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Title

The Impact of Regulation and Policy on Eco-Innovation– the need for a new understanding

Abstract: This paper reviews how current policy instruments drive (or not) environmental innovation and, by doing so, reinvestigates the relationship between innovation and regulation, which is timely as the new shape of recent environmental regulation appears to be fairly strict. So called “smart” regulations are considered as an innovative approach to meet rather ambitious goals towards sustainability. Finally a new model expanding on Jänicke’s diffusion model is presented to encapsulate highly dynamic interaction of environmental innovation and regulation and therefore yields to provide result that reflects on the present innovation behaviour and its implications.

Keywords: Eco-Innovation, Environmental Regulation, Policy Instruments

1 Introduction

Classical economists from Adam Smith, David Ricardo to Karl Marx already discussed depth issues concerning technological and institutional change. However, the very first systematic attempt to understand the processes of innovation was the work of Joseph Schumpeter in the first half of the twentieth century. He identified three stages of the innovation process – *invention, innovation and diffusion* – a classification which is still widely used although it is regarded to be over-simplistic (Foxon, 2003).

Innovation processes toward sustainability, also know as eco-innovations, have received increasing attention during the last decade. As a matter of fact existing theoretical and methodological approaches still do not fully address these issues in detail or with sufficient empirical support and therefore future research still needs to improve the general understanding of the innovation processes towards sustainability in its different dimensions, complex feedback mechanisms and interrelations.

The traditional understanding of innovation as clearly defined in the Oslo-Manual of the OECD (1997) distinguishes principally between process, product and organisational innovation:

- *Process Innovations* occur whenever a given amount of outputs (good, services) can be produced with less input.
- *Product Innovations* requires improvements to existing goods (or services) or the development of new goods. Product innovation in machinery in one firm often turns out to be a process innovation in another firm.
- *Organisational Innovation* includes new forms of management, e.g. total quality management.

By contrast, eco-innovation is defined in two ways: Firstly, by the effects of the innovation on the environment; secondly, by the intention of the innovator to reduce the environmental impact of processes or products.

Innovation that is not driven by a conscious intention to reduce the environmental impact may nevertheless have this quality. An example is improved fuel efficiency in the automobile sector due to the incremental improvement of engines performances. The major motivation for such an innovation is most likely performance or price considerations, but the impact on the environmental performance may be considered to be a positive side effect.

Hemmelskamp defines eco-innovation as innovation to prevent or reduce anthropogenic burdens on the environment, clean up damage already caused or diagnose and monitor environmental problems. He also makes a distinction between end-of-pipe and integrated environmental technologies, where end-of-pipe technologies are by their very nature incremental process innovations that leave much of the technologies that are on the root of the environmental problems intact (Hemmelskamp, 1997).

According to Kemp et al., (2007) most eco-innovations consist of simple improvements or the adaption of technologies that were developed by others because economic incentives are absent to go beyond standards that are required by law, a low level of taxes when applied, regulatory preference for quick results which leads regulators and permit writers to set unchallenging standards from an innovation point of view as well as the problem sector's preference for non-disruptive technology responses.

In this matter, eco-innovations shall be used as an indicator for "smarter" regulation that have a crucial role in the ongoing debate how to push industries into a more sustainable and yet competitive future. However, the nature of innovation towards more sustainable technologies that has become eco-innovation had a parallel movement in the regulatory context. There, regulators also became also innovative with the emergence of "smart regulation", and it is worthwhile to briefly review the effect these may have had so far on eco-innovation.

Given the relevance of eco-innovation for a shift towards a more sustainable future it is crucial to study the role of past and present policies that somehow affect eco-innovation and its diffusion (Mickwitz et al., 2007). According to Horbach (2007) there is a broad agreement on the significance of eco-innovation on the relationship between different types of regulation and technological development. Studies of eco-innovation have found repeatedly that regulation is the most important stimulus for innovation with other incentives such as cost reductions, effects of supply chain pressure and influence of NGO campaigning being also crucial in some circumstances (Green, 2005).

These is especially the case where regulation is comparatively strict already, or where other pressures to innovate, such as competition or the development of an organisations core technical competence, are less pronounced. Generally, there are contrary views being expressed in the heated debate about the impact of environmental regulation on innovation and the competitiveness of industry (Triebswetter et al., 2007). The traditional, neoclassical cost-based approach suggests that private costs induced through strict environmental regulation compromises competitiveness and productivity (Palmer et al., 1995). This is the main reason why scholars like Palmer essentially doubt that environmental regulation has an effect on innovation.

Interestingly, Marklund (1997) argues that regulation might act as a stimulus for innovation because firms do not always make optimal choices. In reality, the actual process of dynamic competition is characterised by changing technological opportunities coupled with highly

incomplete information, organisational inertia and control problems reflecting the difficulty of aligning individual, group and corporate incentives.

On the other hand several studies (Porter and van de Linde, 1995a/b; Kemp et al., 2001; Jänicke, et al., 2002) predict that strict environmental regulations stimulate innovation in a number of ways (e.g. first mover advantages created by the development of new environmental so called “green” technologies) and that there are “win-win” opportunities through environmental regulation, where simultaneously pollution is reduced when having an increase in productivity. Hence, Porter (1995) argues that properly designed environmental regulation can trigger innovation and even may partially or more than fully offset the costs of complying with them – the Porter Hypothesis. Jaffe and Palmer (1995) distinguish between three variations:

In the “*weak*” version, Porter declares that strict environmental regulation will spur innovation. The “*narrow*” version predicts that flexible environmental policy instruments such Pigovian taxes which provide companies with more targeted incentives to innovate, compared with traditional command and control sanctions. However, it remains unclear how and to what extent the choice of instruments essentially affects innovation (Jaffe, 2004). In the “*strong*” variation, Porter claims that properly laid-out environmental regulation will induce innovation that will entirely compensate given costs of compliance. In policy circles, the thesis of a positive relationship between strict environmental regulation, innovation and competitiveness became very popular in the nineties but is still controversial, primarily because of the complexity of attributing specific innovations to singular stimuli, such as regulation; and the largely ambiguous empirical evidence so far.

