Environmental policy without costs?

A review of the Porter hypothesis[1]

Runar Brännlund[*,†] and Tommy Lundgren[*,^]

[*]Department of Forest Economics
Swedish University of Agricultural Sciences
Umeå, Sweden

[†]Department of Economics
Umeå University, Sweden

[^]School of Business
Umeå University, Sweden

March 6, 2009

Abstract

This paper reviews the theoretical and empirical literature connected to the so called Porter Hypothesis. That is, to review the literature connected to the discussion about the relation between environmental policy and competitiveness. According to the conventional wisdom environmental policy, aiming for improving the environment through for example emission reductions, do imply costs since scarce resources must be diverted from somewhere else. However, this conventional wisdom has been challenged and questioned recently through what has been denoted the "Porter hypothesis". Those in the forefront of the Porter hypothesis challenge the conventional wisdom basically on the ground that resources are used inefficiently in the absence of the right kind of environmental regulations, and that the conventional neo-classical view is too static to take inefficiencies into account. The conclusions that can be made from this review is (1) that the theoretical literature can identify the circumstances and mechanisms that must exist for a Porter effect to occur, (2) that these circumstances are rather non-general, hence rejecting the Porter hypothesis in general, (3) that the empirical literature give no general support for the Porter hypothesis. Furthermore, a closer look at the "Swedish case" reveals no support for the Porter hypothesis in spite of the fact that Swedish environmental policy the last 15-20 years seems to be in line the prerequisites stated by the Porter hypothesis concerning environmental policy.

Keywords: Environmental policy, the Porter hypothesis, productivity, profitability.

JEL classification: D20, H23, Q52, Q55, Q525, Q56.

[1] The authors wish to thank MISTRA, FORMAS, and the Swedish Energy Agency (STEM) for financial support.

1. Introduction

The fact that environmental problems have received increasing attention in recent years has led to an increased interest in the effects of different environmental policy measures. By "effects" we mean in part what governments want to achieve (i.e., a better environment), but also the effects on companies' efforts to succeed in an increasingly competitive world market. In other words, the interest in environmental policy issues is not only related to the "benefit side" but also the "cost side." The interest in the costs of environmental policy is especially salient in Sweden, and other similar countries that have made significant environmental progress, because further environmental improvements are assumed to be achieved at the expense of higher societal costs. The conventional wisdom is that strict environmental policy imposes costs for companies, which affects their competitiveness, and hence in the end have negative social economic impacts such as lower employment and welfare. However, this conventional wisdom has been challenged recently by proposing ideas and theories that see environmental policy as a possible "win-win" situation. Strongly connected to this increased interest and debate around environmental policy is, of course, the saliency of global warming. There seems to be a wide consensus that this issue must be dealt with on a large scale and that it is likely to require economic sacrifices of some type. Policy instruments and measures that can contribute to reducing the negative economic impact of fighting global warming is therefore of great relevance in the debate.

It's important at this point to emphasize that regardless of whether a win-win situation is possible in today's environmental policies, all policy measures should be based on the value of environmental improvements. In other words, the absence of a win-win situation does not necessarily mean that we should avoid implementing environmental improvement policies. Rather, we should follow the traditional rule of thumb that a policy should be undertaken as long as the cost of an incremental emission reduction is lower than the incremental environmental improvement expected by the policy. The main question discussed in this paper is whether or not there may be an "extra profit" from an environmental regulation. If such extra profits do in fact exist, they should be considered in the benefit-cost calculation discussed above, which then will have consequences for what, and how much, measures that should be undertaken. For example, the absence of a win-win situation (e.g., "extra profit") does not necessarily mean we should avoid carbon dioxide emission reductions, given that such emissions lead to environmental damage. Rather, it means that we should set the emission level such that the marginal abatement cost equals the marginal benefit of emission reductions. Given a target set in this way, it can be achieved by, for example, setting a carbon dioxide tax equal to the marginal damage at this level. However, if there is an "extra profit" from the use of such a carbon dioxide tax, the conclusion is that the tax should be set at a level higher than the marginal damage.[2] Thus, the purpose of this report is to study the win-win hypothesis, i.e., whether there is reason to believe that some types of environmental policies in general may create the possibility of "extra profits."

In the last 10 to 15 years the conventional thinking regarding the costs of environmental policies has been questioned and discussed in earnest. The discussion was inspired by the Harvard professor Michael Porter. Professor Porter's fundamental argument is put forth in an article in *Scientific American* in 1991. In it, he asserts that "strict environmental regulations do not inevitably hinder competitive advantage against foreign rivals." His argument was that more stringent environmental policies, if they are implemented correctly, can in fact lead to the opposite outcome: higher productivity, or a new comparative advantage, which can lead to improved competitiveness.[3] In other words, environmental policy can lead to a win-win situation, or an extra profit. Porter's ideas were developed in more detail in an article in the *Journal of Economic Perspectives* (Porter & van der Linde, 1995). In it, the authors developed two main reasons why "well-designed" environmental policies can lead to improved competitiveness. The first was that more stringent environmental regulations can put pressure on a company to become more efficient. According to Porter, "pressure" in the form of an environmental regulation can bring to light inefficiencies within firms that were previously hidden. The second was that more stringent regulations initiate innovation in companies. Taken together, these effects may lead not only to neutralizing the regulation's initial costs, but also to improving the company's competitive position.

It is in light of these considerations that one should view the debate in for example Sweden regarding the country's desire to be at the forefront of environmental policy, i.e., to be the

[2] The discussion about the possible benefits of environmental policy -- that is, whether or not a win-win situation is possible -- has a distinct similarity with the so called "double-dividend" idea behind an environment tax shift. In connection to that discussion a similar question applies; namely whether a rational argument exists for creating environmental policies that are more stringent than the environmental damage would otherwise justify.

[3] In his well-known book from 1990 "The Competitive Advantage of Nations" Porter notes that the traditional comparative advantage, or what he calls "inherited factors" such as large natural resource reserves, can be a hindrance to competitiveness. The "Dutch disease" may be an example of this, when the Netherlands discovered natural gas at the end of 1950s and beginning of the 1960s. Gas exports increased which made the real exchange rate rise. The strong appreciation of the currency made it difficult for the other export sectors in the country. In a sense the “competitiveness” decreased (due to the change in exchange rate).

"first mover." If Porter's assertion is correct, then there would seem to be a strong argument for, say, Sweden to gain a "first mover advantage" in regards to environmental policy - not only to ensure environmental protection, but also to improve their companies' competitive positions and therefore the country's well-being.

Naturally, Porter's ideas are controversial; the reason is that they build on the assumption that a company itself is somehow unable to take economically beneficial measures on their own (see for example Palmer, Oates and Portney, 1995). According to Porter this occurs in part because companies are unable to find the most efficient way to produce or in part because they do not have the ability or capacity to make investment decisions that benefit the company in the long-term. Porter's ideas have inspired many to study the topic, both from a theoretical and empirical perspective. A fairly general consensus from the literature is that the Porter hypothesis can be supported in cases where there is a systematic lack of information, some type of limited, or bounded, rationality, or when the environmental regulation - as a side effect - either reduces or eliminates market imperfections within a sector.

The main purpose of this paper is to summarize the state of knowledge surrounding environmental policy and competitiveness. The key question here is whether or not one can expect a Porter effect in general and, if so, which mechanisms are likely to be driving this effect. A related question is whether or not there are unique attributes of environmental regulations that make a Porter effect possible. In other words, why is it that all regulations in general do not display a Porter effect?

More specifically, this paper aims to give a systematic review of the Porter hypothesis. The fundamental question is whether scientific evidence – theoretical and empirical - exists to support the hypothesis. If the hypothesis can be supported, does it only apply only within environmental policy? If evidence can be found to support the theory in general it would not only have wide-ranging effects for the development and design of social policy in general, but would also be a strong critique against the free market's ability to effectively allocate resources.

The method in this paper builds on a literature review of the theoretical and empirical research in the field of economics. Treatments of the Porter hypothesis in other research fields are omitted for sake of limited space.[4] Furthermore, a closer look at the Swedish case is offered by reviewing some recent evidence. This is an interesting case since Sweden has been on the forefront with regulatory measures that seems to be in line with what Porter denotes “well-designed” policy measures, e.g. the industry-wide CO_2 tax which was introduced in 1991.

The rest of this paper is structured as follows: section 2 provides a systematic assessment of what is meant by the Porter hypothesis. In many respects, the interpretation of the Porter hypothesis is based upon the neoclassical framework (the basis for this report), which means there may be alternative interpretations and aspects of the Porter hypothesis that are not captured here. Section 3 provides an overview of the current understanding in the literature with respect to the applicability and relevance of the Porter hypothesis. One of the objectives of this section is to address the main question of what is unique about environmental regulations and why only these types of regulations have the possibility of a "win-win" outcome. Section 4 concludes with a summary of what we know today and to what extent this information can provide guidance to environmental policy-makers.

2. Envirionmental regulations and competiveness, what did Porter mean?

A review of the literature reveals several interpretations of the Porter hypothesis, especially when it relates to the mechanisms assumed to be driving the connection between "competitiveness" and "environmental regulations."

On a micro-level there seems to be two mechanisms for improving competitiveness: (1) product improvement and therefore higher product value and (2) process improvements - or productivity/efficiency improvements - and therefore lower costs. In principle both mechanisms can be directly related to the environmental regulation and/or be implemented via investment in new capital and/or investment in research and development (R&D). The focus of this paper will be primarily on the second mechanism, although the first mechanism will also be briefly discussed.

A question related to the first mechanism (product improvement) is the extent to which

---

[4] For example, the business and management literature contains a considerable amount of studies in connection with Porter’s hypothesis.

environmental regulations generate "new growth" in the form of the "green sector" expansion. This question will not be explicitly addressed in the theoretical review that follows. However, in many empirical studies “product improvement” is implicitly included through changes in value added. Furthermore, the issue of an eventual expansion, or contraction, of the green sector is more or less an issue of pure structural change and has very little to do with the fundamental idea behind the Porter hypothesis. Environmental regulations will almost certainly lead to an expansion of the “green sector”, at least in the long run, but this will be balanced by a contraction in another sector in the economy. This is, of course, the whole point of environmental policy. Again, it is important to point out that the idea behind the Porter hypothesis is that environmental regulations generate an *additional value* above and beyond the positive environmental effects, which will manifest itself at least partially through a structural economic change.

In addition, an analysis of the "product improvement" mechanism can be associated with several pitfalls if the purpose is to study the Porter effect described above. For example, in many cases environmental regulations are driven by changes in consumer preferences, i.e., consumers demand an environmentally-friendly product. A product improvement, or an entirely new product, that is the result of environmental regulations is therefore not necessarily the result of a company's improved innovation "post-regulation." Instead, it may simply be a change in consumer demand toward a new product that forces companies to change, or leads to the creation of new companies that take market share away from companies unable to adapt. Such a change would not be connected to the Porter effect, as depicted in this report.[5]

In conclusion it is worth noting that Porter's ideas may be considered new but when one reviews the argument in fine detail, large similarities begin to emerge with respect to the long-running discussion around a company's pressure to transform itself. This entire discussion can be traced back to Schumpeter (1936).[6] According to this view, there is always pressure upon a company to transform and develop, but whether such transformation actually occurs depends on the type of "pressure" to which the company is subjected. Pressure to transform might manifest itself in the form of competitors, suppliers, or society (new regulations). The

[5] As we will see later, this type of change is included in Michael Porter's own definition of the Porter hypothesis.

[6] See Roediger-Schluga (2004) for a discussion in relation to the Porter hypthesis.

transformation that can occur may range from technical adaptation and product development to changes in leadership or organizational structure.

As discussed in the introduction, the conventional understanding has been questioned, particularly by Michael Porter (Porter 1991; Porter and van der Linde, 1995). Porter asserts that more stringent environmental policies, if they are well-designed and implemented correctly, can in fact lead to the opposite outcome: higher productivity or a new comparative advantage of some type, which can lead to improved competitiveness. Thus, if we implement a more stringent environmental policy *a la Porter* then - assuming the measure has at least a positive effect on the environment - we need not worry about the impact on competitiveness. Put another way, as long as the regulation does not have a negative environmental impact, the measure should be implemented because it improves companies' competitiveness.

