which gave us the opportunity to get very detailed information necessary to answer our question. Therefore, the Dutch paper and board industry is the object of study in this research. More detailed information about the Dutch paper and board industry can be found in Appendix 1. In this research we focus on three environmental topics, which are related to the production processes of this industry. First, the production of paper and board is energy-intensive and therefore, among other emissions, carbon dioxide emissions are high. The energy costs in the total production costs are about 15% (VNP, 2003b). A second topic is wastewater. The process of paper making requires a lot of water that needs to be treated before it can be discharged or reused, because otherwise heavy metals and other substances are discharged. As a consequence of regulation in the seventies, the industry implemented wastewater treatment installations. An associated problem related to wastewater is the production of purification sludge during wastewater treatment. This sludge/waste needs to be handled and discarded. This is part of the last important environmental topic, namely, waste. The fact that the Dutch paper and board industry uses a lot of recovered paper leads paradoxically to a waste problem. The recovered paper contains 4%–5% contamination. First of all, solid waste (such as plastic and metal) is found in recovered paper. These rejects need to be separated and handled. Furthermore

the use of recovered paper often leads to de-inking sludge, which also needs to be handled. For each topic the government implemented several policy measures. These are given in Table 1. This table is a clear example of the concept of accumulation of policy measures. More information about these measures can be found in Appendix 2.

Table 1 The accumulation of policy measures with regard to wastewater, waste and energy in the Dutch paper and board industry in the period 1980–2003

<i>Year</i>	<i>Measure</i>	<i>Environmental domains</i>
1981	New calculation system levies	Wastewater
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)	Wastewater, 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)	Wastewater, 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)	Wastewater, waste and energy

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

The remainder of the work is divided into four sections. Section 2 describes the theoretical background. Then the research design is elaborated in Section 3. We then describe our result in Section 4. Finally, the discussion and conclusion are given in Section 5.

2 Theoretical background

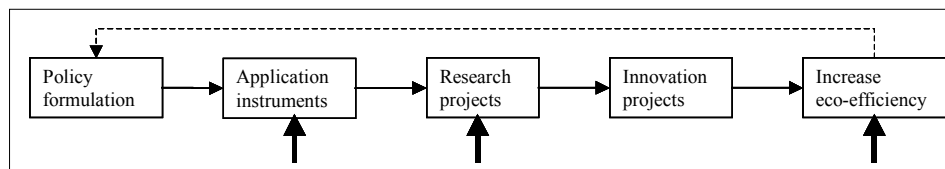
In the literature, governmental policy is described as a process (c.f. Winsemius, 1989; Vermeulen, 2000). For this research we use the work of Vermeulen (2000), in which he proposes a model of policymaking, as a starting point. His model consists of several steps

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 extend 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 such as 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, such as subsidies, that result in a decrease of costs (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 government 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.

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 links economy and the environment (Hoffrén, 2000; Fet, 2003), achieving greater value with lower adverse environmental consequences (Verfaillie and Bidwell, 2000). The above is visualised in Figure 1. In this study we focus on the following aspects: the application of instruments, research projects and eco-efficiency (see the vertical arrows in Figure 1).

Figure 1 Policy-effect cycle



Source: Vermeulen (2000)

In short, the process with regard to these three concepts is as follows: 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 T_1 . 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 paper 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 Hypotheses 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, owing 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, owing to the fact that companies need to prioritise eco-efficiency goals.

3 Research design

To study the effect of policy measures on research activities and eco-efficiency, we will study their effects on the three environmental domains as stated in the introduction: energy, wastewater 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:

- The implementation of governmental environmental policy measures directed at the paper and board industry with regard to energy, wastewater and solid waste (see Table 1)
- The development of collective research activities with regard to energy, wastewater treatment and solid waste¹
- The development of the eco-efficiency of the industry over time.

In Tables 2 and 3, the operationalisation with regard to the collective research projects and eco-efficiency, respectively, 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.