Although qualitative case studies (e.g., Bonifant et al., 1995; Porter and van der Linde, 1995b; 1995a; Shrivastava, 1995) rest upon rather anecdotal evidence according to Bernauer et al. (2006), more sound econometric surveys have failed to provide unambiguous results (e.g., Jaffe et al., 1995).

However, two conclusions concerning the impact of the Porters hypothesis can be drawn so far,

Firstly, a competitive advantage might be achieved in terms of strict environmental regulation, which diffuses internationally later on. If there has been a development of technologies in response to strict environmental standards, industries (not necessarily the polluting industry itself), might be able to sell and therefore export their technologies. Their competitive advantage may be based on learning effects or patent protection of their innovation.

Secondly, strict environmental regulation might lead to innovation in the polluting industry which is able to compensate for the costs of adaptation. According to Jänicke (2002) this part of the Porter hypotheses has been entitled the “free-lunch” hypotheses. However, there are also uncertainties remaining as it is still not quite clear what actually distinguishes different versions of the hypothesis, and what is the relationship between regulation types and innovation. Equally, the question remains why, if the Porter Hypothesis is universally applicable, is there evidence for so much dysfunctional and innovation-hampering regulation, and under which circumstances does the Porter Hypothesis work and when not? Finally, the Hypothesis does not consider differences in the radicalness of innovation.

Rödiger-Schluga (2004) have improved Porter’s argument by offering a stepped theoretical illustration for the existence of previously overlooked win-win opportunities that could be stimulated by regulation. Further scenarios under which strict regulation can spur eco-innovations that fully offset compliance costs were shown by Gabel and Sinclair-Desgagné

(1998), Bonato and Schmutzler (2000), Schmutzler (2001) and Mohr (2002) by applying principal-agent theory, bounded rationality and spillover effects.

Many of these approaches are, in one way or another, derived from Schumpeter's hypothesis (Schumpeter, 1942), postulating a positive influence of market concentration and firm size on innovation. Schumpeter argued that market concentration reduces market uncertainty and motivates firms to invest in R&D.

Most economists who consider technical change and the long-term dynamics of the system turn to Schumpeter, and it is intriguing that he still is almost alone among major twentieth-century economists to place technological change at the heart of his system, which then also address problems of social and institutional change (Dosi, et al, 1988).

However old the interest in the debate about how to regulate towards innovation is, the Porter Hypothesis has undoubtedly revitalised this discussion and brought it into the realm of Corporate Environmental Management. However, it is probably worthwhile to review more fundamentally how, if any, regulation and innovation interact, which is the aim of the next section where the highly dynamic interactions of regulation and innovation are specified.

2 The Interaction of Regulation and Innovation

The influence of regulation on technology is complex, and as argued depends on the technology stringency of regulation and – the design and instrument choice of the regulatory intervention as well as how the regulation of technology is being progressed. Therefore it is crucial to know what part regulation plays in the innovation process? In general regulation can be perceived by a company as a constraint (to comply with or...to bypass), or as an opportunity (the company can go beyond the ordinary compliance of the given regulation) (Bascourret et al., 1999). If companies can innovate as the regulation evolves, they can also use the existing regulation to their advantage to obtain a competitive advantage. It is very likely that regulation will particularly affect those innovations which are somehow developed as an answer to the rising awareness of environmental problems. Therefore, innovation management should take into account current and future direction of regulations. This is especially the case regarding the “sustainable” new technologies. On the other side, new technologies developed as an alternative to growing environmental problems often have to face a regulation which is not suited to their diffusion, as this regulation was developed in the framework of existing “traditional” technologies. Therefore, the innovation process must be strongly linked with actions which aim to change regulations to obtain a “match” with new technology. To apply a current example of how regulation drives innovation the intention of the European Commission to propose binding rules that would force car manufacturers to produce vehicles that would emit less carbon dioxide. The plan whether a limit of 120 grams of CO₂ per kilometre for cars sold or imported into the EU by 2012 will be investigated. As regulation is always seen as a tool to level the playing field during the transition period to innovation-based environmental solutions, ensuring that one company cannot gain position by avoiding environmental investments it is crucial to know how individual companies are trying to take advantage of this situation in order to stay competitive.

In neoclassical economics, environmental regulation is an instrument to force companies to internalise external costs they would normally impose to society. However, according to Rennings (1998) its exigency in terms of market failure is beyond dispute in environmental

economics. The instruments to be chosen in specific cases and the appropriate applied stringency of regulation are not specified here although, theoretically, the marginal regulatory cost should be equal to the material pollution cost.

Again it was the conventional neoclassical views that gave strict regulation a rather negative effect on productivity and competitiveness as it arguably leads to increased expenses and therefore induces boundaries for businesses originated by Palmer (1995).

Neoclassical economists have thus criticised the “win-win” hypothesis given the significant compliance costs of industry, competitive disadvantages of domestic firms in international markets, and opportunity costs of forced environmental activities. Further on, it is argued that regulation might motivate companies to develop eco-innovations, but that these efforts would produce additional opportunity costs offset only in extraordinary situations (see e.g., Jaffe et al., 1995; Palmer et al., 1995).

Jaffe and Palmer (1997) found various results for the previously mentioned innovation indicators. Brunnermeier and Cohen (2003) discovered that rises in pollution abatement expenditure measured by the number of successful environmental patent applications granted to industry marginally affect eco-innovation. Observing a theoretical model provided by Bonato and Schmutzler (2000) who derive strategic (spillover effects) and organizational (principal agent problem) factors explaining why environmental regulation could spur cost-reducing innovations that would not have been carried out without given regulation.

The question of *what drives eco-innovation and what role environmental regulation can or should ideally play in this regard* has become even more relevant to policy and decision making process within the last decade. According to Bernauer et al (2006) the total consumption and degradation of natural resources is continuously growing and environmental innovations are considered an important option in terms of mitigation or avoidance of environmental degradation. However, worries about declining competitiveness of the European industry compared to their American and Asian competitors lead policy makers to reduce the regulatory burden on industry.