Central to Porter's argument is that governments design and implement the "right type" of policy instrument. As Porter explains it: "Turning environmental concern into competitive advantage demands that we establish the right kind of regulations” (Porter (1991), p. 168). According to Porter ”the right kind of regulation” results in ”a process that not only pollutes less but lowers cost or improves quality.” Specifically "the right kind of regulation" is an instrument that leads to new technical solutions and innovation, which in turn leads to improved resource allocation.

Well-designed regulations, according to Porter, serve several purposes. First, regulations act as a signal that efficiency gains and technological improvements are possible. In the absence of an environmental regulation, companies are unaware of their own ecological impact, as well as potential efficiency improvements and the potential for innovations. According to Porter, regulations are aimed to visualize the ecological impact as well as potential technological and technical process innovations. Second, regulations can contribute toward a company's increased environmental awareness. Environmental regulations are often implemented in conjunction with regular reporting requirements where a company must report their emissions. This transparency in a company's environmental impacts is meant not only for the public, says Porter, but for the company itself. The third argument for well-designed regulations is that they reduce the uncertainty that is associated with many types of investments. This argument assumes that environmental policies will be consistently implemented over a long time period. The fourth argument, according to Porter, is that regulations contribute to an improved environmental awareness in general, which affects consumers' preferences. That is, regulations force companies to transform themselves and their products in order to survive.

To give a picture of the dynamics involved in the hypothesis, Porter and van der Linde assume that the innovations generated by environmental regulations can be divided into two broad categories. First, companies become more adept at handling pollution in the sense that they improve their handling of waste and their use of input factors that cause environmental damage. According to Porter, innovations and investments that target these aspects reduce the company's environmental adaptation costs. The other type of innovation arises when a company simultaneously considers the regulation and a production-process improvement, a product improvement, or even an entirely new product. The latter adaptation is the basis for the Porter hypothesis because it explains the mechanism that makes it possible not only to reduce the company's costs, but to neutralize them completely, and even generate "extra profits."

Porter divides the possibility for cost neutralization into the product and process mechanisms. The former arises when environmental regulations not only reduce pollution, but also improve the product's quality and performance, which leads to a higher product price. The latter arises when an environmental regulation not only leads to reduced pollution, but to improved productivity/efficiency, i.e., increased output for a given quantity of input.

Porter and van der Linde point to many other possibilities, including selling by-products (which were previously considered waste) as inputs for the production of other goods. Alternatively, the authors note the possibility to reduce process costs by reducing energy use or costs associated with inventory, etc.

As noted above one of the arguments for environmental regulation is the increase in general environmental awareness that can, among other things, mean an increased willingness to pay for "green" products, thus leading to new products and markets. Porter and van der Linde point to an interesting Swedish example of product improvement in the Scandinavian pulp and paper industry. The producers in this sector promoted and introduced new environmentally-friendly processes. This development allowed the suppliers that designed the technology - Kamry (now Kvaerner Pulping) and Sunds Defibrator - to win greater international market share in their sales of paper-bleaching technology. Porter's interpretation is that these suppliers were forced to adapt to the Scandinavian pulp and paper industry's new development such that when the international demand for environmentally-friendly bleaching processes increased, the Swedish suppliers had already developed the product.

The above case study is what Porter refers to as the "first mover advantage." In other words the regulated company is not the only entity that can experience improved competitiveness; rather, the positive effects can even spread down the supply chain. As Porter points out, the Swedish pulp and paper industry example assumes that environmental regulations are consistent with the international trend for environmental protection.[7]

What conditions and principles must be met in order for environmental regulations to have maximum positive effect? The first, according to Porter, is to create an environment where companies can be innovative and new processes can be shared among the regulated industry. Furthermore, the regulations must generate a continuous process for innovation such that no specific technology is preserved or protected (patented). Last, but not least, industry should be released from the uncertainty that is often connected to environmental policy and the associated requirements for environmental investment. In other words, Porter states that regulations should be driven by results, not methods; rather than targeting specific technological changes, regulations should integrate economic incentives such as environmental taxes/fees, environmental deposits, and transferrable emission permits.

In summary, Porter does not make the assertion that all environmental regulation leads to improved competitiveness; instead his argument is that well-designed environmental policy can be more conducive to improved competitiveness. According to Porter, well-designed environmental policy:

- must be preventative
- must not be based on prescriptive (quantitative) technology
- must be based on a structure of market incentives

The complete cost neutralization that can arise from "well-designed" environmental regulation has been referred to as "a strong Porter effect" (see for example de Vries and Withagen, 2005). If, instead, a well-designed environmental regulation not leads to complete cost neutralization, but rather to a cost outcome that is lower than the second best regulatory alternative, it is generally referred to as a "weak Porter effect." However, it should be clearly

[7] See also the discussion in Porter (1990) regarding "clusters" and "Porter's Diamond."

noted that the existence of a "weak Porter effect" does not imply a cost-free environmental policy; rather the choice of an *alternative* instrument to fulfill the same policy would have led to a higher cost.

Figure 2.1 is an attempt to illustrate and summarize some aspects of the Porter effects discussed above. The top Figure (a) illustrates the conventional, or traditional, effect of a regulation. For simplicity we assume that a good, q, is produced with one input factor that generates emissions of some pollutant, z. In other words, increased production necessarily brings increased emissions (if firms are on the production possibility frontier). The connection between production and emissions is described by the production function $f(z)$, where f_0 indicates the pre-regulation level of technology. A profit-maximizing firm in the pre-regulation period chooses to produce q^0 units, which leads to an emissions level of z^0. This means that the company utilizes the existing technology to its maximum potential and produces in the most efficient manner, given the assumptions mentioned above. A regulation that limits emissions to z^R by definition limits the company's options, or choice set, which ultimately leads to lower production and lower profits. Production falls from q^0 to q^R, and profits from π^0 to π^R. This scenario provides improved competitiveness for companies located in other countries that are not subject to the same regulations.

The lower Figure (b) attempts to illustrate some of the effects that arise according to the Porter hypothesis. According to Porter, a regulation will highlight inefficiencies in a company. One way to illustrate this in the pre-regulation period is to assume that a company is not producing on the production possibilities frontier but rather at point C. A regulation of emissions from z^0 to z^R would highlight inefficiencies which would allow the company to move (outward) to the production possibilities curve. At point B all inefficiencies are neutralized and the company increases production (from q^0 to q^R), earns higher profits (from π^0 to π^R) and, at the same time, reduces emissions. The hypothesis assumes implicitly that it is cost-free to move toward the frontier. There could, of course, be several reasons why a company might not be producing as efficiently as it could. There is empirical evidence to support the idea that some companies do not always choose energy investments that maximize profits. For example, the US Environmental Protection Agency recognized this and introduced the "Green Lights Program" which provides companies information and advice on energy-saving measures.

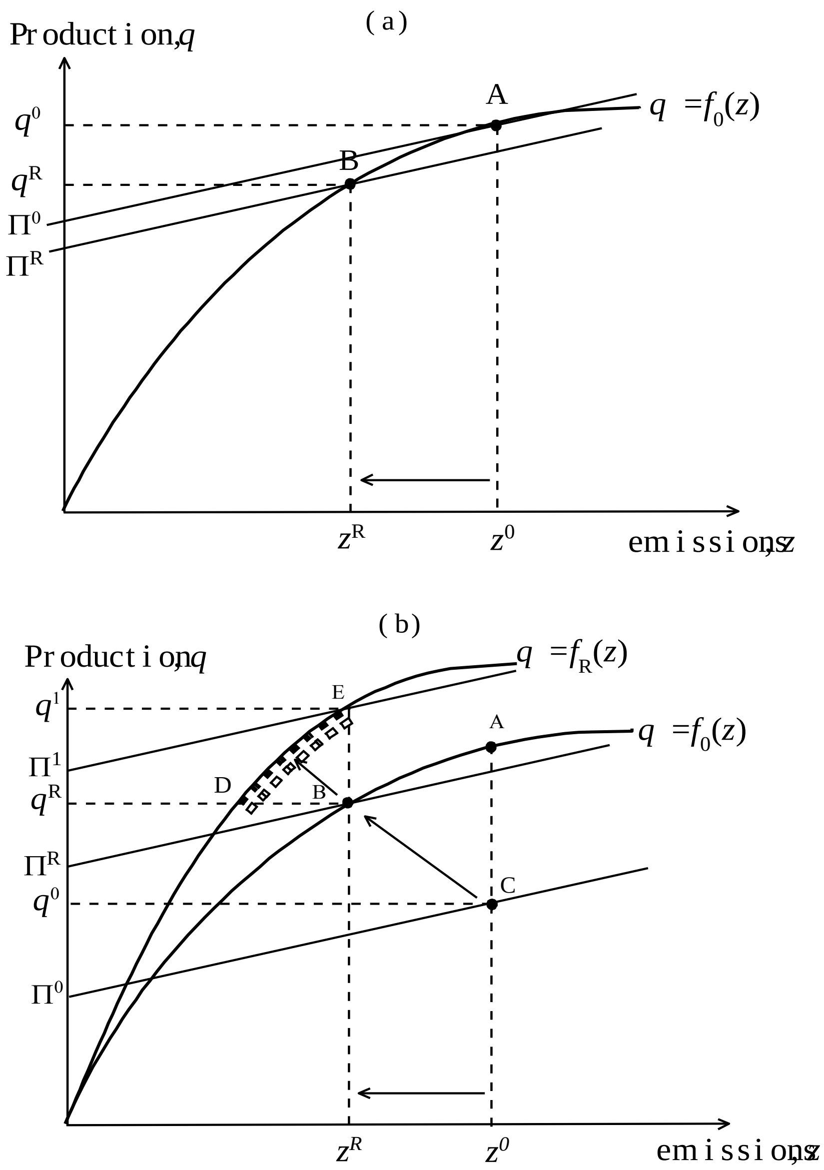

Figure 2.1. The Porter hypothesis

According to the Porter hypothesis, environmental regulations have a "dynamic" effect in that they stimulate innovation and new processes. Figure 2.1b illustrates this by showing how the "frontier" (production possibilities curve) shifts upward and represents a "new" technology $f_R(z)$. The new production technology means that the production and emission levels at point B are inefficient, but the regulations make this inefficiency visible to the company. Ultimately, this means the company will move itself from point C to B and then move even further as a result of the new technology to a point between D and E. Given stable prices (in both the product itself and the "emissions" input), profit is maximized at point E. Even in this part of the Porter hypothesis the implicit assumption is that the development of the new technology does not make us of the company's productive resources, or at least are very small.

Porter and his co-authors do not develop any formal test of whether or not their hypothesis can be rejected. In order to verify the hypothesis Porter and van der Linde provide several examples in the form of case studies. One example from the company Raytheon shows how regulation-generated innovation often refers to improvements in product performance or quality. The company introduced a program to eliminate all ozone-depleting chlorofluorocarbons (Freon), which were used for cleaning delicate electronic circuit-boards. Raytheon now introduced a new environmental friendly method based on water, turpentine, and most importantly, recycling. The new process improved the average product quality compared with the previous process. The authors asserted that this new process would not have been possible in the absence of environmental policy.

Another example of cost neutralization that Porter points to is the measures undertaken by the jewelry manufacturer Robbins Company. The company converted to a closed-loop "zero-discharge" waste system that completely eliminated the release of polluted spill water. The new process resulted in spill water that was 40 times cleaner than household tap water. The outcome was a more effective plating system that resulted in higher product quality and fewer product re-calls.

Porter and van der Linde (1995) give several other examples to which we refer the interested reader. Our review of the empirical evidence generates two interesting questions: First, does the empirical evidence support the hypothesis in general, or simply support these particular case studies? Second, and perhaps even more important, are these case studies the rule or the exception?