Table 2 Operationalisation research activities

<i>Category</i>	<i>Classes</i>	<i>Indicators</i>
Knowledge generation and collection for wastewater treatment, waste and energy efficiency	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 3 Operationalisation eco-efficiency

<i>Category</i>	<i>Classes</i>	<i>Indicators</i>
Eco-efficiency: the presence, the emission or discharge of substances divided by sales for wastewater treatment, waste and energy efficiency	Wastewater	Discharge zinc per sales
		Discharge copper per sales
		Discharge nitrogen per sales
		Discharge phosphorus per sales
	Waste	Landfill coarse rejects per sales
		Landfill wastewater treatment sludge per sales
		Landfill de-inking sludge per sales
		Landfill paper rejects per sales
	Energy efficiency	Primary energy use per sales

To compose trends of eco-efficiency, the figures of discharges, disposal and energy use are divided by sales.² 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 and Bidwell, 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 paper. Moreover, it does not have any consequences for the reliability of the results. The only consequence is that the reader should be aware that if in this paper the eco-efficiency increases, we would observe a 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:

$$\Delta \text{ Research activities year } t_{0+1} = \text{number of new projects started in year } t_{0+1} \\ - \text{number of new projects started in year } t_0.$$

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:

$$\Delta \text{ Eco-efficiency year } t_{0+1} = (\text{environmental indicator} \times \text{year } t_{0+1} / \text{sales year } t_{0+1} \\ - \text{environmental indicator} \times \text{year } t_0 / \text{sales year } t_0) \\ / (\text{environmental indicator} \times \text{year } t_0 / \text{sales year } t_0).$$

To conduct the research the following documents are analysed:

- The annual reports of the Royal Netherlands' Paper and Board Association (Koninklijke VNP)³
- Minutes of the Research Unit of the Dutch Paper Industry⁴
- Minutes of the Research, Technology and Environmental Group of the VNP⁴
- Minutes of the Competence Centre of the Paper and Board Industry
- Some yearly overviews of the Research Unit of the Dutch Paper Industry⁵
- Project plans of the Competence Centre
- Monitoring reports of the FO-industrie; the organisation that supports the implementation of a specific policy measure, namely, the Target Group Policy (see Appendix 2 for more information)
- PhD thesis of Bouwens (2004); this thesis describes the development of the Dutch paper and board industry
- 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).

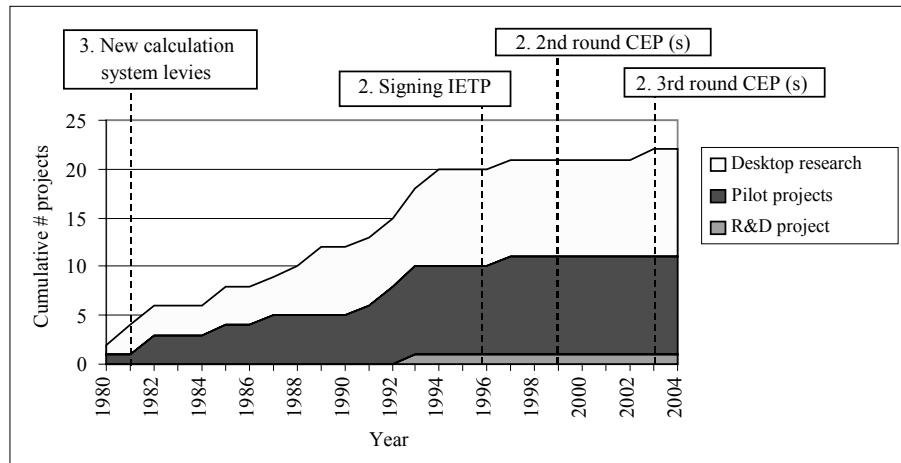
4 Results

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

4.1 Wastewater

Figure 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 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 substitutes another policy measure (indicated by an (s)).⁶ Several observations can be made with regard to Figure 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 wastewater 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 of Hypotheses 1a and 2a).