Requate et al., (2003) provided a vast outline on the incentives for the adoption and implementation (including R&D) of innovation subject to environmental regulation they analysed 28 different models and concluded that it seems to be unclear as to which regulatory instruments dominate other instruments although instruments which provide economic incentives normally perform better than command and control regulation. It is therefore clear that results from such theoretical models are valid under constricted circumstances given that they suffer from severe constraints in terms of the description of the innovation and the regulation-making process.

As a matter of fact those studies are primarily limited to the incentives for pollution control innovation that were caused by regulation.

According to Jaenicke (2007) regulation and policy instruments are innovation friendly when they fulfil certain criteria:

Regulation are innovation friendly if it is:	Policy Instruments that are innovation friendly
<ul style="list-style-type: none"> → based on dialog and consensus → calculable, reliable, and has continuity → decisive, proactive, and demanding → open and flexible 	<ul style="list-style-type: none"> → provide economic incentives → act in combination → are based on strategic planning and goal formulation → support innovation as a process and take account of the different phases of innovation and its diffusion

In contrast, how should regulation be implemented to stimulate innovation? According to Porter and van der Linde (1995a), for environmental standards to foster innovation, three principles must be attained:

1. They must create the maximum opportunity to innovation, leaving the approach to innovation to industry and not the standard-setting agency.
2. Regulation should foster continuous improvement, rather than locking in any particular technology
3. The regulatory process should leave as little room as possible for uncertainty at every stage.

2.1 Smart regulation within a competitive industry

So called “Smart”¹ regulations are presented as an alternative to both, the inherently limited “command and control” model of first-generation environmental regulation and the perceived excesses of neo-conservative deregulation (Jaenicke, 2008).

In this paper “smart regulation” is an umbrella for efforts to take a more detailed and sophisticated approach to environmental and other problems. It aims to make more effective and efficient use of public resources by using a greater variety of regulatory instruments, from taxes and emissions trading to corporate environmental disclosure and public participation rights. It seeks to stimulate self-reflection and self-correction by regulated actors in line with public goals, rather than dictating the details of permissible behaviour. Such an approach attempts to create incentives and procedures that induce entities to act in certain ways and to engage in internal reflection about what form that specific behaviour should take. Hence, government sets goals, but shares more of the responsibility for achieving them with regulated entities (Fiorino, 1999).

Three different fuel-economy instruments, that are considered to be “smart” as they create incentives to enter new markets for domestic industries, shall be discussed:

¹ The word “smart” is used here as an acronym for “Specific, Measurable, Attainable, Realistic, and Timely,”

2.1.1 ACEA Agreement – EU

The so called voluntary agreements are an important element of the EU's strategy to reduce CO₂ emissions from passenger vehicles and to generally improve fuel efficiency. According to those agreements the automobile industry committed to reduce total new passenger fleet average CO₂ emissions according to specific targets and timetables. The voluntary agreements were in 1998 concluded with the European Automobile Manufacturers' Association (ACEA), the Japan Automobile Manufacturers Association (JAMA), and the Korea Automobile Manufacturers Association (KAMA). In the future these agreements will be labelled collectively as the ACEA Agreement. The target for new passenger fleet average CO₂ emissions are 140 g CO₂/km by 2008/9. The Community's target for 2012 is 120 g CO₂/km. This longer-term target has not yet included in any formal agreement with the car industry (ACEA, 1998).

2.1.2 CAFE – USA

In 1975, the US Congress established Corporate Average Fuel Economy (CAFE) standards to conserve petroleum and to reduce US reliance on imported oil (Gerard and Lave, 2003). It has continued to enjoy public support, also as a means to reduce air pollution and to curb greenhouse gas emissions, although it has also been criticised by economists on the grounds that the aforementioned goals could be achieved with other instruments at less costs (see, for example, NAS, 2002).

The CAFE standards set mandatory average fuel economy standards for car manufacturers for passenger cars and light-duty trucks. For passenger cars, the standards increased from 18 mpg (miles per gallon) in 1978 to 27.5 mpg in 1985 and have not been raised since. For light-duty trucks 20.7 mpg has been set.

Compared to the European targets, the CAFE standards are not conceived to be very ambitious. The 140 g CO₂/km target from the ACEA Agreement translates into a fuel economy standard of 5.9 l/100 km. The US CAFE standard for petrol passenger cars is 22.1 l/100 km and the light-duty truck standards for minivans, pickups and sport utility vehicles are even less ambitious (Kuik, 2006).

2.1.3 TOP RUNNER – JAPAN

The Top Runner approach has been established in Japan in 1999 and aims to address energy use in the commercial, private as well as transport sector. One of the targeted sectors is the car industry. Among the desired product groups (e.g., passenger cars), the most energy-efficient product (the "Top Runner") becomes the basis of the standard in 3 to 12 years time, taking into account the potential for technological innovation and diffusion. The standards in the program are used in the "Green Purchasing" law and the green automobile tax scheme. The most energy-efficient products and systems will be awarded annually (NAS, 2002).

With respect to eco-innovation, the EU and Japanese policy instruments seem to be more efficient than the US CAFE approach. This is not really astonishing, given the large gap in regard to stringency of fuel-efficiency standards in Europe and Japan on the one hand and the US on the other. However, none of the standards is expected to give the crucial incentives for radical or break-through innovations. Both ACEA and Top Runner focus more on the rather quick diffusion of new technologies and incremental innovations. As yet, however, the ACEA agreement has not been extremely successful in stimulating promising technologies such as direct injection in gasoline cars and the production of hybrid cars (Kuik, 2006).

2.2 The effect of Strict Environmental Regulation on Innovation

There are several aspects to bear in mind when designing regulations. Probably the most important factor influencing the impact on technological innovation is the stringency of regulation, which is defined as the regulation requiring meaningful environmental improvements, being costly or inducing significant technological change (Ashford et al, 1985, 2000; Frondel, 2007).