It is nearly impossible to answer the first question without going into the detail of each and every case. The actual evidence that the regulation itself was responsible for making these inefficiencies "visible" to the company cannot be documented. However, it's also not possible to conclude that many of the measures would have been implemented for purely economic reasons, even in the absence of the regulations. Regarding the second question, there does not appear to be a certain answer there either. There were very few companies investigated and, as Palmer et al. (1995) suggest, "It would be an easy matter for us to assemble a matching list where firms have found their costs increased and profits reduced as a result of environmental regulations, not to mention cases where regulation has pushed firms over the brink into bankruptcy" (Palmer et al. 1995, p. 121). It is certainly possible that the companies to which Porter and van der Linde (1995) refer could have experienced positive economic impacts. The problem from a policy point of view is, of course, that this may not apply in the general sense. A policy that is based only on the "positive" examples may underestimate the regulation's true cost, which ultimately results in a level of regulation where the social costs and benefits are not in balance.

Thus, an interesting and important question is whether we can find any systematic connection between environmental regulations and competitiveness. The previous discussion provides some guidance on how to investigate this issue. The theory on comparative advantage says that the development of a country's net exports depends upon the development of the country's comparative advantage. In theory one can separate out the real effects of regulation on a company's competitiveness by studying, for example, the effects on the country's net exports given that real wages and exchanges rates are held constant. However, in practice it is very difficult, although maybe not impossible, to separate out the environmental effects from all other effects. The best approach would be to study the effects of environmental regulations *before* the exchange rate adjusts and therefore also *before* the net exports of non-regulated goods adjusts. This is a significant problem in most empirical studies. Therefore most studies rely on indirect indicators to measure the effect of regulations on a company's competitiveness, rather than considering the adjustment mechanism itself such as the exchange rate. Besides net exports, other indicators have also been studied (e.g., the country in which the pollution-intensive good is produced and whether the international trading patterns have changed over time).

A more direct method - and one that is more in line with Porter's original idea - is to study the environmental regulation's effects according to the illustration in Figure 2.1. That is, study the development of productivity in a company, a sector, or an entire country. This approach has several advantages. First, a change in competitiveness must sooner or later affect production. Second, it is possible - at least theoretically - to divide the productivity change into an efficiency and technological component. However, one should be aware of the fact that this does not enable a hypothesis test of a "strong Porter effect." In other words, even if one finds that more stringent environmental regulations lead to increased productivity via an efficiency improvement and/or technological advance, it does not directly support the idea that this would (*at least*) neutralize the company's cost of the environmental regulation. What can be said, however, is that the company has become more efficient (more productive) and the cost of reaching this environmental goal was lower than what it would have been if no efficiency improvements had been undertaken.

A literature review -- both theoretical as well as empirical - that addresses the questions above is provided in the next section. Included in this is a discussion of the concepts that are central to the Porter hypothesis, as well as the arguments in favor and against the hypothesis.

3. What are the arguments, a review of the literature

The objective with this section is to review the theoretical as well as the empirical literature that is relevant for the objective with this paper. An attempt will be made to present a systematic review, considering different aspects of the Porter hypothesis, such as regulatory effects on (i) R&D, (ii) investment, (iii) productivity/efficiency, and (iv) costs and profits.

The objective here is to cover the most relevant theory and empirics given the main purpose of this paper. The review is most likely not complete, but hopefully covers the most important elements and arguments. The Porter hypothesis is a type of "win-win" hypothesis. Importantly, a "win-win" situation can arise due to a number of reasons other than what Porter discusses, but this brings us into other research areas that will not be addressed in this paper. One example of a research area not covered here is the theory and empirics around a tax shift and the resulting "double dividend." Another area is the theory and empirics around endogenous growth, the diffusion of technology and so-called spillovers. The work from these more general research areas will be highlighted only to the extent that they have a direct and relevant connection to the Porter hypothesis.

3.1 Theory

As mentioned above the academic debate around the Porter hypothesis started soon after Michael Porter's original article in *Scientific American* in 1991, but gathered steam following the publication of two articles in the *Journal of Economic Perspectives* in 1995. The first article by Porter and van der Linde (1995) further developed the ideas from Porter (1991), while the second article by Palmer et al. (1995) argued strongly against these ideas. Using a relatively simple model Palmer et al. (1995) argued that the Porter hypothesis simply was not plausible. Moreover, they asserted that the empirical evidence that Porter and van der Linde point to consists of only a few examples of companies that benefitted from regulation or for some other reason were successful, but failed to identify the other companies that were harmed by environmental regulation.

Porter's argument rests in large part on the assumption that the traditional neoclassic viewpoint on the connection between the environmental regulations and competitiveness is too static. Porter and van der Linde (1995) points out that one must have a more dynamic view of the effects of environmental regulation. The fundamental theory behind their argument finds its roots in Michael Porter's earlier work in 1990 related to companies' dynamic change. Porter (1990) states that long-term sustainable economic growth cannot be built upon what he calls a country's "inherited factors of production" (labor, natural resources, etc) which, in the neoclassical theory, is assumed to determine a country's comparative advantage. Porter even makes the claim that a lot of these "inherited factors of production" can lead to a competitive *disadvantage*. In the so-called Diamond Model, Porter emphasizes that competition and rivalry between competitors, as well as proximity to customers and suppliers are the driving factors in a dynamic process. Clustering, or proximity to each other, is the key to competitiveness according to Porter. Efficiency improvements can thus very quickly be shared with customers and suppliers, which increase the dynamics. The State's role in Porter's Diamond Model can be viewed as a driver of the process through "the carrot and the stick." An example of this type of dynamic cluster-environment according to Porter is Silicon Valley. Another example might be the Swedish pulp and paper industry, discussed above, which includes not only paper companies but also suppliers and technical companies with an orientation toward industrial processes.

Porter and van der Linde (1995) simply transfer these theories to the environmental policy arena by assuming that the State can create pressure for innovation and change through environmental regulations. Two weaknesses to this approach can be identified directly. The first is that Porter's competitive model is built upon the cluster idea, i.e., in order to establish a business climate that thrives on the dynamic processes that Porter describes, the companies - including everybody from their customers to their suppliers - must be grouped together at a specific geographical place. What is actually meant by this is not exactly clear. Thus, the question that arises from an environmental perspective is what kind of effects that are expected when environmental regulations are applied to companies that are spread over a large area rather than at a specific place. Another potential weakness in the theory is that the dynamic process seems to occur independent of "the sticks and carrots" used by the State. In other words the State's key role is to be the entity that applies the pressure, but the type of pressure it applies seems to be of secondary importance. The only reasonable interpretation is that any other means of applying pressure on companies could ostensibly bring about Porter's dynamic process and also lead to improved competitiveness.

The view on "dynamics" appears to be one of the main differences between the Porter perspective and the neoclassical view put forward by Palmer et al. (1995). They, however, point to two other fundamental differences. The first is that Porter assumes that the private sector systematically fails to capitalize on all profitable opportunities. The second is that the Porter hypothesis is based on the assumption that the State (or other regulatory authority outside of the private sector) is not only in a position to observe the inefficiencies of the private sector, but can even correct for such inefficiencies. Porter assumes, in other words, that the regulator are a more informed actor in the market place and, moreover, are in a position to implement measures to encourage companies to neutralize their inefficiencies. Palmet et al. find this view " ... hard to swallow." A general question that arises - which in fact was posed by Palmer et al - is whether or not Porter's hypothesis about government regulations applies in general, or if there is something unique about environmental policy?

The arguments expressed in Palmer et al. helped to "jump-start" a new theoretical and empirical research area focusing the connection between environmental regulations and competitiveness. The theoretical literature has to a large extent searched for the mechanisms and circumstances that might lead to the effects that Porter describes. The explanatory models that have been developed so far can be roughly categorized as either (1) models that focus on the diffusion of technological innovations and positive externalities associated with research and development (R&D) in the environmental arena; (2) models based on imperfect markets and strategic interaction; and (3) models based on the idea that companies may not act rationally due to problems of coordination associated with internal decision-making (Gabel and Sinclair-Desgagné, 1998, 2001);. Theories within (1) and (2) rests predominantly on neo-classical theory, while (3) fits better within the Porter framework that focuses on a company's internal dynamics and how pressure from "without" can facilitate change "within."[8]

Examples of models and theories in the first group - positive externalities and the diffusion of technology - are given in Xepapadeas and de Zeeuw (1999), Mohr (2002) and Feichtinger et al. (2005). A related explanatory model (simulation model) is given in Popp (2005), which builds upon the result that investment in R&D is uncertain.

Xepapadeas and de Zeeuw (1999) build their explanatory model on two key assumptions.

[8] This branch of theory can potentially be connected to bounded rationality (see e.g. Simon, 1982). We discuss this further in the concluding section in relation to thoughts on future research.

First, they assume two companies: a domestic company that is regulated (environmental tax) and a foreign company that is not regulated. Because there are only two companies, their individual decisions regarding production affect the market price for their good (the good is demanded in a "third country"). Second, they assume that each company's machinery (capital stock) is of variable age, where the newer machines are not only more productive than the older machines, but also less polluting. Further, they assume that the companies have the possibility to invest in newer machinery, but at a cost. Given these assumptions, it is not possible to demonstrate a "strong Porter effect" but the conflict between competitiveness and environmental regulation is not necessarily as significant as one might think. In principle there are two mechanisms that lessen the supposed contradiction. The first is that it can be relatively profitable to invest in the newer less-polluting capital due to the improved productivity. However, investment comes at a cost and the so-called "capital composition effect" is not sufficient to neutralize the initial cost increase. However, the initial cost increase has a "scale effect" which in this case works for the Porter hypothesis. The higher costs actually mean that the domestic regulated company reduces its capital stock in absolute terms, thus decreasing production. It is here that the first assumption plays a decisive role. The first assumption means that the company faces a downward-sloping demand curve. Thus, the decrease in production causes the market price to rise. The net effect of the increasing market price, together with the positive production effect driven by the new capital investment, dampens the decline in profits. As the authors note, the strength in this dampening effect depends upon the modernization of the capital stock as well as the "scale effect" via the higher market price.

Simpson and Bradford (1996) generated a result where the domestic regulated company obtains a higher profit then the non-regulated foreign company, but their strategic model (duopoly) relies on several very specific assumptions. The authors themselves note that "In our model we find that this [domestic industrial advantage] may be a theoretical possibility, but that it is extremely dubious as practical advice" (p. 296, Simpson and Bradford, 1996).

In summary, we can say that both of these models demonstrate that under special circumstances a "strong Porter effect" may almost arise. However, relatively small changes in assumptions lead to radical changes in results, which then do not give any clear support for a Porter effect in general. Perhaps even more important is that the results are not unique to the case of environmental regulations, as both studies point out. The studies note that the same results could be reached through an industrial policy in general that focuses on R&D and new technology. For example, there is a strong argument that direct subsidies to R&D are a superior instrument in cases involving positive externalities associated with R&D. This is consistent with fundamental economic theory as well as the empirical evidence; i.e., we should tax negative external effects and subsidize positive external effects. In some cases we may observe *ex post* that an environmental regulation has helped to correct other externalities, but this does not mean that one can base a policy on this effect *ex ante*. Simpson and Bradford go so far in their critique (even in their own model) to completely dismiss the idea that more stringent environmental regulations can provide benefits to competitiveness. Their argument, in many ways, is that the Porter effect arises only under very special assumptions - which admittedly may be adequate and reasonable in some specific cases - but rarely as a general rule. For example several of the models where the actors act strategically may predict a Porter effect, but it is independent of the "scale effect" of the type described in Xepapadeas and de Zeeuw (1999). Thus, even if there was some type of "first mover advantage" it is, by definition, only temporary because the higher price will entice new producers to enter the market.