Figure 2 Research projects started for wastewater (1980–2004)

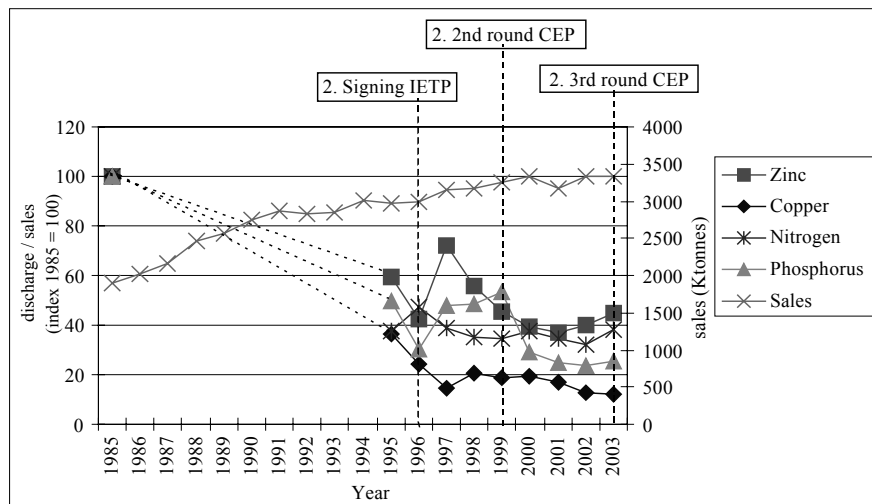


Notes: 1 = top-down regulation; 2 = interactive regulation; 3 = neg. economic instr.; 4 = pos. economic instr.; (s) = substitution. The full forms of abbreviations can be found in Table 1.

The discharges that are most important with regard to wastewater 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 wastewater treatment installations (Koninklijke VNP, 2004a). As a consequence of the WVO, many paper mills have built their own wastewater treatment installation (Koninklijke VNP, 2004a). In Figure 3, an overview is given of the eco-efficiency for the domain of wastewater 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 3. In this figure the implementation of different policy instruments are also shown. Sales and eco-efficiency 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 wastewater treatment installations. Policy objectives with regard to discharges to wastewater are aimed 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.⁷ However, as stated above, in terms of eco-efficiency we observe an 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 to 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.

Figure 3 Environmental impact for wastewater (1985–2003)



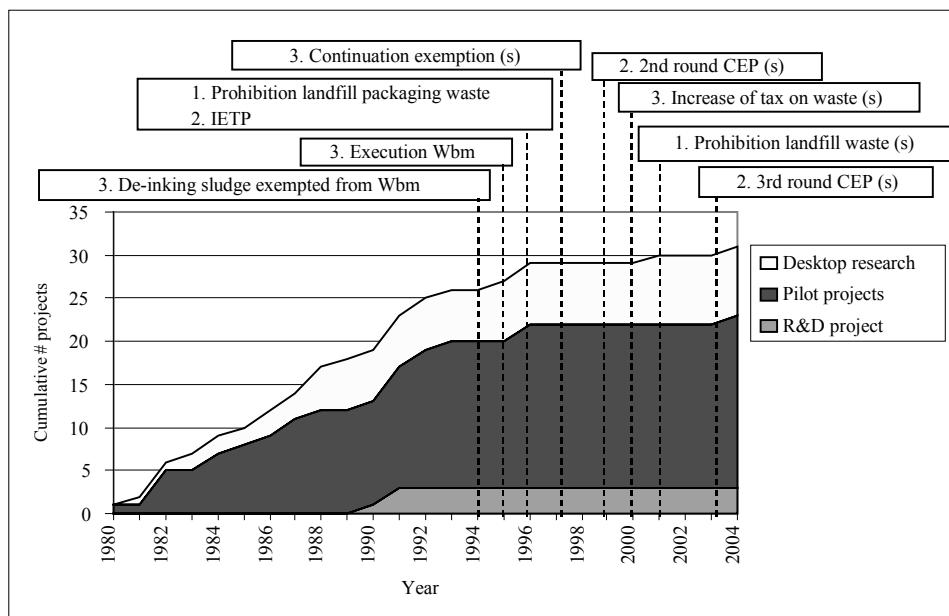
Notes: 1 = top-down regulation; 2 = interactive regulation; 3 = neg. economic instr.; 4 = pos. economic instr.; (s) = substitution. The full forms of abbreviations can be found in Table 1.

Source: FO-industrie (2004)

4.2 Waste

Figure 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 into the separation of waste streams has been done. 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 Hypotheses 1a and 2a).