In fact, the very emphasis on “*stringent*” regulation implies stringency, as well as direction and focus, are key determinants in the innovation response regulation may trigger. Small regulatory changes are thus assumed to cause less innovation stimulus. And, furthermore, it implies a non-linear response action of the regulated, where proportional increases in “stringency” does not lead to proportional innovation responses. Instead with increasing stringency, situation-dependent and typically unknown trigger values or run-off points separate more from less radical responses. Therefore, a central problem remains how stringent regulation must become to trigger innovation and how “lenient” does regulation have to be to avoid resistance and opposition? This also in part depends on contextual factors, much as the availability of alternative technology, the size of the company in question, typical profit margins in the industry etc.

Many stakeholders, particularly from industry, conceive of regulation as interference of competitiveness. This certainly depends on the “*common sense*” approach that if industry has to comply with lots of regulations they are less likely to spend time innovating and that they are likely to move their plants away from regions with more regulations. This assumption has been particularly challenged by Porter (1995) who suggested that environmental progress requires that companies innovate to raise resource productivity so that regulation becomes not an obstacle but a driver for innovation, and implicitly the more prescriptive the regulation, the more confined must innovation be. There is anecdotal evidence to suggest that this can happen in highly regulated but innovating industries, such as airplane production. Looking at behavioural differences of companies with varying economic success, it is likely that similar regulation may yield innovation more in more successful companies and vice versa. However, there are conflicting arguments for a size effect, where, on one hand, larger companies have a larger capital base to fund (more long term and more speculative) innovation research than smaller companies. Yet, smaller companies, by virtue of their flexibility and adaptability, are also likely to be more innovative by design than their larger, more complex, competition. The argument which of these two dominate, maybe resolved by including regulatory stringency. Where regulation is very prescriptive, smaller companies may have less flexibility to start with, leaving the field of innovation for larger

companies – or leave innovation outsourced and to be bought in only when proven to work and comply with the regulatory standards.

A major deficit in the existing literature that evaluates the interactions between environmental stringency and international competitiveness is the lack of an appropriate method of measuring environmental stringency. Even though some authors, notably Jaffe et al. (1995), specify several indicators of competitiveness, such as net exports, share in world production, and the amount of foreign direct investment (FDI) a country receives, an agreed method to measure the stringency of environmental policy that allows an international comparison has still not been found.

There is also a debate to be had about the effect of enforcement, in particular whether stringent but poorly enforced standards yield a greater innovation drive than lax but fully enforced standards. It is speculated here that the former case is leading to bureaucratisation and obfuscation of diffuse compliance whilst the latter may yield less pressure to change in the first place. Either extreme are unlikely to stimulate innovation success.

The ongoing debate about the implication of globalisation for national policy making raised the problem of free movement of production factors that limit the opportunities for regulation on a national level, which lead to rising costs for companies and therefore competitive disadvantages (Jänicke et al., 2002). Thus globalisation induces a “*race-to-the-bottom*” effect which emerged as the *Delaware* effect of globalisation (Vogel, 1995). It was in Delaware where the competition on deregulation of corporate chartering began. In the US charters are granted by individual states, but all states are required to recognize each other's charter. In the course of this competition, a race to the bottom was won by Delaware by lowering the level of protection for employees, shareholders, and customers (Drezner, 2006).

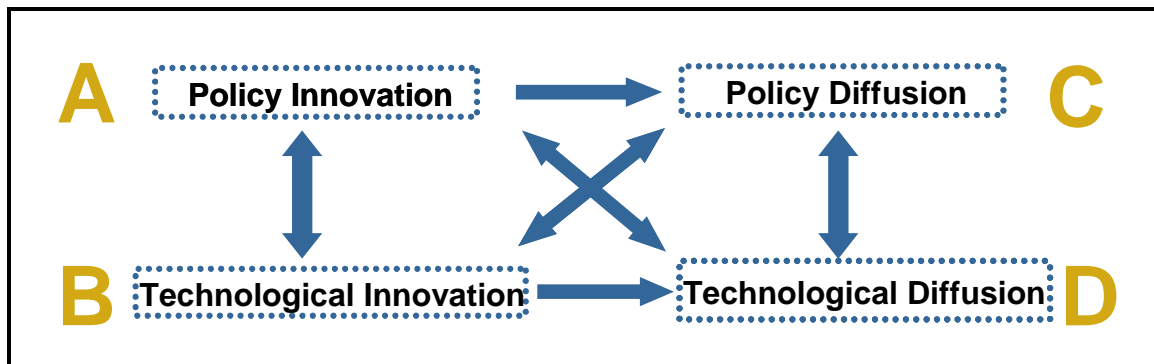
3 The interaction between the diffusion of environmental policy innovation and environmental technology

To understand the relationship between environmental policy and innovation the paper seeks to widen the concepts of innovation which are used in environment-oriented studies, while at the same time challenging the idea that regulation is either a straight forward mediator or inhibitor of innovation.

How can environmental innovation be controlled and guided politically? This is no less true for environmental innovations (Jänicke and Weidner, 1995). When it comes to the effects of innovations the political uncertainty appears to be even deeper. Environmental innovators in particular often prefer not to wait until a suitable policy has been passed and enacted (Jacob, 1999) but often rely instead on the government's recognition that a problem exists and on the early phases of policy formulation. Whereas with “normal” innovations state and politics form only one factor among many influencing the radius of action open to the potentially innovative company, environmental innovations benefit from the state's clearly stronger role.

The idea that state regulation and control by means of specific instruments could achieve specific innovation effects have, in the light of subsequent empirical investigations, met with growing scepticism. Initially this “instrumentalism” was increasingly criticized by empirical researchers in environmental policy; subsequently, however, this was relativised by representatives of the empirical environmental economy (Hemmelskamp, et al., 2000). However, the interactions between environmental policy and environmental technology in the case of innovation diffusion are characterised by a wide variety of possible constellations.