In contrast to Xepapadeas and de Zeeuw (1999), Mohr (2002) shows that a "strong Porter effect" is possible under assumptions that are similar to those discussed above. Besides the assumptions that newer machines are more environmentally-friendly and more productive, Mohr also assumes that there are several companies and that there exists positive external economy of scale in the sense that the productivity within a company that applies a specific type of technology depends upon the collective "experience" of using that type of capital. In other words, there is a "learning effect". The implications of this assumption are obvious. Assume that a company uses "old" capital, which is used by many other companies. Even though the capital is "old", it is relatively productive due to "the learning effect." Assume further that a new type of capital becomes available and that this new capital is fundamentally more productive. The problem is that now there is a disadvantage of being the "first mover" in the sense of investing in the new technology. All companies prefer to wait until others have invested in order to avoid incurring the "learning costs." In other words "it costs money to be on top" or, to use the more prevalent terminology, there is a "second mover advantage." In simple terms this implies that it is profitable to wait until others have invested and then benefit from the experience that they gain. It is also evident that there are positive externalities of investment because other companies can benefit - without paying - from the experience that arises when other companies invest in the new technology. The positive externalities mean that the actual investments made within a sector may be non-optimal from a social perspective, which in turn provides a rationale for some type of policy intervention.

Mohr (2002) shows that if the State introduces a policy that forces all companies to use a new technology, and simultaneously introduces a restriction that companies must reduce emissions, then production will fall in the short-term, but increase in the long-term.[9] The same result is reached if the new technology is subsidized.[10]

According to Mohr (2002) a Porter effect is possible if one allows for the possibility for a technological change that also leads to positive external effects. If we interpret the Porter effect as a simultaneous increase in production and decrease in emissions, then we can be even more specific and say that Mohr's analysis identifies the circumstances, or policies, under which this type of effect may arise. However, one cannot say that such a policy in fact will lead to a Porter effect, i.e., reduced environmental impacts and increased production. Essentially, it is not possible to exclude the possibility that a policy aimed at stimulating more productive technology can lead to both increased production and increased emissions. It means that an optimal policy is not necessarily a policy that leads to increased production and reduced emissions. In sum, the analysis in Mohr (2002) shows that environmental regulations can lead to increased productivity (efficiency) as well as increased production and profits. The driving factor is the positive externalities associated with investment in new technology via the "learning effect."

Thus, an environmental policy that stimulates, or forces, the implementation of a new technology can be justified. However, it should be emphasized once again that productivity effects are not unique to environmental regulations but rather are generally applicable as long as there is some form of positive externalities associated with the increased capital use and/or change in capital composition.

The conclusion that can perhaps be drawn from the latter is that even if positive "learning effects" are likely this does not justify the introduction of a regulation (environmental tax or quantitative regulation) that is more stringent than what is justified from an environmental

---

[9] By "long-term" we mean the time it takes to reach the same or greater level of experience with the new technology that had already been in play with the old technology.

[10] Another possible intervention could be to tax production that relies on the old technology.

perspective. Instead one should implement an *industrial policy* that benefits, or gives incentives for, investment in the new technology.[11] Subsidies to have in part been justified by this type of argument, i.e., a learning effect (Mohr, 2002, however, does not give any explicit argument for subsidizing wind power[12]). His analysis gives further support to the idea of eliminating uncertainty around environmental policy. Once again wind power can act as a prime example. As shown in Michanek and Söderholm (2006) there may be a value for a company to wait to invest in wind power if there is uncertainty associated with the existing subsidy systems, as there is now in Sweden. Furthermore, if there are learning effects associated with this behavior, as discussed above, the effects of uncertainty can be worsen by causing otherwise socially-profitable investments to be postponed.

Feichtinger et al (2005) essentially draw the same conclusions as Mohr with respect to the effects of optimal policy. In a generalized version of Xepapadeas and de Zeeuw (1999) they show that if one has a modernizing effect, as in Xepapadeas and de Zeeuw (1999), and a learning effect of the type discussed in Mohr (2002), the emissions reduction effect becomes lower. Feichtinger et al. (2005) show that a learning effect can negatively strengthen the decline in profits for a policy designed to reach a specific environmental goal. The reason for this, expressed in simple terms, is that the environmental tax level must be increased *more* in the case of learning effects in order to off-set the emissions increase driven by the higher productivity. Overall, we can say that the three studies referred to above do not give any definitive answers to the questions of what conditions that must prevail in order to see a Porter effect, and to the question of what may be unique about an environmental regulation, viewed from the Porter perspective. Xepapadeas and de Zeeuw (1999) show that under their specific assumptions a weak Porter effect associated with an environmental regulation (environmental tax) can arise. In this case "weak" refers to the fact that the negative effects of a "forced modernization" are dampened to some degree predominantly by the increase in the price of the good they are producing. This price increase assumption follows naturally from the duopoly model the authors employ (i.e., two companies produce the same good). In other words, the Porter effect is entirely dependent on this price effect or, in more general terms, is

---

[11] Jaffe et al. (2005) supports this conclusion, but also note that one should have a long-term strategy that tests different policy options; above all these options should be valued systematically.

[12] Michanek and Söderholm (2006) show that there is significant uncertainty associated with investment in wind power. This uncertainty is associated primarily with uncertainty around the future support (state subsidies) and the market conditions that may arise over the long-term and, above all, on the permitting process.

entirely dependent upon the assumptions regarding the type of market within which a company operates. Mohr shows that a productivity effect can be strengthened by the existence of a "learning effect." Thus, a more stringent environmental policy may in fact benefit companies, but the eventual emissions reduction is presumably reduced relative to the original target because emissions will likely increase even further in the second stage. Thus, as shown in Feichtinger et al. (2005), if a specific emission target is to be reached, the more likely it is that companies' profits will ultimately decline, which discredits the Porter effect.[13]

Perhaps the most important conclusion from these three studies is that the effects that may possibly arise are in no way unique to environmental regulations; instead, they can arise from other types of regulations. This points clearly to the idea that if one's objective is to realize profits from improved productivity as a result of positive externalities, then it is presumably more effective to implement a more general industrial policy that is not necessarily aimed at environmental investments. Further, one can draw the conclusion that if learning effects of the type discussed above are prevalent in an industry or sector, there is no "first mover advantage." Instead, it is more profitable to wait until others have invested in the newer technology. The effect of another type of externality is studied in Greaker (2006). The idea here is that environmental regulations give rise to a new industry: suppliers of pollution abatement equipment. A more stringent environmental policy implies an increasing demand for such equipment, which in turn means that the companies that supply this equipment no longer need as big price premium as before to cover the costs to develop this kind of equipment. The model used in Greaker (2006) consists of three actors: an "upstream" company that produces the abatement equipment, a "downstream" company that pollutes and produces a good on the world market, and the government (regulator) that determines environmental policy. Given these assumptions, a more stringent environmental policy leads to increased demand for pollution abatement equipment, which attracts several potential producers of this equipment, which in turn reduces the development costs in this industry. The result is that the price of the abatement equipment falls. A direct effect of the more stringent environmental regulation is that the costs for the exporting (downstream) company increases, but this effect is opposed in the model by the fact that the price of pollution abatement equipment falls, which can completely neutralize the direct effects. A necessary condition to

[13] The reason is that if a, say, tax, is introduced and this also affects productivity in a positive way, production will increase, and hence emissions. This demands even further regulations, in order to reach the target.

ensure the positive neutralizing effect is that the price of the pollution abatement equipment falls as a consequence of the more stringent environmental regulation. However, this is not a sufficient condition; instead a number of rather technical conditions must also be fulfilled. Overall it is interesting that this type of up/downstream model can lead to a Porter effect. Even if the model's assumptions in some cases may be adequate, it is still difficult to draw some more general policy conclusions. For example, it is assumed that the export company acts on a world market and is a price-taker. At the same time it is assumed that the upstream company that develops and supplies pollution abatement equipment is exposed to relatively little competition and does not operate on the world market. This may be a reasonable assumption at the very beginning of the regulatory process. However, it is difficult to argue for this assumption to hold true in a longer time perspective. Thus, there might be some type of "first-mover advantage", but this benefit is likely short-lived. If the competitor’s is also eventually regulated, or perhaps requires new equipment for some other reason, they can also benefit from this type of development because it ultimately leads to lower costs for them. Thus, the price of the good traded on the world market will fall and neutralize the "home country's" initial competitive advantage. Despite this criticism, one policy conclusion that can be drawn from the Greaker-study is that politicians should not be afraid to take steps toward needed environmental regulations because the costs might not be as large as they initially thought.

Finally, it is worth noting a study by Popp (2005), whose model is significantly different than those discussed above. Popp's model has no strategic connection or imperfections of the type discussed above; instead, it is built on the fundamental assumption that the result of an R&D project is uncertain. It is a simulation model where a company is exposed to an environmental regulation that requires lower emissions in period 1. The company can reduce the use of the "dirty" input or spend money on an R&D project. However, the company does not know *ex ante* with certainty which of the alternative projects will be profitable. The company chooses to invest only if the expected profit of an R&D alternative is higher than the profits in the next best alternative. The result of the simulation shows that *ex post* an R&D project can lead to a complete neutralization of the environmental regulation's cost. However, the results show that an incomplete neutralization is more common. Popp asserts that this uncertainty can explain why some studies, or case studies, have found complete neutralization of costs, but that even more studies have shown that the costs are not neutralized. Popp's analysis shows the clear problem with relying on case studies of the type provided in Porter and van der Linde. The policy conclusion he draws is that "While induced innovation can lower the cost of complying with environmental regulation, policymakers should not expect such innovations to completely eliminate these costs." (Popp, 2005, p. 10).

The theoretical review above shows that there is no consensus around the costs of environmental regulation. As noted, the effects of environmental regulations are strongly dependent upon the assumptions made. A relatively robust, or in this case relatively common, result is that there must be some form of market imperfection - above and beyond any environmental problem - that is met with some sort of "negative correction" in the form of a regulation designed to correct the environmental problem. In simple terms it seems that a Porter effect requires that (1) there must be two problems and (2) that they can be addressed with one measure; to use a crude analogy we must be able to "kill two birds with one stone." This gives rise to two fundamental questions: First, is whether or not this type of positive connection between two different external effects is common? Second, can a regulator know *ex ante* when such a situation is present? The general answer to the first question is that this type of connection rarely exists. The answer to the second question is that the regulator is presumably unaware of this information *ex ante*; instead the policy must be implemented in order to get the answer *ex post*. Even if this "extra" positive effect from the environmental regulation would arise - i.e., that an environmental regulation corrects for other market imperfections - several studies have shown this is not a sufficient condition. That is, even if environmental regulations allow for positive externalities associated with technological development, it is not certain that we obtain a "strong Porter effect" simply because the new technology is costly.

In conclusion we can only say that the theory trying to rationalize the Porter hypothesis can identify mechanisms that are central in the Porter discussion and how different assumptions affect these mechanisms. From this literature we can draw the robust conclusion that very specific circumstances are required in order to say that the costs of more stringent environmental regulations can be completely neutralized. Another conclusion is that any eventual cost neutralizing - even if it is not complete - is not unique to environmental regulations.

Even if theory can give us knowledge about the important mechanisms, we cannot really answer these questions until we join theory with reality, which we do in the next section.

3.2 Empirics

The purpose of this section is to give a summary overview of the empirical research related to the Porter hypothesis. The empirical studies we review are listed and briefly described in tables 3.1 through 3.3 in the Appendix.

There is an extensive empirical literature related to the connection between competitiveness and environmental regulations.[14] However, it should be pointed out that explicit tests of a "strong Porter effect" are rare. By "strong" we mean at least complete cost neutralization. Several of the studies test individual parts of the Porter hypothesis without actually making a clear distinction between the weak and strong forms. The aspect of the Porter hypothesis most subjected to empirical research is environmental regulation's effects on innovation and R&D, investment, and productivity. In the somewhat older literature one can find an extensive literature around regulation's effects on trade (see Jaffe et al., 1995).

Before we go further, we should be clear about the difficulties that arise when testing the Porter hypothesis. As we already mentioned several times, the Porter hypothesis does not state that competitiveness increases as a result of any or all regulation; instead Porter and van der Linde assert that environmental regulation must be well-designed. Most people - including the authors of this study - interpret "well-designed" to mean economic instruments in the form of taxes and transferrable permits. However this distinction is rarely made in the empirical literature. Instead, most studies completely remove any reference to the type of instrument underlying the regulation. Reasons for this may be the lack of data and/or the difficulty of defining and measuring the strength of an environmental regulation. Another reason is that environmental taxes and transferrable permits have a relatively short history and are not extensively used.