Figure 4 Research projects started for waste (1980–2004)

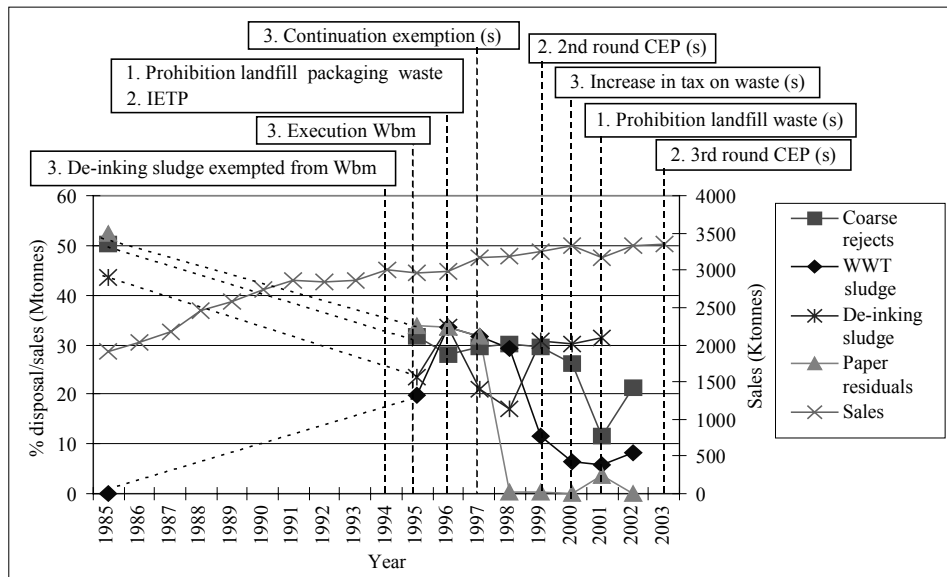


Notes: 1 = top-down regulation; 2 = interactive regulation; 3 = neg. economic instr.; 4 = pos. economic instr.; (s) = substitution. The full forms of abbreviations can be found in Table 1.

As stated in the introduction, the paper and board industry has to deal with several waste streams. These waste streams have different causes: rejects in recovered paper; and sludge of the wastewater treatment installation; residuals of the de-inking process; paper rejects that can no longer be reused. Figure 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 wastewater, 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 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 5 Eco-efficiency for waste (1985–2002)

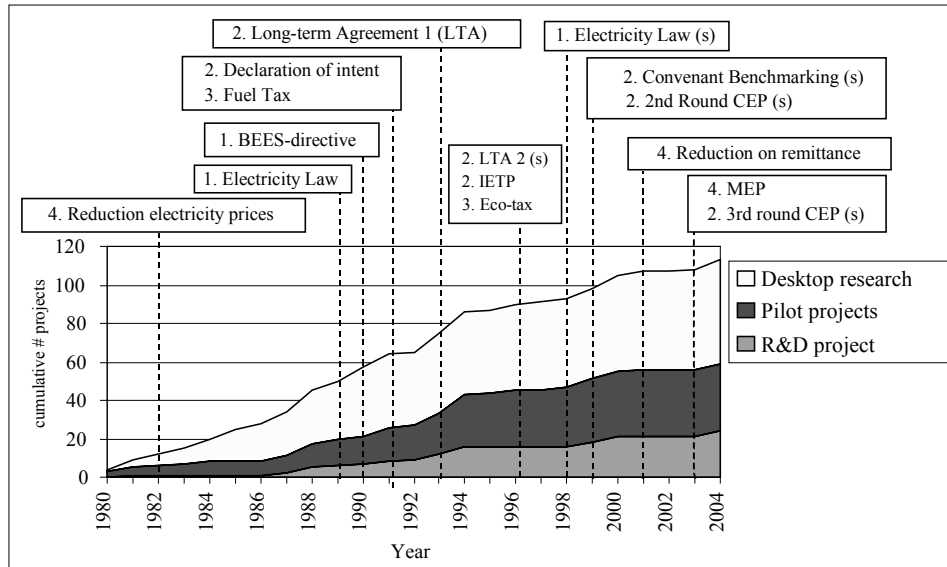


Notes: 1 = top-down regulation; 2 = interactive regulation; 3 = neg. economic instr.; 4 = pos. economic instr.; (s) = substitution. The full forms of abbreviations can be found in Table 1.