According to Jänicke (2002) it is theoretically possible to distinguish between the following diffusion scenarios, depending on the factors leading to the political and technological innovations:



1. *Technology Forcing* (**A→B→C→D**): An environmental innovation enforces a technological innovation that can only diffuse if there is policy innovation diffusion as well.
2. *Technological Initiative* (**B→A→C→D**): An existing environmental technology induces a policy innovation; the diffusion supports the technological diffusion.
3. *Political Initiative* (**A→B→D→C**): A national environmental policy leads to technological innovations whose diffusion in turn encourages diffusion of the political innovation.
4. *Technological Dominance* (**B→A→D→C**): An innovation in environmental technology is successfully diffused and as a result receives political support both nationally and internationally.
5. *Political Dominance* (**A→C→B→D**): The environmental policy innovation diffuses, before the technology is actually available.
6. *Autonomous Diffusion* (**B→D**): Environmental technology innovation diffuses without political impact.

The purpose of the above pathways is to show specific characteristics of environmental innovations and is divided into policy and technology induced diffusion.

In addition, a closer study of the pathways may yield ideas as to why certain regulation or policy initiatives here brought about more technology change than others.

According to Jänicke (2002), there is reason to support the assumption that autonomous emergence and diffusion of innovations in environmental technology is the exception rather than the rule and that such developments usually remain limited to incremental increases in efficiency in companies. The reverse border-line case is innovation in environmental policy where politics clearly exceeds the given technological possibilities.

The boundaries of ecological innovation are thus defined by the limits of technology. However, these boundaries could be considered as dynamic and can be extended by appropriate research. For example, research into the development of procedures for reducing CO₂ emissions, if successful, could substantially widen the scope for clever manoeuvres in climate politics – even if only in terms of end-of-pipe measures. The variations of the interaction between politics and technology in any case are a central topic in research into the diffusion of ecological innovations, especially when it comes to selectively optimizing such innovations (Jänicke, 2002).

4 Discussion

Given the stiff relationship between regulators and regulated has become more interactive, complex and obscure the effect of regulation on competitiveness becomes increasingly important.

In responds to the expected decline in competitiveness caused by environmental regulation the “race to the bottom” hypothesis becomes highly questionable as it ignores the role of innovation in the global competition. However, innovation typically and sustainably contributes to competitive advantage, and to the extent that regulation spurs innovation this may contribute to competitiveness. Regulation can by its very nature stimulate innovation, even radical ones. There is even more evidence of regulation spurring radical innovation than of market-based-instruments doing so (Kemp, et al., 2004).

Just by studying the literature it is challenging to generalise the innovation effects of command and control instruments, through regulations and a market-based Instruments that include the use of economic instruments such as incentive taxes and tradable permits. However, those studies clearly show that those techno-economic and political factors interact towards inducing eco-innovation.

The question which environmental policy instrument really has an effect on innovation and therefore should be adopted remains inconclusive. In fact it is believed that there is no single best instrument given that instruments have varying strengths and weaknesses as well as mutual influence, policy makers should give attention to the problems and opportunities of simultaneous and coordinated use of more than one instrument.

A broad range of instruments should be used in order to experiment and find out what works best. Evaluations should include the innovation dimension. All these require innovation orientated studies to be conducted.

Smart regulation which are mainly applied by pioneer countries and could be identified by interaction of high environmental pressures and high innovation potential (e.g. “Top-Runner” approach) are often stimulated by anticipated competitive advantages. Therefore environmental policies are often considered to be a mandatory requirement for both innovation and its diffusion.

In contrast to the market driven nature of sustainable innovation regulation, the involvement of mixed instruments partly adopted from their sensibility to market observations with the process of designing sustainable innovation regulation appears to be an appropriate approach. Standardisation and benchmarking as possible competitive regulatory tools (e.g. BAT) appear to be powerful means. (Whenever a company decides to set/shape/define a regulatory standard it therefore imposes its own system within a sector and seeks to establish that in the regulatory system)

However, Jänicke’s model always allows for an important feature that makes the relationship between policy and innovation dynamic, which is not explored in the exemplified six pathways, namely that innovation may reflect back to policy: There are strategic advantages for innovating companies to affect regulatory standards as this can solidify their first-mover advantage towards the competition or in fact it may produce a market for the innovation.

Probably the best example of this are the Best Available Techniques (BAT) reference documents (BREFs) under the IPPC Directive 96/61/EC where industries that fall under this Directive have to have environmental permits that are conditional for the company adapting BAT. What that entails is outlined in the BREFs, so that innovators, to establish a

market for their innovation, can make representation to amend the BREFs, thus ensuring a competitive market for their new products (Martinez, 2006).