In an earlier review of the literature focusing on regulations' effects on trade, Jaffe et al. (1995) conclude that in general there does not exist any strong evidence that environmental regulations have especially large and/or negative consequences on a company's competitiveness, given that competitiveness is measured as changes in trade. The studies referred to by the authors have analyzed the effects on net exports, the decision of where to

[14] As already noted there are a number of research overviews of the Porter hypothesis (see e.g. Marklund, 1997; Mulatu, 2001; Wagner, 2003; Lundgren 2004; Ambec and Barla, 2006).

locate production, and the flow of trade. The overall conclusion is that the effects are either small or insignificant.[15]

Jaffe et al. (1995) make reference to, among others, Kalt (1988) as one of the first studies to examine the connection between regulations and competitiveness. Kalt (1988) used a relatively traditional econometric trade model where he added an independent variable that represented the costs incurred by regulated industries. A conclusion was that environmental regulations had a negative effect on the US's trade development in the period 1967 to 1977 when examining the manufacturing industry. Remarkably enough, this result was strengthen when the chemical industry was *excluded*. A more reasonable result might have been that the negative effects had weakened when the chemical industry was removed, since it is a sector with well-known environmental impacts. One interpretation could be that there is some form of Porter effect within the chemical industry. Another interpretation is that the chemical industry is extremely heterogeneous and even includes the pharmaceutical industry, which has reaped large benefits associated with trade.

Another older study of trading behavior was conducted by Low and Yeats (1992). They found that between 1965 and 1988 the percentage of pollution-intensive goods in world trade fell from 19 to 16 percent and that developing countries developed their comparative advantage in these products at a faster pace than industrialized countries. Jaffe et al. (1995) suggests that these results should be interpreted with some caution. It is possible that people in developing countries simply increased their demand for these types of products during the study period. Another explanation that was put forth and has wide empirical support is simply that trading behavior depends in part, or entirely, on natural resource supplies. This discussion and the possible explanations illustrates, to some extent, the difficulty of interpreting the results from these types of indirect models, particularly if the goal is to use the results to better understand the effect of environmental regulation on competitiveness.

Jaffe et al. (1995) also refer to other studies that focus on the flow of investment between countries. These studies are, however, of a more general character and do not look specifically at environmental regulations. Wheeler and Mody (1992), for example found no connection between foreign direct investment and taxes on companies. They assert that many other factors dominate over the effects of taxes. A possible conclusion is that environmental

[15] See also Marklund (1997).

regulations do not play a decisive role when companies make investment decisions. A more recent overview by Brunnermeir and Levinsson (2004) questions this conclusion. They draw the conclusion that environmental regulations have a clear impact on a company's site location such that polluting industries move to countries with lower environmental requirements.

Tables 3.1 through 3.3 in the Appendix summarize the empirical research that is directly related to the Porter hypothesis. The tables attempt to classify the studies in different groups based in part on the theoretical discussion in the previous section. The majority of empirical research exists within two areas: environmental regulation's effect on investment, innovation and R&D (Table 3.1) and environmental regulation's effects on efficiency and productivity improvements (Table 3.2). Once again it should be emphasized that the results from these tests cannot always be used to make a definitive statement about whether or not the Porter hypothesis applies. However, it is possible to say that the Porter hypothesis can be discredited in cases where one finds a negative connection between productivity improvement and environmental regulation. A third class of studies includes those analyses that specifically focus on the connection between some form of profit, or other result measurement, and regulation (Table 3.3). In principle, these types of studies can more directly test for the Porter hypothesis.

The summary of studies that analyze the effects of capital accumulation and investment - Table 3.1 - does not show any direct support for the Porter hypothesis. Nelson et al. (1993) even find that environmental regulations seem to have a negative effect on capital re-investment in the American electricity production sector, which stands in direct contradiction to the "modernizing effects" that were supported in many theoretical explanatory models (Xepapadeas and de Zeeuw, 1999). Gray and Shabegian (1998) find that environmental investments crowd out productive capital in the American pulp and paper industry. According to their study, a 1 percent increase in environmental investment results in a decrease of 1.88 percent in investment in productive capital. In summary, one can say that there is a lack of strong evidence to support the idea that environmental regulations can have some sort of positive effect - with respect to Porter - on capital formation and investment. But one should be careful about concluding that the Porter hypothesis does not hold because the actual environmental regulations discussed were not exactly of the character and type to which Porter referred.

Regarding the effects on R&D the most common type of study is one that examines an environmental regulation's effects on R&D expenditures and on the number of successful patent applications. Jaffe and Palmer (1997) study the effects of R&D expenditures in the American manufacturing industry and measure the strength of environmental regulation in terms of outlays on pollution abatement. They find that R&D expenditures increase if the outlay on abatement increases, but that the increase is relatively small. Interestingly enough, they find that the effects are larger for the petroleum and extraction industry. However, they found no significant correlation between environmental regulations (measured as abatement costs) and the number of successful patent applications. Brunneheimer and Cohen (2003) use a similar approach and find a weak but positive relationship between environmental regulations and successful patent applications in the American manufacturing industry. Focusing specifically on the abatement of sulphur dioxide (SO2), de Vries and Withagen (2005) study the number of successful patents by specifying three models where each relies on a different metric to measure environmental regulation. The results are ambiguous. In two of the specifications they find a negative correlation between patents and regulations, but for the third specification they find a positive correlation.

Environmental regulation's effects on productivity and efficiency have a relatively long history, resulting in a larger number of studies. A summary is provided in Table 3.2. One of the first studies, by Gollop and Roberts (1983), found that regulation of sulfur dioxide slowed productivity growth in the American electric utility sector by 43 percent in the 1970s. Similar results are found in Smith and Sims (1983), Gray (1987), and Barbera and McConell (1990). Later studies have, in part, confirmed these results (Gray and Shadbegian, 2003)

However, there are a few studies that show a somewhat different result. Berman and Bui (2001) find that refineries in Southern California - where environmental regulations are quite stringent - have had significantly higher productivity than refineries located in other parts of the US. Alpay et al. (2002) come to a similar conclusion for the Mexican foodstuff industry where productivity increased at the same time that environmental requirements increased. Similarly, Hamaoto (2006) finds some support for the idea that environmental regulations have had a positive effect on productivity improvements in the Japanese manufacturing industry, via positive effects from R&D. In another study van der Vlist et al. (2007) find that small and medium-sized companies that voluntarily signed on to an energy-efficiency program had better efficiency improvements than the companies that did not participate. The fact that the regulation in this latter case is in the form of a voluntary participation makes the interpretation of the results difficult, since the measured effect might be a selection effect rather than a Porter effect. It cannot be excluded that those companies that volunteered are companies that anyway would invest in energy-saving capital, or in some manner change their production process. To agree to volunteer for such a project may therefore only bring profits - not the least goodwill.

There are also several Scandinavian studies of a similar character. These studies can be divided into two categories where the first focuses on different aggregate industries and the second focuses on the micro level (i.e., where data exists on the facility or firm level). It is predominantly in the later group that the Porter hypothesis is explicitly studied. In the first group, Wibe (1986, 1990) focuses an analysis on Sweden, but also includes Finland and Denmark. In Wibe (1990) a productivity index is constructed for the Swedish manufacturing industry as a ratio between the industry's total value added and the total factor use. In the second step, the calculated index is used as a dependent variable in a regression analysis in which the dependent variables includes, among others, environmental and labor regulations. A problem encountered also in that study is how to quantify regulations adequately. In the study, the regulatory pressure is approximated by the number of employees in the relevant government authority. Note that the study comprises not only environmental regulations, but also labor regulations. The main results of the study are that (1) productivity growth during the period 1970-1980 was significantly lower than for the period 1963-1970 and (2) the regulation variable (index) did not show any significant correlation with productivity. In the same study, Wibe presents a similar analysis for Denmark and Finland. Due to limited access to data, the strength of environmental regulation is defined slightly differently in each country. As was the case in Sweden, the Danish results do not provide any evidence that regulations have a negative impact on productivity improvements. In fact, the results tend to indicate some positive effects. The explanation provided is that environmental regulations may have a "modernizing effect" of the type discussed in Xepapadeas and de Zeeuw (1999). However, in the Finnish analysis the effects were shown to be weakly negative, but significant, which would indicate that Finland, like Sweden, does not seem to have any modernizing effects.

Marklund (1997) calculates productivity growth in the Swedish manufacturing industry during the period 1974-1993. In general, productivity growth fell during this period. However, it is interesting to note that the sectors that are believed to create the largest environmental impacts - iron and steel, chemical, pulp and paper - had the most beneficial development in productivity. The study did not make any attempt to explicitly measure environmental regulations, which makes it hard to draw any concrete conclusions related to correlations between productivity and environmental regulation.

The other category of Scandinavian studies focused instead on the micro level but also differentiate themselves in terms of method and fundamental assumptions. Besides the use of firm-level data, these Scandinavian allow for possible Porter effects due to both technology development and neutralization of inefficiencies. These studies correspond to the illustration of the Porter hypothesis shown in Figure 2.1 which means that these studies allows that companies are off the production possibility frontier. The first Scandinavian studies with this approach - Hetemäki (1995) and Brännlund (1996) - analyzed the Finnish and Swedish pulp and paper industries, respectively. The studies assumed that companies are multi-output companies, producing both goods (pulp and paper) and bads (emissions). To represent the industry's technology these studies relied on the so-called "distance function", which is able to characterize the existing multi-output technology. One of the interesting attributes of the distance function, in contrast to the production function, is that it can model multiple-output production technologies without the need for specific price data. The benefits of this are obvious from an environmental viewpoint. In the case of production involving two products - a market-priced good such as paper and a nonmarket-priced bad such as pollution - reliance on the distance function seems to provide a superior model because it allows for the estimation of a "shadow price" of pollution. The "shadow price" simply measures the change in revenues due to the constraint associated with an emissions limit. A negative (positive) "shadow price" indicates increased (decreased) costs associated with a more stringent environmental policy. Another interesting attribute of this approach - which is in line with Porter - is that it precludes having to make the often restrictive assumption that companies *always* maximize profits or minimize costs. In other words, companies are allowed to be inefficient. The benefit of the latter is that one can, in principle, study the correlation between efficiency and environmental regulations.

The main result from the Hetemäki (1995) study is that the shadow price on the regulated emissions of biological oxygen-demanding agents (BOD)[16] from the Finnish pulp and paper industry is negative. That is, regulating the BODs from the Finnish forest-products industry

[16] Biological oxygen-demanding agents (BODs) suck oxygen out of the natural water environment, thus leading to impacts on marine life and fish spawning.

imposes a cost on firms. One explanation for this could be that the Finish forest-products industry chose to address the problem of BOD emissions by constructing a large external facility to abate the pollution which, despite the higher investment costs, did not affect the production process itself, nor the properties of the final product. Another finding from the Hetemäki study was that the companies that were subject to relatively stringent regulatory pressure tended to be relatively inefficient companies, while the more efficient companies were believed to be subject to relatively less stringent regulatory pressure.

A further development of the above-named study is found in Marklund (2003) where a similar approach was used to measure efficiency that considers both production and estimated emissions. In the second step, the analysis applies a regression analysis in order to estimate the effects of environmental regulations on the estimated efficiency measurement. The analysis, which was performed using data from the Swedish pulp and paper industry, did not provide any support for the hypothesis that environmental regulations stimulate efficiency improvements.