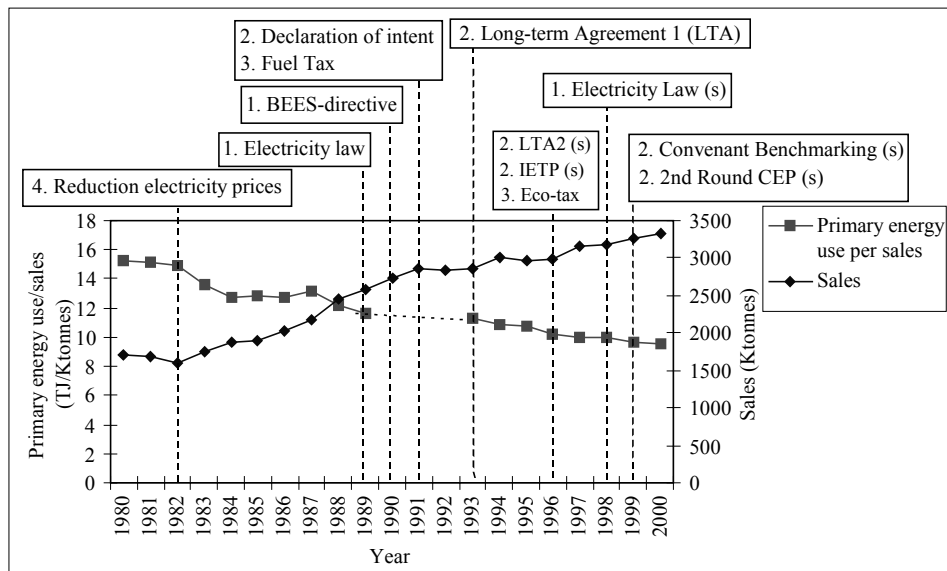
Source: FO-industrie (2004)

4.3 Energy

Energy has been an important topic for the industry for a long time (VNP, 2003b). 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 6 shows the collective research projects for the topic of energy efficiency. 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 have been substituted and new objectives have been formulated. On the bases of these observations, it can be concluded that an increase in policy pressure results in an increase in research activities (first part of Hypotheses 1b and 2b).

Figure 6 Research projects started for energy (1980–2004)

Notes: 1 = top-down regulation; 2 = interactive regulation; 3 = neg. economic instr.; 4 = pos. economic instr.; (s) = substitution. The full forms of abbreviations can be found in Table 1.

Figure 7 Eco-efficiency for energy (1980–2000)

Notes: 1 = top-down regulation; 2 = interactive regulation; 3 = neg. economic instr.; 4 = pos. economic instr.; (s) = substitution. The full forms of abbreviations can be found in Table 1.

Sources: Cuelenaere and Blok (1992); Koopman *et al.* (2004)

In the 1980s, the use of primary energy still increased. However, since the 1990s the primary energy usage has remained stable. Moreover, the increase in sales in the period 1980–2003 was large. The sales almost doubled. Therefore, the improvement in energy efficiency of the industry was high. Figure 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 of Combined Heat Power (CHP) has contributed the most to this reduction. (VNP, 1986; Koopman *et al.*, 2004). Policy objectives (see Appendix 2) 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.