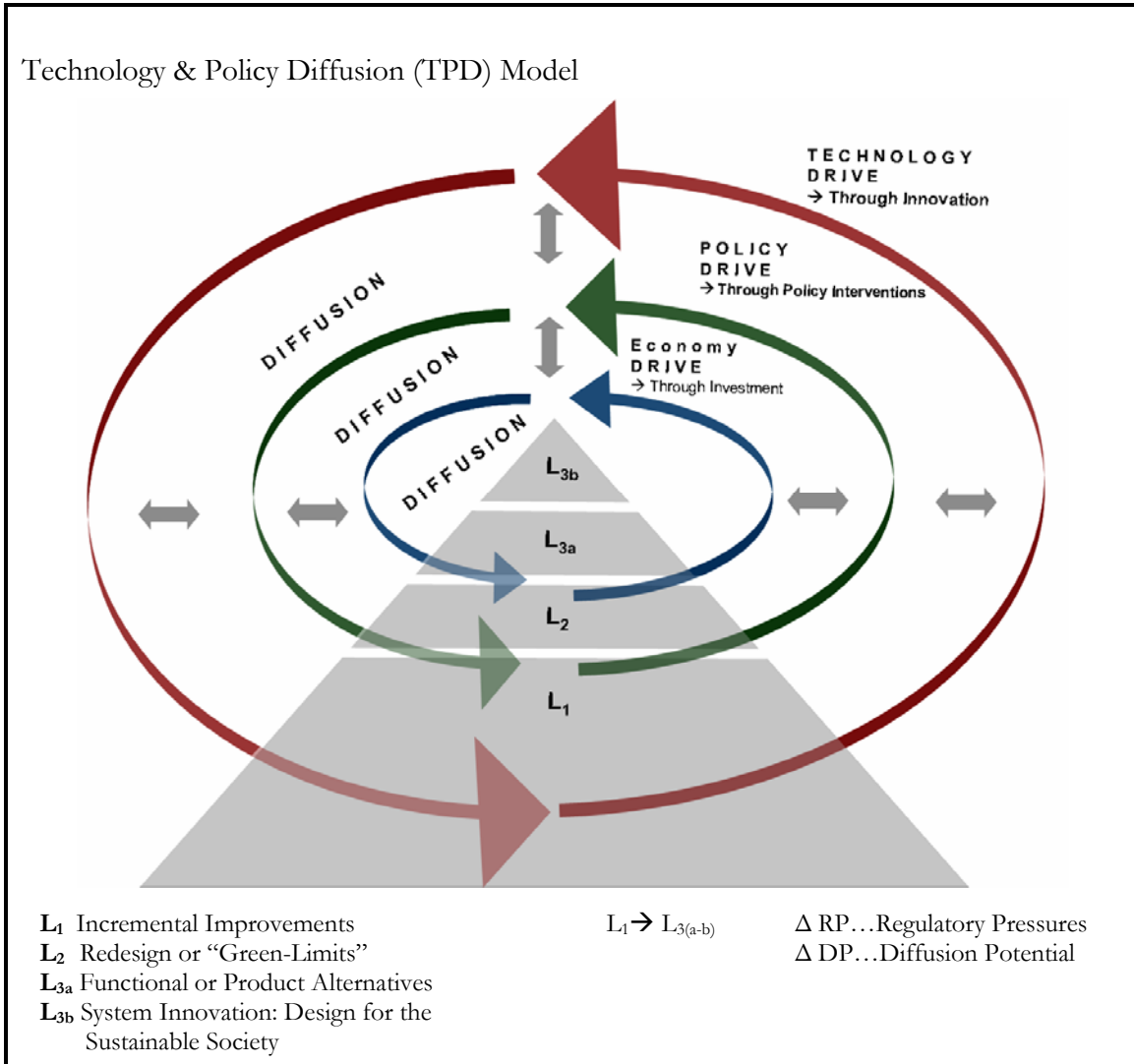
Interestingly, a recent study of BAT on competitiveness came to a broadly supportive conclusion without actually mentioning the word innovation once (Hitches et al., 2001).

5 A new model

Jänicke's model primarily focuses on the importance of the diffusion of environmental innovations between countries for the global development of environmental policy. By doing so, it somehow misses the relationship between policy and innovation. Therefore, a new model based on Jänicke's core assumptions is suggested in order to stress the crucial interaction between a rather new shape of environmental regulation and technological innovation.

In the new Technology & Policy Diffusion Model (TPD-Model) a third rather dominant driver of innovation, which is the economy through competition of rivalling firms, is integrated. In addition the model involves four Levels of Eco-Design that are taken from Stevels (1997) providing a basis for the dynamic interaction of technological innovation on one side affected by drivers on the other. By doing so the interactions between technological innovation, policy instruments and a competitive economy are exemplified and therefore provide a feasible framework of understanding the role of innovation within the TPD-Model.

The different layers of innovation that are illustrated in orbits revolving the pyramid that involves the four levels of Eco-Design aim to exemplify how innovation is affected by the previously mentioned drivers and how innovation is likely to diffuse. The different levels of Eco-Design are important as they show the development from incremental to radical innovation processes and the diffusion potential that is controlled by the radicalness of the innovation.



In order to formulate the interaction of sustainability, industrial ecology and eco-innovation towards a sustainable innovation policymaking future the concept has to be made operational.

- (L₁)-CHANGE → (INCREMENTAL IMPROVEMENTS): Incremental or small, progressive improvements to existing products that are mainly based on common sense or check lists.
- (L₂)-CHANGE → (RE-DESIGN or “GREEN-LIMITS”): Major re-design of existing products limited by the level of improvement that is technically feasible.
- (L_{3a})-CHANGE → (FUNCTIONAL or “PRODUCT” ALTERNATIVES that lead to “Green”-Innovation): New product or service alternatives based on life cycle assessment (LCA) and life cycle cash flow analysis (LCFA) for alternative products systems, also identifying weaknesses in the infrastructure of society.
- (L_{3b})-CHANGE → (Design for the sustainable society that lead to “Green-System”-Innovation): Functionality completely fitting into sustainable society based on LCA and scenarios of alternative infrastructures of the societies.

In addition, each level requires a different level of information. *Level 1* typically requires operational information and research and would therefore use so called *What-if* scenarios. Those scenarios are widely used in Life-Cycle approaches and basically compare two or more options in a well-known situation where the researcher is familiar with the decision problem and therefore being able to postulate on the basis of existing data. These are often studies where specific changes within the present system are tested and their implications to environmental impacts are examined. Results of studies using the *What-if* scenario are usually quantitative comparisons of the selected options.

Level 2 aims to achieve a major re-design of existing products limited by the level of improvement that is technically feasible.

At *level 3a* as well as *3b* strategic information need to be gathered and therefore it is recommended to apply the *Cornerstone scenario* where several options are available, which ideally differ from each other in order to get an overall overview of the analysed field. These alternatives then serve as so called “Cornerstones” of the studied field. Typical results of this approach accentuate a potential direction of a future development and therefore the *Cornerstone scenario* approach marks a powerful tool for long term planning. Some general characteristics of the introduced levels of “Eco-Design” e.g. time horizon, required degree of regulation, risk and uncertainty involved, investment intensity etc. are exemplified in the following table.

Those improvement levels are a combination of technical, social, and institutional innovation and would be also suitable to advance current debates on environmental issues like recycling, ELV-directives, eco-labels, energy reduction etc. and therefore build a new throughout competitive platform for new concepts. According to CHAINET (1998) higher level of design requires changes in society and particular the engagement of multiple stakeholders.

The table illustrates how the four levels of change differ in their characteristics with a range covering from weak (+) to strong affiliation (++++).