Table 3.3 accounts for a number of studies that have examined the correlation between environmental regulations and profits (or other type of financial impact). Brännlund et al. (1995) for example estimate the costs of regulations designed to reduce emissions of BODs and other pollutants from the Swedish pulp and paper industry. The costs were measured as the difference in profits between a regulatory scenario and a hypothetical unregulated scenario. The results show that for a large percentage of the companies (almost half) profits were not affected. For the industry as a whole, however, the regulation imposes a cost. The author's interpretation is not that a Porter effect is present, but rather that the current regulatory system is not cost-effective in the sense that some companies carry a relatively large burden of the industry's total cost reduction. The other studies do not provide any clear results. The exception is Filbeck and Gorman (2004) who show a negative correlation between environmental regulations and financial impact. King and Lenox (2001) can also be mentioned as they come to the opposite conclusion; however their positive correlation between regulation and financial impact was weak and insignificant.

Based on a review of the empirical literature the main conclusion is a lack of strong evidence for the existence of a Porter effect. However, it should also be noted that the literature does not provide strong evidence against the hypothesis either. The few studies that exist on the topic of environmental regulations and investment show that regulations affect both the investment and modernization of capital stock negatively. Yet, it is also true that evidence exists to indicate that environmental regulations affect innovation and R&D positively. But it should be repeated here again that any possible positive correlation between environmental regulations and innovation (for example measured as the number of successful patent applications) does not necessarily mean that a Porter effect exists. Even in the absence of a Porter effect one would expect that companies will try to avoid, and reduce the cost of, environmental regulations (i.e., avoid the cost of investing in new technology). Regarding the correlation between environmental regulation and productivity growth, several studies show either a negative or insignificant relationship. The studies that examine the correlation between environmental regulation and financial impacts do not in themselves provide any support for or against the Porter hypothesis.

In summary, we can say that the fundamental question of whether or not the Porter hypothesis is in fact applicable is still unanswered. What we can say based on a review of the theoretical and empirical literature is that a generally positive correlation between environmental regulations and competitiveness does not exist, but that this type of correlation can occur under specific circumstances. The fact that the question cannot be answered definitively based on the existing research is presumably the result of several different factors. The most important factor is perhaps that existing studies are unable to apply a formal hypothesis test to Porter's idea, at least in part because there is no general consensus about what should be tested. Other factors include the problems of measurements and definitions; namely, what we mean by the term "competitiveness" and how it can be measured and what we mean by the term "environmental regulation" and how it can be measured.

It is interesting to note that most studies do not clearly differentiate between regulatory measures or instruments, despite the fact that Porter is relatively clear that only specific types of regulations can actually neutralize the initial costs. Perhaps a more successful approach might be to try and separate regulations into different groups or categories and then analyze the differences in effects.

The overall policy conclusion that can be made from the theoretical and empirical review is that it's not possible to show a general Porter effect, i.e., that more stringent environmental regulation will lead to a general improvement in competitiveness. It does not mean, however, that under some special circumstances we will never find cases where a company experiences improved competitiveness following implementation of an environmental policy; in fact, the so-called "*ex post* studies" demonstrate the possibility for these improvements (Porter and van der Linde, 1995). But this does not mean that we can design environmental policy based on these specific cases that are observed *ex post* because (1) we cannot identify these cases *ex ante* and (2) because these cases may arise for reasons other than environmental regulation. Instead, environmental policy must take as a starting point the environmental problem itself, as well as the expected costs (*ex ante*) associated with a company's adaptation and/or investment. If instead the estimates of these costs are based on unique cases under special circumstances, it can lead to a credibility problem for environmental policy which, in turn, can have dire consequences for the implementation of important environmental policy measures in the future.

3.2.1 The Swedish case: some recent evidence

Sweden has to a large extent been forerunner in environmental policy, especially in introducing policy instruments that seems to fulfill the criteria necessary for a Porter effect, according to Porter. Here we will present and discuss some empirical results for Sweden from two recent studies performed on both long-run, historical aggregate data, and firm level data (Brännlund, 2008, and Brännlund and Lundgren, 2008). The first study focuses on productivity measures and environmental regulatory pressure in general, while the second study focus on especially the CO2 tax which came into effect in 1991 and its effects on firm-level profitability.

Brännlund (2008) is to evaluate the potential effects on productivity development in the Swedish manufacturing industry due to changes in environmental regulations over a long time period, 1913 to 1999. A two stage model is used were the total factor productivity is calculated in the first stage over the whole period, which is then used in a second stage as the dependent variable in a regression analysis where one of the independent variables is a measure of environmental regulatory intensity.

The results show that the productivity growth has varied considerably over time. The least productive period was the Second World War period, whereas the period with the highest productivity growth was the period after the Second World War until 1970. Development of emissions, in this case carbon and sulphur, follows essentially the same path as productivity growth until 1970. After 1970, however, there is a decoupling in the sense that emissions are decreasing, both in absolute level and as emissions per unit of value added.

Concerning the relationship between regulations and productivity growth, a rather robust conclusion is that there is no clear relationship, given the regulatory measure used. One explanation is that the effect actually does not exist, or that it is too small to be measured compared to other factors affecting productivity growth. Another potential explanation is that the measure used does not capture actual regulations in a correct way. A tentative conclusion, though, is that the part of the Porter hypothesis that asserts that the right kind of regulations enhances productivity can be rejected.

The objective of Brännlund and Lundgren (2008) is to evaluate the potential effects on Swedish manufacturing industry in terms of input demand, output and profits of the Swedish CO_2 tax regime that started 1991. More specifically the objective is to test the Porter hypothesis, i.e. whether environmental regulations (the right kind), that usually is associated with costs, triggers mechanisms that enhances efficiency and productivity that finally may outweigh the initial cost increase. To test the hypothesis an econometric partial equilibrium model[17] is developed for the Swedish industrial sector which relies on firm-level data from 1990 to 2004. The model deviates from the standard setting by allowing for a kind of a firm level, environmental policy induced technological progress, in the sense that the changes in the CO_2 tax is allowed to affect productivity through changes in technological progress.[18] Thus, given this particular set up the model, apart from providing standard static estimates of supply and demand elasticities, allows us to test for a more potential dynamic effect due to the tax effect on productivity.

The basic structure of the model is based on standard microeconomic foundations, assuming that each firm (i) maximizes profits, (ii) operates in a competitive environment, and (iii) has a technology that transforms inputs to a single good output, but also produces a bad output in an efficient way. Assumption (i) implies, among other things, that given an output decision, each firm will choose a bundle of inputs that minimizes costs. Assumption (ii) implies that all input and output prices are exogenous to the firm. Assumption (iii) implies that we can describe the

---

[17] They use a slightly modified version of the econometric model in Brännlund and Lundgren (2007).

[18] The seminal reference on endogenous technological change is Romer (1990). For general discussions and reviews on environmental policy and endogenous technical change from a national level perspective see, e.g., Goulder and Schneider (1999), Jaffe et al. (2002), Gillingham et al (2007), or Peretto (2008).

technology with a production function. Apart from this standard set-up we add a technological progress component that may shift the profit function. The novelty in this study is that the technological progress component is a function of the actual payment of carbon dioxide tax for each firm.

Thus, the effect on profit due to an increase in the CO2 tax has two potential effects; a direct cost effect, through a price increase in fossil fuels, and an indirect effect due to a change in technological progress, via transformational pressure due to the tax. For a Porter effect to exist the indirect effect must be higher than the direct cost effect.

The results show that the direct tax effect, via the price, is negative for all sectors, as expected since it corresponds to a direct increase in costs. The tax effect via technical change is significantly negative for most of the sectors. An exception is the rubber and plastic industry in which the effect is significantly positive. Furthermore, for the mining (non-iron) industry it seems as if the tax has no effects on profit via technical change. Looking at broader aggregates, the energy intensive and the non-energy intensive industries, reveal that the tax effect via technical change is positive, although not significant different from zero, for the non energy intensive industry, whereas it is significantly negative for the energy-intensive industry. Thus it can be concluded that the necessary condition for a positive porter effect is fulfilled only for the rubber and plastic industry. For all other sectors, and the industry as a whole, we find no evidence that the CO_2 tax has lowered the cost via productivity improvements. One explanation to this may be that different sectors in the industry are subject to different kind of exemptions from the tax. The CO_2 tax fluctuates more over time for the non-energy intensive industry. More importantly, the right tail of the price distribution has become larger over time for the non-energy intensive industry, compared to the energy intensive industry. That is, more firms that belong to the non-energy industry have been faced with a higher CO2 price over time, compared to firms in the energy intensive sector. This may have led to a more significant cost pressure on firms that are not subject to exemptions. In summary, it may be the case that energy intensive industry has been more or less unaffected of increases in the nominal CO2 tax, whereas non energy intensive industries have not.

It should also be stressed that the results presented do not imply that there is no positive productivity development in the manufacturing industry due to an increase in the CO_2 tax. Rather they imply that the productivity development that occurs is independent or slowed down through the indirect tax effect. Thus a negative tax effect may be interpreted as a crowding out effect; i.e., a higher tax, which may or may not lead to an improvement in energy efficiency, is crowding out other potential productivity improvements.

6. Conclusions and directions for future research

Here we will provide a summary of our findings, and provide some modest guidance for future research.

The main purpose of this paper has been to highlight, review and analyze the so-called Porter hypothesis, i.e., the idea that more stringent environmental regulations give rise to benefits (other than environmental improvement or environmental protection) that not only reduce the initial cost of the environmental policy, but can off-set the cost or even lead to the realization of "extra profits." More specifically, the purpose has been to give a systematic review of the so-called Porter hypothesis. We can also say that the purpose was to relate the Porter hypothesis - or more specifically the "well-designed" requirement placed upon environmental policy by Porter - to the more conventional or neoclassical view on choice of instrument within environmental policy.

When considering the universe of instruments available to policy makers, economic instruments in the form of taxes and transferrable permits are generally believed to have an advantage, relative to other types of instruments, with regard to cost-effectiveness. That is, these types of measures provide policy-makers with the best approach to reach a given environmental goal at the lowest cost. Economic instruments give clear incentives for cost-saving and stimulate technological innovation, thus ensuring dynamic efficiency in the long run. In other words, if one selects the right type of instrument then some of the costs - i.e., those that might arise from choosing the "wrong" instrument - may be partly neutralized.

Based on the literature review conducted in this study we can draw three robust conclusions. The first is that very special assumptions are required to affirm the validity of the Porter hypothesis, including how companies and markets function and how they are organized. The second conclusion is that the Porter hypothesis requires not only the presence of an environmental problem but also some additional market imperfection that can be neutralized or alleviated through the environmental regulation. In simple terms, we must have two problems that can be addressed with one measure or, to use a crude analogy, we must be able to "kill two birds with one stone." The literature review also pointed to the mechanisms that are paramount in a Porter discussion and how different assumptions affect these mechanisms. If policy-makers select the right type of instrument, companies will search for the cheapest solution to the problem. In some special circumstances it may lead to a case where companies have lower costs then before the instrument was implemented, but in the majority of cases this will imply a cost. The third conclusion is that the Porter effect should not be considered in any *ex ante* calculation of costs arising from proposed environmental policy.

When looking specifically at the Swedish case, empirical results suggests that value added increased by a factor 12 since 1913, while the emissions of sulphur and carbon dioxide had a similar development up to the 70s, when there was a clear break in the trend. The level of emissions of sulphur and carbon dioxide are today at the same level as in 1913, even though the industry now contributes 12 times the value added to GDP. In other words, environmental efficiency has increased steadily during the past century. The analysis, however, show no significant relationship between environmental regulations and productivity, neither it seem to be any contradiction between high growth and improved environment. The results from studying the Swedish industry on firm level and the effect of a CO_2 tax (imposed 1991) between the years 1990 and 2004 also fails to support the Porter hypothesis, with the exception of the Rubber and Plastic sector. A higher CO_2 tax does lead to higher energy efficiency, but other negative productivity effects dominate. The overall negative “tax effect” could be interpreted as a crowding out effect.