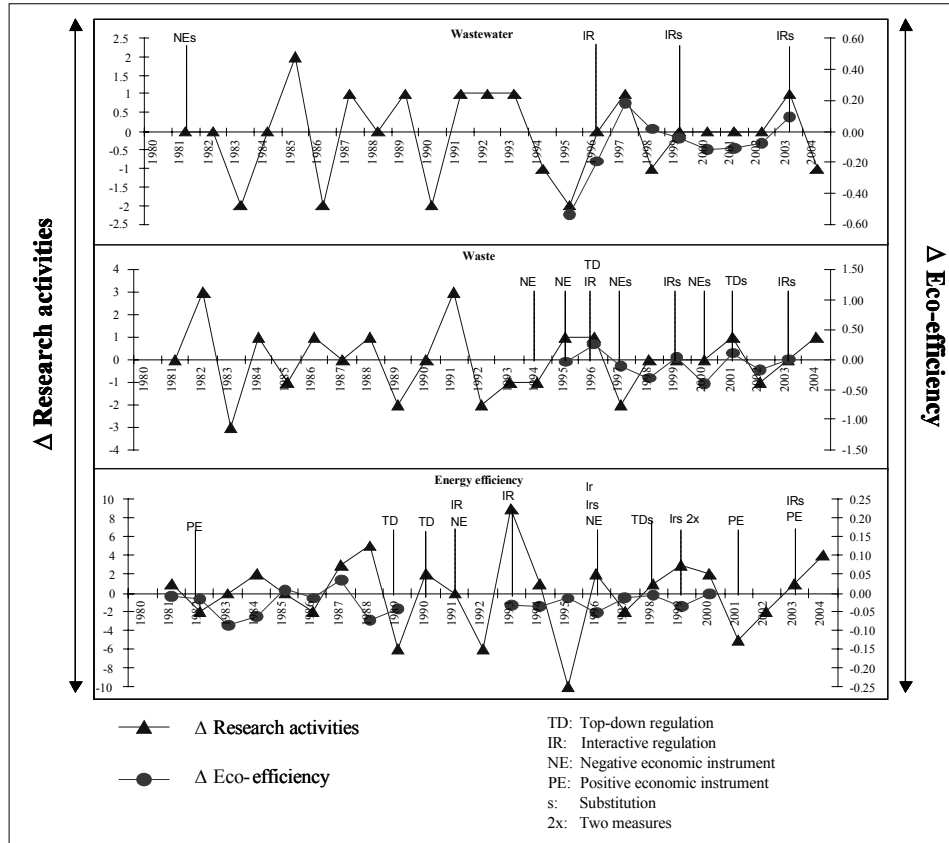
4.4 Overall results

In Figure 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 wastewater and waste we used several indicators for eco-efficiency. In Figure 8, the mean of these indicators per environmental domain is presented.

For the domain of wastewater, Figure 8 shows a little increase in policy pressure since 1996. For waste, Figure 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 8 shows that Δ research activities, with regard to wastewater, became 0 in 1999. The eco-efficiency fluctuates over time; however, it seems that the eco-efficiency has started to increase and therefore in Figure 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 8 shows that the Δ research activities became 0 in 1998. In the meantime, the Δ eco-efficiency fluctuates. Since 1997 the eco-efficiency has been increasing, because since then Δ eco-efficiency has been 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 8 shows that in the meantime 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.

Figure 8 The overall results

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: wastewater, 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.³⁻⁶ However, since different types of documents described the same events, this drawback has been reduced to a minimum. Besides, owing to data limitations, it was only for the domains of wastewater and of waste that it was possible to give the eco-efficiency trends for 1985–2003; 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 only 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 wastewater 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 were not taken into account in this research. This is a possible explanation for the fact that in our paper the research activities do not increase for the wastewater 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, resulting 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 (wastewater and waste), for this domain a delay between the different indicators policy pressure, research activities and eco-efficiency, was not observed. It has 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 the 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.