	Time Horizon	Degree of Regulation	Risk & Uncertainty	Investment	Return Possibility	Complexity
(L ₁)-CHANGE	0-2 years	N/A	N/A	N/A	+	N/A
(L ₂)-CHANGE	0-5 years	+	N/A	+	++	+
(L _{3a})-CHANGE	0-10 years	+++	+++	++	+++	+++
(L _{3b})-CHANGE	0-30 years	++++	+++	++++	++++	++++

The notion of developing a three dimensional model was to reflect on the highly dynamic interaction of innovation and various drivers that tend to diffuse according to the radicalness of innovation involved. In order to attain a realistic result of how innovation diffuses in the “real world” it is necessary to implement the model in current business processes that are certainly not characterised by a linear innovation process.

6 Conclusion

More than ten years after Porter and van der Linde promoted their popular “win-win” propositions among business leaders it appears that this has turned into a lively but still very controversial research field where results have so far remained inconclusive.

The solution for many environmental problems is often found in new technology development and innovation. For many years the incentive to apply environmental friendly technologies were given by strict environmental regulations and obligations to industry to meet short-term environmental goals. This has often resulted in the application of expensive, and often inefficient, end-of-pipe technologies.

From the literature it appears that the effects of environmental policy instruments in the “real world” are governed by the complexity of the innovation processes and political considerations of using those. Regulatory instruments are complex and the same is true for the innovation dynamics. The impact of regulation depends on the design of the instrument and the context in which they are applied.

Rather than asking which instrument is best in order to promote innovation a more meaningful question, given the available range of policy instruments, would be which is most likely to be successful in achieving the desired goals?

Properly designed regulatory instruments are extremely important. The common and rather broad distinction between CAC and MB instruments may sometimes be too general, and therefore may require modification. It would be recommendable to pay much more attention to the implication of choosing proper indicators.

The ways in which regulation are drafted and implemented desperately need to incorporate the highly dynamic nature of the innovation process. Accordingly, a greater understanding of how innovation processes de facto work is therefore crucial.

Although the relationship between regulation and innovation is complex and not fully understood yet, the study suggests concentrating on “smart” regulation as example of policy instruments that have both a positive effect on environment and innovation and therefore will lead industries towards sustainability. These “smart” regulation are often more efficient and effective in achieving environmental goals and stimulate companies to view environmental issues as a business challenge and opportunity.

Environmental innovation will certainly contribute to shifting society towards sustainable development. For this to happen there is a need for systematically improved environmental regulation as well as environmentally motivated innovation policy.

Given that the shape of existing environmental regulation has changed considerably within the last two decade it is mandatory to reinvestigate the nexus between regulation and innovation. The recommended model aims to exemplify its ability to yield clarity and therefore shall be applied in various case studies in order to test the dynamics involved and reflect on the rather new shape of regulation and its impact on today’s innovation process.

REFERENCES

- ACEA (1998), "ACEA Commitment on CO2 Emission Reductions from New Passenger Cars in the Framework of an Environmental Agreement between the European Commission and ACEA", Brussels July 27th.
- ACEA (2003), "ACEA's Statement on the potential for additional CO2 reduction, with a view to moving further towards the Community's objective of 120g CO2/km by 2012", Brussels 27.11.2003.
- Bascourret, J.M., Delaplace, M., Gaignette, A. (1999), "Eléments de réflexion relatifs à l'interaction réglementation/structures industrielles", *Economie Rurale*, No.260, pp.66-78.
- Bernauer T., et al (2006), Explaining Green Innovation: "Ten Years after Porter's Win-Win Proposition: How to Study the Effects of Regulation on Corporate Environmental Innovation?", published by the Center for Comparative and International Studies (ETH Zurich and University of Zurich)
- Bonato D., Schmutzler A., (2000), "When Do Firms Benefit from Environmental Regulations? A Simple Microeconomic Approach to the Porter Controversy" *Schweizerische Zeitschrift für Volkswirtschaft und Statistik* 136(4): 513-530.
- Bonifant, B., Arnold M., and Long F., (1995), "Gaining Competitive Advantage Through Environmental Investments", *Business Horizons* 38(4): 37-47.
- Brunnermeier S., and Cohen M., (2003), "Determinants of Environmental Innovation in US Manufacturing Industries", *Journal of Environmental Economics and Management* 45(2):278-293.
- CHAINET (1998): "Definition Document", Final Version, CML Leiden University, The Netherlands
- Dosi, G. (1988) The nature of the innovative process. *Technical Change and Economic Theory*. G. Dosi, Freeman, C., Nelson, R., Silverberg, G., and Soete, L. London, Pinter: 221-238.
- Drezner, D., (2006), The race to the bottom hypothesis: An empirical and theoretical review, The Fletcher School, Tufts University
- Fiorino, D.J., "Rethinking Environmental Regulation: Perspectives on Law and Governance" 1999) 23 *Harv. Envtl. L. Rev.* 441, 448.
- Foxon, T. and Carbon Trust (2003), "*Inducing Innovation for a Low-Carbon Future: Drivers, Barriers and Policies*", London, The Carbon Trust.
- Frondel, M., Horbach J., and Rennings K., (2004), 'End-of-Pipe or Cleaner Production? An Empirical Comparison of Environmental Innovation Decisions Across OECD Countries', in ZEW
- Gerard, D. and Lave, L.B. (2003). The Economics of CAFE Reconsidered: A response to CAFÉ Critics and a Case for Fuel Economy Standards. Regulatory Analysis 03-10, AEI-Brookings Joint Center for Regulatory Studies.
- Green K. Towards environmental innovation e a policy synthesis. In: Weber M, Hemmelskamp J, editors. Towards environmental innovation systems. Berlin: Springer; 2005. p. 319e23.
- Gunningham N, Grabowsky PN, (1998). Smart regulation. Designing environmental policy. Oxford, UK
- Hemmelskamp, J. (1997): Environmental Policy Instruments and their Effects on Innovation, in *European Planning Studies*, Vol. 2, 177-194