Cost-free environmental policy? The answer to this question, which was asked in the title of this review, cannot be anything other than “probably not”. The possibility of "extra profits" that neutralize or even exceed the initial cost of regulation should not be expected. This is the "take-home" message of this review. It does not mean that we cannot find a firm that "wins" from regulation, but it does mean that such a situation would be the exception rather than the rule. Nor does it mean that we should avoid stringent environmental policies or leave weak policies in place. To the contrary, policy-makers should focus their energy on setting relevant environmental goals and selecting the most effective instruments and, most importantly, weighing the expected costs against the expected environmental profits of individual regulations. This conclusion is not particularly controversial, especially when we view a "clean environment" as a good that is "produced" and thus demands resources. The resources demanded for our "environmental good" could, of course, have been used to produce another type of good demanded by society, and this is the cost of obtaining a clean environment. Thus, this conclusion is based on the principle that, considering the economy as a whole over the long-term, there are no free resources lacking an alternative use.

The discussion above opens up for several options concerning future research. Perhaps the most interesting, and urgent research direction is to model the technological progress as part of an adjustment process taking dynamics, environmental policy, and environmental performance, explicitly into account.

Two research areas that seem to be increasingly relevant to the Porter hypothesis, and could motivate future theoretical and empirical research efforts, are bounded rationality and behavioral economics.[19]

In behavioral economics the basic point is that in an increasingly large number of cases it has become clear that people, or in the case of the Porter hypothesis the managers of the firms, do not move from the status quo even when it is in their best interest to do so (see e.g. Shogren et al., 2008, Samuelson and Zeckhauser, 1988, or Kahneman et al., 1991). Hence, in these circumstances, regulations that force the changes could actually lead to enhanced efficiency and increased competitiveness. In the context of Porter's argumentation, there is a need to investigate and study this further in future research.

In some energy efficiency studies it is shown that bounded rationality (see e.g. Simon, 1982, or Khaneman, 2003) seems to characterize decision-making in some cases. Simon (1982) suggests that economic agents employ the use of heuristics to make decisions rather than a strict rigid rule of optimization. They do this because of the complexity of the situation, and their inability to process and compute the expected utility of every alternative action. Deliberation costs might be high and there are often other economic activities where similar decision making is required. For example, Stern and Aronson (1984) noted that routines are rather commonly substituted for rigorous decision-making. These routines, such as replacing a depreciated piece of equipment with the same brand and type, may economize on the time and effort spent searching for the best product or strategy, but they can lead (and have led) to substantial biases against energy efficiency when technologies are rapidly changing.

[19] We thank Editor T. Tietenberg for pointing us to these two relevant areas for future research.

References

Alpay, E., Buccola, S. and Kerkvliet, J. (2002). Productivity Growth and Environmental Regulation in Mexican and U.S. Food Manufacturing. *American Journal of Agricultural* $_2$*Economics*, 84(4), 887-901.

Ambec S. and Barla, P. (2006), Can Environmental Regulations be Good for Business? An Assessment of the Porter Hypothesis. *Energy studies review*, 14, 42-63.

Barbera, A.J. and McConnell, V. D. (1990). The Impact of Environmental Regulations on Industry Productivity: Direct and Indirect Effects. *Journal of Environmental Economics and Management*, 18, 50-65.

Berman, E. and Bui, L.T.M. (2001). Environmental regulation and productivity: evidence from oil refineries. *The Review of Economics and Statistics*, 83(3): 498-510.

Boyd, G A och J D McClelland (1999). The Impact of Environmental Constraints on Productivity Improvement in Integrated Paper Plants. *Journal of Environmental Economics and Management*, 38, 121-42.

Brännlund, R. (2008). Productivity and environmental regulations - A long run analysis of the Swedish industry. Umeå Economic Studies, no. 728.

Brännlund, R. (1996). Estimating Shadow Prices of Undesirables. Mimeo, department of economics, Umeå University.

Brännlund, R. and Liljas, B. (1993). The Effects of Emission Standards: The Case of the Swedish Pulp and Paper Industry. Umeå Economic Studies, no. 320.

Brännlund, R. and Lundgren, T. (2008). Environmental policy and profitability - Evidence from Swedish industry. Umeå Economic Studies, no. 750.

Brännlund, R., Färe, R. and Grosskopf, S. (1995). Environmental Regulation and Profitability: An Application to Swedish Pulp and Paper Mills. *Environmental and Resource Economics*, 6, 23-36.

Brännlund, R. and Lundgren, T. (2007). Swedish industry and Kyoto - An assessment of the effects of the European CO2 emission trading system. *Energy Policy* 35(9), 4749-4762.

Brunnermeier, S.B. and Cohen, M.A. (2003). Determinants of environmental innovation in US manufacturing industries. *Journal of Environmental Economics and Management*, 45, 278-293.

Brunnermeier, S.B. and Levinson, A. (2004). Examining the Evidence on Environmental Regulations and Industry Location. *Journal of Environment & Development*, 13, 6-41.

Dasgupta S. and Laplante, B. (2001). Pollution and Capital Markets in Developing Countries. *Journal of Environmental Economics and Management*, 42, 310-345.

Dufour, C., Lanoie, P. and Patry, M. (1998). Regulation and Productivity, *Journal of Productivity Analysis*, 9, 233-247.

Feichtinger, G., Hartl, R.F., Kort, P.M., and Veliov, V.M. (2005). Environmental policy, the porter hypothesis and the composition of capital: Effects of learning and technological progress. *Journal of Environmental Economics and Management*, 50, 434-446.

Filbeck, G. and Gorman, R.F. (2004). The relationship between the Environmental and Financial Performance of Public Utilities. *Environmental and Resource Economics*, 29, 137-157.

Gabel, L. H. and Sinclair-Desgagné, B. (1998). The firm its routines, and the environment. In Folmer, H. and Tietenberg, T. (eds.), *The International Yearbook of Environmental and Resource Economics 1998/1999*. Edward Elgar publishing company.

Gabel, L. H. and Sinclair-Desgagné, B. (2001). The firm its procedures and win-win environmental regulations. In Folmer, H., Gabel, L. H., Gerkin, S., and Rose, A. (eds.), *Frontiers of Environmental Economics*. Edward Elgar publishing company.

Gillingham K., R. G. Newell, W. A. Pizer (2007). Modeling Endogenous Technological Change for Climate Policy Analysis, *Energy Economics* 30(6), 2734-2753.

Gollop, F.M. and Roberts, M.J. (1983). Environmental Regulations and Productivity Growth: The Case of Fossil-fuelled Electric Power Generation. *Journal of Political Economy*, 91, 654-674.

Goulder L. H., S. H. Schneider (1999). Induced Technological Change and the Attractiveness of CO2 Abatement Policies, *Resource and Energy Economics* 21, 211-253.

Gray, W.B. (1987). The Cost of Regulation: OSHA, EPA and the Productivity Slowdown. *The American Economic Review*, 77, 998-1006.

Gray, W.B. and Shadbegian, R.J. (1998). Environmental regulation investment timing, and technology choice. *The Journal of Industrial Economics,* XLVI, 235-256.

Gray, W.B. and Shadbegian, R.J. (2003). Plant vintage, technology, and environmental regulation. *Journal of Environmental Economics and Management*, 46, 384-402.

Greaker, M. (2006). Spillovers in the development of new pollution abatement technology: A new look at the Porter-hypothesis. *Journal of Environmental Economics and Management*, 52, 1411-420.

Gupta, S. and Goldar, B. (2005). Do stock markets penalize environment-unfriendly behaviour? Evidence from India. *Ecological Economics*, 52, 81-95.

Hamamoto, M. (2006). Environmental Regulation and the Productivity of Japanese Manufacturing Industries. Resource and Energy Economics, 28, 299-312.

Hetemäki. L. (1995). Environmental Regulation and Production Efficiency: Evidence from the Pulp Industry. Mimeo, Finnish Forest Research Institute, Helsinki.

Jaffe, A.B. and Palmer, K. (1997). Environmental Regulation and Innovation: A Panel Data Study. *The Review of Economics and Statistics*, 79, 610-619.

Jaffe A.B., Peterson, S.R., Portney, P.R and Stavins, R.N. (1995). Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us? *Journal of Economic Literature*, XXXIII, 132-163.

Jaffe A. B., R. G. Newell, R. N. Stavins (2002). Environmental Policy and Technological Change, *Environmental and Resource Economics* 22, 41-69.

Jaffe, A., Newell, T. and Stavins, R.N. (2005). A tale of two market failures: Technology and environmental policy. *Ecological Economics*, 54, 164-174.

Jung, C., Krutilla, K. and Boyd, R. (1996). Incentives for Advanced Pollution Abatement Technology at the Industry Level: An Evaluation of Policy Alternatives. *Journal of Environmental Economics and Management*, 30, 95-111.

Kahneman, D. (2003). Maps of bounded rationality: psychology for behavioral economics. *American Economic Review*, 93(5), 1449-1475

Kahneman, D., Knetsch, J. L., Thaler, R. H. (1991). Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias. *Journal of Economic Perspectives*, 5(1), 193-206.

Kalt, J.P. (1988). The Impact of Domestic Environmental Regulatory Policies on U.S. International Competitiveness. In *International Competitiveness*. Eds.: Spence A.M. & Hazard H.A. Cambridge, MA: Harper & Row, Ballinger, 221-262

Khanna, M., Quimio, W.R.H. and Bojilova, D. (1998). Toxics Release Information: A Policy Tool for Environmental Protection. *Journal of Environmental Economics and Management*, 36, 243-266.

King, A.A. and Lenox, M.J. (2001). Does It Really Pay to Be Green? *Journal of Industrial Ecology,* 5, 105-116.

Low, P. and Yeats, A. (1992). Do 'dirty' industries migrate?, in P. Low (ed.), *International Trade and the Environment*, Washington DC, World Bank.

Lundgren, T (2004). Vad kostar en offensiv Klimatpolitik? (What does an aggressive climate policy cost?) *Ekonomisk Debatt*, 6, 19-31.

Marklund, P-O. (1997). *Miljöpolitiska styrmedel och konkurrenskraft, en litteraturgenomgång (Environmental policy instrument and competitiveness - a literature review)*. Underlagsrapport nr 11 till Skatteväxlingskommitténs slutbetänkande, Skatter, Miljö och Sysselsättning, SOU 1997:11.

Marklund, P-O. (2003). Environmental Regulation and Firm Efficiency: Studying the Porter Hypothesis using a Directional Output Distance Function. Umeå Economic Studies, no 619.

Michanek och Söderholm (2006). *Medvind i Uppförsbacke. En studie av den Svenska vindkraftspolitiken (Tailwind in an uphill. A study of the Swedish wind power policy)*. Rapport till Expertgruppen för miljöstudier, 2006:1, Finansdepartementet.

Mohr R. D. (2002). Technical Change, External Economies, and the Porter Hypothesis. *Journal of Environmental Economics and Management*, 43, 158-168.

Mulatu, A., Florax, R.G.J.M and Withagen, C.A.A.M. (2001). Environmental Regulation and Competitiveness. TI 2001-039/3, Tinbergen Institute Discussion Paper.

Nelson R.A., Tietenberg, T. and Donihue, M.R. (1993). Differential Environmental Regulation: Effects on electric utility capital turnover and emissions. *The Review of Economics and Statistics*, 75, 368-373.

Palmer, K., Oates, W.E. and Portney, P.R. (1995). Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm? *Journal of Economic Perspectives*, 9, 119-132.

Peretto P., (2008). Energy Taxes and Endogenous Technological Change, *Journal of EnvironmentalEconomics and Management*, forthcoming (accepted July 23, 2008).

Popp, D. (2005).Uncertain R&D and the Porter Hypothesis. *Contributions to Economic Analysis & Policy*, 4, article 6.

Porter, M.E. (1990). *The Competitive Advantage of Nations*. The Free Press, New York.

Porter, M.E. (1991). America's Green Strategy. *Scientific American*,. April, p 168.

Porter, M.E., C. van der Linde (1995). Toward a new conception of the environment competitiveness relationship. *Journal of Economic Perspectives* 9(4), 97–118.

Roediger-Schluga, T. (2004). *The Porter Hypothesis and the Economic Consequences of Environmental Regulation. A Neo-Schumpeterian Approach*. Edward Elgar, Cheltenham UK.

Romer P. (1990). Endogenous Technological Change, *Journal of Political Economy* 98, 71-102.