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Notes

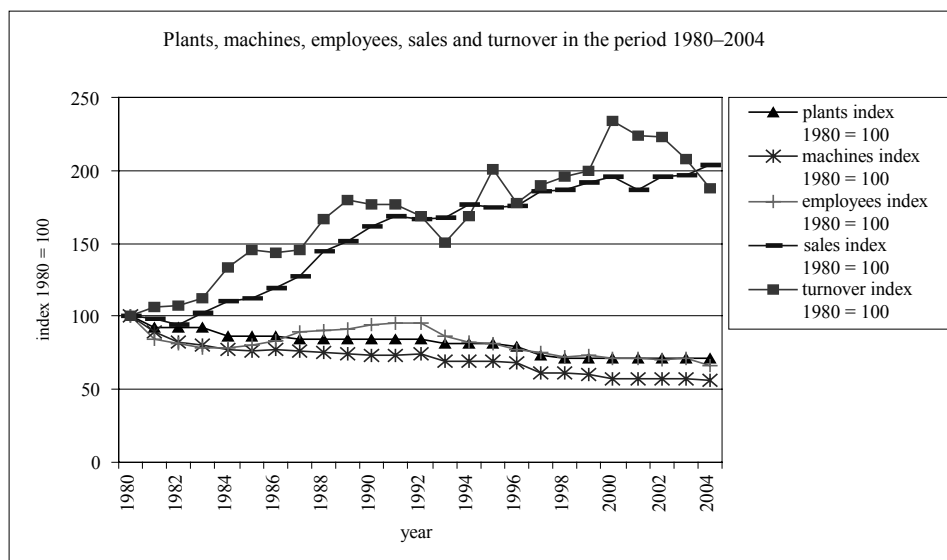
- 1 Ideally, we would also want to identify the trend of individual research and innovation projects of all firms. However, these data are not available for two reasons. First of all, we take into account a very long period and therefore information has been lost over the years. Secondly, not all firms make these overviews.
- 2 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 be possible that 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.
- 3 The annual report for 1980 was not available. As a consequence, the annual reports of 1981–2003 were used.
- 4 Not all minutes were available for the whole period.
- 5 Not all overviews were available for the whole period.
- 6 When substitution takes place, the new measure replaces an old one and it is not implemented next to the other measure.
- 7 Objectives of policy: the aims to reduce in 2000 and 2010. Zinc: 65%; 80%. Copper: 50%; 80%. Nitrogen: 70%; 75%. Phosphorus: 75%; 95%.

Appendix 1

Overview of the Dutch paper and board industry and the production process

The Dutch paper and board industry consists of 27 paper mills. The total sales in the year 2004 was 3.5 Mtonnes and the corresponding turnover was almost 2 billion euros (Koninklijke VNP, 2005). The paper and board industry can be divided into three sectors: graphic papers, packaging and board, and household and sanitary papers. In the period under investigation (1980–2004), the number of paper machines and mills decreased from 92 and 38 to 52 and 27, respectively. As a consequence the number of employees decreased from more than 9000 to 6000 fte (full-time equivalent) in 2004 (VNP, 1981; Koninklijke VNP, 2005). However, during the same period both sales and turnover have increased. From Figure 9 it becomes clear that the sales and turnover doubled, while the number of employees, machines and mills has reduced to 60%–70%. This shows an impressive improvement of their efficiency; more paper is produced and sold with less employees, machines and mills.

Figure 9 The development of plants, machines, employees, sales and turnover for the period 1980–2004 in the Dutch paper and board industry (based on annual reports of the Koninklijke VNP)



A large part of the raw material input (namely, 75%) is covered by the use of recovered paper. However, wood is still necessary. The Dutch paper and board industry does not produce wood themselves. They mainly order wood from private and state owners, sawmills and foreign producers of wood. Only two factories produce pulp. Turnkey pulp is imported from Europe and the USA (Koninklijke VNP, 2006).

The interests of the Dutch paper and board industry are represented by the Royal Netherlands' Paper and Board Association (Koninklijke VNP in Dutch). This organisation was established in 1904. One of the goals of The Royal Netherlands' Paper and Board Association is to have an environmental friendly, innovative and attractive industry (Koninklijke VNP, 2004b).

Knowledge development in the Dutch paper and board industry has been supported by different organisations over time. In the period 1980–1990 the Research Unit of the Dutch paper industry (RNP in Dutch) had taken care of the knowledge support (VNP, 1981). In 1990 a research unit was integrated in VNP: the Research, Technology and Environment Group of the VNP (RTM in Dutch). Since 1998 knowledge development has been supported by the Competence Centre Paper and Board (KCPK), which is a separate organisation.

Appendix 2

Environmental policy for the Dutch paper and board industry

Before turning to the overview of environmental policy measures for all three domains, an instrument that is important for each domain, 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 a 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, 2003a). 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-industrie (2005).

Wastewater

Wastewater has become an important topic for the Dutch paper and board industry since 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 waste domain, 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 has been 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 by 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 Covenant Benchmarking Energy Efficiency (VNP, 1999). The aim is to be part of the world's top with regard to energy efficiency in 2012, this means that a firm should belong to the best 10% of the world (VNP, 2003b). 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 imposed on natural gas and electricity that are not green. The fuel tax has been imposed since 1991 and since the execution of the Wmb in 1995 has been 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 Covenant 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, 2003b). 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 Act (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.