- Hitches, D et al., (2001), “The Impact of Best Available Techniques (BAT) on the Competitiveness of European Industry”, European Commission Joint Research Centre, Report EUR 20133 EN
- Horbach, J., (2007). Determinants of environmental innovation—New evidence from German panel data sources, *Research Policy* 37 (2008) 163–173, *University of Applied Sciences Anhalt, Strenzfelder Allee 28, 06406 Bernburg, Germany*
- Jaffe, A.B., Peterson, S.R., Portney, P.R., Stavins, R.N., (1995). Environmental regulation and the competitiveness of U.S. Manufacturing: What does the evidence tell us? *Journal of Economic Literature* 33 (1), 132–163.
- Jaffe A, Palmer K. (1997), Environmental regulation and innovation: a panel data study. *Review of Economics and Statistics*;79:610e9.
- Jaffe A., Newell R., and Stavins R., (2004), 'Technology Policy for Energy and the Environment', *Innovation Policy and the Economy* 4: 35-68.
- Jaenicke M., (2007), Ecological modernisation: new perspectives, *Journal of Cleaner Production* 16 (2008) 557e565, Environmental Policy Research Center, Freie Universitaet Berlin, Ihnestrasse 22, D-14195 Berlin, Germany
- Jaenicke M., Jacob K., (2002), Ecological modernisation and the creation of lead markets, FFU-report 03-2002, Forschungstelle fuer Umweltpolitik, Freie Universitaet Berlin
- Kemp, R., Arundel, A., Smith, K., (2001). Survey indicators for environmental innovation (paper presented to conference “Towards Environmental Innovation Systems” in Garmisch-Partenkirchen)
- Kemp, R., Anderson M., (2004), “ Strategies for eco-efficiency innovation”, IMR Strategielijen project voor VROM
- Klemmer, P., Lehr, U. and Loebbe, K., 1999. Environmental Innovation. Volume 3 of publications from a Joint Project on Innovation Impacts of Environmental Policy Instruments. Synthesis Report of a project commissioned by the German Ministry of Research and Technology (BMBF), Analytica-Verlag, Berlin.
- Kuik, O., (2006), Environmental Innovation Dynamics in the Automomotive industry Case study for project “Assessing Innovation Dynamics Induced by Environment Policy”, EU DG Environment, Specific Agreement, no. 07010401/2005/424497/FRA/G1
- Marklund, P-O. (1997) “Environmental policy instruments and competitiveness – a literature survey” SOU 1997:11 “Taxes, environment and employment”, Annex
- Martinez, J-L. (2006), “The IPPC Directive: The EU Meets Pollution Prevention”, Environmental Quality Management/ DOI 10.1002/tqem/Spring 2006
- Michwitz, P., Hyvaettinen H., Kivimaa P., (2007). The role of policy instruments in the innovation and diffusion of environmentally friendlier technologies: popular claims versus case study experience. *Journal of Cleaner Production* 16S1 (2008) S162eS170, Finnish Environment Institute, P.O. Box 140, FIN-00251 Helsinki, Finland
- Mohr R., (2002), “Technical Change, External Economies, and the Porter Hypothesis”, *Journal of Environmental Economics and Management* 43: 158-168.
- NAS (2002). Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards. National Academy of Sciences, National Academies Press, Washington, D.C..
- Naturvårdverket (2005). The Top Runner Program in Japan: its Effectiveness and Implicaitons for the EU. The Swedish Environmental Protection Agency, Stockholm.
- Nordqvist, J., (2006). Evaluation for Japan’s Top Runner Programme within the Framework of the AID-EE Project

- OECD,(1997). OECD Proposed Guidelines for Collecting and Interpreting Technological Innovation Data – Oslo-Manual,OECD:Eurostat, Paris.
- Palmer K, Oates W, Portney P. (1995), Tightening environmental standards: the benefit-cost or the no-cost paradigm? *Journal of Economic Perspectives*; 9:119e32.
- Porter, M. E. and C. Van der Linde (1995a). „Green and competitive; Ending the stalemate.Harvard Business Review: September-October J658/H.
- Porter, M.E., van der Linde C. (1995b): Towards a New Conception of the Environment-Competitiveness Relationship. *Journal of Economic Perspectives*, Vol. 9, No. 4, 97-1
- Rennings K., (1998), 'Towards a Theory and Policy of Eco-Innovation - Neoclassical and (Co-)Evolutionary Perspectives', in ZEW Discussion Paper 98-24, Mannheim: Center for Economic Research (ZEW).
- Requate, T. (2005), Dynamic incentives by environmental policy instruments – a survey, *Ecological Economics*, 54(2-3), 175-195.
- Roediger-Schluga (2004), *The Porter Hypothesis and the Economic Consequences of Environmental Regulation*, Northampton, MA: Edward Elgar Publishing.
- Schmutzler A., (2001), “Environmental Regulations and Managerial Myopia”, *Environmental and Resource Economics* 18: 87-100.
- Schumpeter, J., (1934) “*The Theory of Economic Development*”, Cambridge, Massachusetts: Harvard University Press, 1961 [reprint of 1934 edition].
- Schumpeter, J., (1939), *Business Cycles - A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, New York: McGraw-Hill.
- Shrivastava P., (1995), “Environmental Technologies and Competitive Advantage”, *Strategic Management Journal* 16(Special Summer Issue): 183-200.
- Stevens, A. (1997): Moving companies towards sustainability through eco-design: Conditions for success. *Journal of Sustainable Product Design*
- Triebswetter U., Wackerbauer J., (2007). Integrated environmental product innovation in the region of Munich and its impact on company competitiveness, *Journal of Cleaner Production* xx (2007) 1e10, Ifo Institute for Economic Research, Poschingerstr. 5, D-81679 Munich, Germany
- Triebswetter U. (2004).The impact of environmental regulation on competitiveness in the German manufacturing industry e a comparison with other countries of the European union. Frankfurt am Main: Peter Lang
- Vogel, David (1995): *Trading Up. Consumer and Environmental Regulation in a Global Economy*. Cambridge (MA): Harvard University Press 1995.
- Vollebergh, H. (2007), Impacts of environmental policy instruments on technological change, OECD Report, 07-Feb-2007.
- Wood, S., Johannson, L., (2008). How Not to Incorporate Voluntary Standards into Smart Regulation: ISO 14001 and Ontario's Environmental Penalties Regulations: CLPE Research Paper 07/2008, VOL. 04 No. 02 (2008)