Samuelson, William and Richard Zeckhauser. (1988). Status Quo Bias in Decision Making. *Journal of Risk and Uncertainty* (1): 7-59.

Schumpeter, J. (1936). *The Change of Economic Development*. Harvard University Press, Camridge, Ma.

Shogren, Jason F. and Laura O. Taylor. (2008). On Behavioral-Environmental Economics. *Review of Environmental Economics and Policy*, 2(1): 2644.

Simon, Herbert A. (1982). Models of Bounded Rationality, Vols. 1 and 2. (MIT Press).

Simpson D. and Bradford, R. L. (1996). Taxing Variable Cost: Environmental Regulation as Industrial Policy. *Journal of Environmental Economics and Management*, 30, 282-300.

Smith J.B. and Sims, W.A. (1985). The Impact of Pollution Charges on Productivity Growth in Canadian Brewing. *The Rand Journal of Economics*, 16, 410-423.

Stern, P. C., E. Aronson (1984). *Energy use: the human dimension* .New York, W. H. Freeman.

Xepapadeas, A. and de Zeeuw, A. (1999). Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital. *Journal of Environmental Economics and Management*, 37, 165-182.

Wagner, M. (2003). The Porter Hypothesis Revisited: A Literature Review of Theoretical Models and Empirical Tests. Center for Sustainable Management, Lüneburg.

Wheeler, D., A. Mody (1992). International investment location decisions: the case of US firms, *Journal of International Economics* 33, 57–76.

Wibe, S. (1986). Regleringar och teknisk utveckling (Regulation and technological development). Ministry of Finance, Ds Fi. 1986:15.

Wibe, S. (1990). Regleringsteori (Regulatory Theory). Working Report, Department of Forest Economics, Swedish University of Agricultural Sciences, Umeå, Sweden.

Van der Vlist, A.J., Withagen, C. and Folmer, H. (2007) Technical efficiency under alternative environmental regulatory regimes: The case of Dutch horticulture. *Ecological Economics*, Vol 63, No. 1, p. 165-173.

de Vries, F.P and Withagen, C. (2005). Innovation and Environmental Stringency: The case of Sulfur Dioxide Abatement. Discussion paper No. 2005–18, CentER, Tilburg Univeristy.

Appendix

Table 3.1 Empirical studies of the effect of regulations on innovation (R&D) and investment

Study	Purpose and Method	Data	Results
Nelson et al. (1993)	A simultaneous three-equation model where the variables (a) age of capital stock, (b) emissions and (c) costs of regulation depend upon each other Two measures of environmental regulations: (1) costs of abatement for air emissions and (2) total abatement costs	44 electric utilities in the US, 1969-1983	Environmental regulations increase the age of capital stock The age of capital stock has no significant effect on emissions Regulations have an effect on emission levels
Jaffe and Palmer (1997)	Innovation and technology development is approximated with the level of R&D investment and the number of approved patent applications Environmental regulations approximated by the cost of pollution abatement	Panel data for the American manufacturing industry, 1973-1991 Model of reduced form with industry-specific effects.	A significant positive correlation between R&D and environmental regulations (cost of abatement) No significant correlation between environmental regulation and patent applications.
Gray and Shadbegian (1998)	Modeled the choice of technology (multinomial logit) and investments in American pulp and paper industry Environmental regulations approximated by (a) % of state congressmen that voted for environmental regulation and (b) strength of air and water regulation index	Panel data for 116 American paper companies, 1972-1990.	Choice of technology affects environmental regulations Negative effect of environmental regulation on investments Productive investment is reduced considerably following investment in pollution abatement equipment (crowding out)
Brunnermeier and Cohen (2003)	Innovation approximated by the number of approved environmentally-related patent applications Environmental regulation approximated by the cost of abatement and the number of environmental inspectors	Panel data of 146 American manufacturing industries, 1983-1992 Model of reduced form with industry-specific effects	Small positive effect of abatement costs on the number of approved patents Increased enforcement of activities related to existing regulations have no positive effects on innovation Innovation is more likely

			in industries that are highly competitive on international markets
De Vries and Withagen (2005)	Innovation approximated by the number of approved patent applications related to abatement of sulfur dioxide Environmental regulations approximated in three different ways: (a) international agreements with respect to sulphur emissions, (b) an index of regulatory strength and (c) as a latent variable.	Country data for Europe and North American (US and Canada), 1970-2000	Two of the models show a negative correlation between patent applications and regulations, while the third shows a positive correlation.

Table 3.2 Empirical studies of the effect of regulations on efficiency and productivity improvements

Study	Purpose and method	Data	Results
Gollop and Robert (1983)	productivity measurement derived from cost function Econometric model of the cost function which includes environmental regulations Environmental regulations estimated based on actual regulation of SO_2 and how stringent these emissions are relative the company's unregulated emissions of SO_2	56 American power stations (mostly coal-fired), 1973-1979	Environmental regulations have a strong negative impact on productivity improvement resulting in a 43% decline in productivity growth.
Smith and Sims (1983)	Productivity measurement derived from the cost function Econometric model of the cost function which includes environmental regulations Two facilities (brewery) subject to an emissions fee, while two other facilities not subject to the	Four Canadian breweries, 1971-1980	The average productivity growth was 0.08% in the regulated entities and +1.6% in the unregulated entities

	fee		
Gray (1987)	Total factor productivity as the dependent variable in a regression with, among others, abatement cost as an independent variable	450 American manufacturing facilities, 1958-1978	30% reduction in productivity growth following implementation of environmental regulations
Barbera and McConnell (1990)	Derivation of direct effects (abatement costs) and indirect effects (via other inputs and production) on productivity as a result of environmental regulations, based on the cost function	Five American emission-intensive industry sectors (paper, chemical, agriculture, stone and glass, iron and steel, and metal industry), 1960-1980	Decline in productivity in every sector following more stringent abatement requirements (10-50%). Indirect effects also contributed to decline, except in non-iron ore mines
Wibe (1990)	Analysis of the effects on productivity of labor regulations in the Swedish manufacturing industry Non-parametric Törnqvist-index Environmental regulations measured by the number of employees at the environmental agencies	Sector-specific data for the Swedish industry 1963-1980	No significant correlation between productivity and regulations
Hetemäki (1995)	Estimate of shadow price of emissions from the Finnish pulp and paper industry Parametric distance function approach	Facility data for the Finnish pulp and paper industry	Emission reductions constitute a cost for companies
Brännlund (1996)	Estimate of the shadow price of emissions from the Swedish pulp and paper industry Parametric distance function approach	Facility data for the Swedish pulp and paper industry	Negative shadow price on emission of BOD agents in waterbodies Emissions reductions of BOD agents is associated with costs
Marklund (1997)	Estimated productivity improvement in Swedish industry	Branch data for Swedish industry, 1974-1993	In general productivity fell during this period Industries with significant environmental impacts showed greater productivity improvements

Dufour et al (1998)	Total factor productivity as the dependent variable in a regression with, among others, percentage of costs for abatement capital as an independent variable	19 Canadian manufacturing industries, 1985-1988	Significant negative effect of environmental regulations on productivity growth
Boyd and McClelland (1999)	Estimate and analysis of total factor productivity in the American pulp and paper industry Distance function approach that allows for the estimate of inefficiency in both resource use and production, including "production" of emissions	Facility-specific data for American integrated pulp and paper factories, 1988-1992	Emission and resource consumption can be reduced by 2 to 8% without impacting productivity. Environmental regulations reduce production by 9%, of which 25% is the result of requirements for pollution abatement equipment
Berman and Bui (2001)	Comparison of productivity improvement in refineries in Southern California (stringent regulations) and rest of the country (less stringent)	American refineries, 1987-1995	Companies in Southern California exhibited more productivity growth and higher abatement costs. Interpreted as a positive correlation between regulations and productivity
Alpay, Buccola and Kerkvliet (2002)	Productivity growth in the Mexican and American foodstuff industry. An econometric model based on the profit function that includes abatement costs (US) or frequency of environmental inspection (Mexico)	Mexican and American foodstuff industry, 1962-1994	In the US negligible effects of environmental regulation in the US both on profits and productivity In Mexico negative effects of environmental regulation (inspection) on profits, but positive effects on productivity growth
Gray and Shadbegian (2003)	Total factor productivity in the American paper industry as a function of, among others, abatement costs Econometric estimate of production function that includes cost of abatement capital	American paper industry, 1979-1990	Strong significant negative effect of environmental regulation on productivity
Marklund (2003)	Analysis of the effect of environmental regulations on efficiency in the Swedish pulp and paper industry Environmental regulations measured as the actual regulation of	Facility-specific data for Swedish paper industry 1983-1990	No significant correlation between strength of regulation and efficiency

	emissions of BOD agents to waterbodies		
Hamamoto (2006)	Analysis of regulation's effects on efficiency, R&D expenditure, and the age of capital in Japanese industry Environmental regulation measured as abatement expenditures	Sector-specific data for parts of the Japanese manufacturing industry, 1971-1988	Positive correlation between abatement expenditures and R&D expenditures Negative correlation between abatement expenditures and the average age of capital Positive correlation between abatement expenditures and productivity via expenditures on R&D
Van der Vlist et al (2007)	Analysis of efficiency in Holland's horticulture industry Examines the difference in productivity growth between companies that are, and are not, regulated Stochastic frontier production function where companies are allowed to be inefficient (i.e., not on the production frontier)	Panel data for Holland's horticulture industry Medium and small companies, 1991-1999	Voluntary agreement to reduce environmental impacts is (on average) positively correlated with increased technological efficiency Correlation between technological efficiency and voluntary agreements depends upon the type of company (type of ownership, experience, size, etc).

Table 3.3 Empirical studies of the effect of regulations on profits and/or other financial impacts

Study	**Purpose and method**	**Data**	**Results**
Brännlund and Liljas (1993)	Analysis of the effect of environmental regulations on the Swedish pulp and paper industry Strength of environmental regulation derived from actual environmental regulations Profit function with environmental regulations treated as a separate argument	Facility-specific data for Swedish pulp and paper industry, 1986-1990	Some evidence that more stringent regulations have negative effects on company profits However, no clear answer because not all tests show a significant effect
Brännlund et al. (1995)	Regulation's effects on profits in the Swedish	41 Swedish pulp and paper companies, 1989-	Regulations reduce profits on average by 4 to 17%.

	forest industry Nonparametric method that estimates profits under different regulations	1990	Two-thirds of companies are believed to be unaffected, i.e., neither negatively nor positively
Khanna et al. (1998)	Analysis of share performance following the public release of information about a company's emissions of dangerous substances Regression model with panel data designed to identify abnormal stock returns	91 American chemical companies, 1989-1994	Abnormally low share return the day after information is made public Abnormally poor share return is more common for companies that fail to reduce emissions
Dasgupta and Laplante (2001)	Analysis of profit growth following special events such as (a) investment in new pollution abatement equipment and (b) negative environmental news (e.g., complaints, emissions, etc)	126 events that affected 48 companies in Argentina, Chile, The Philippines, and Mexico	20 of 39 positive events lead to positive profits (greater than normal profits) 33 of 85 negative events led to abnormally low profits
King and Lenox (2001)	Analysis of Tobin's Q, where Q value is explained by, among others, a company's environmental impact and environmental regulations Tobin's Q measured as a company's market value divided by the value of its assets Strength of environmental regulation approximated by (1) the number of emission permits required and (2) the average emissions within industry and individual US states, respectively	Panel data for 652 American manufacturing companies, 1987-1996	Positive effect of environmental regulations on financial results, but only significant in one model specification Positive correlation between financial results and environmental impacts
Filbeck and Gorman (2004)	Effects of environmental regulations on financial results	24 American electric power plants, 1996-1998	Negative correlation between profits and environmental regulations
Gupta and Goldar (2005)	Analysis of profit growth following public release of environmental ranking Environmental ranking based on the "best possible technology"	17 Indian pulp and paper industry companies, 15 Indian car companies, and 18 Indian chemical companies, 1999-2001	Negative correlation between profits and environmental ranking