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Abstract

Environmental protection and firms' competitiveness are typically seen as conflicting elements as firms tend to ignore the environmental consequences of their actions and any regulation forcing them to modify their policies can only make them worse-off. Contrarily to this traditional paradigm, the Porter Hypothesis suggests the existence of "low hanging fruits" in the sense that some environmental policies may simultaneously benefit the environment and domestic competitiveness. Our aim is to identify the main theoretical arguments that have been proposed in the literature to support the validity of the Porter Hypothesis and pick the most significant contributions paying special attention to the strategic and international trade aspects. After presenting some general issues and different interpretations of the Porter Hypothesis, we review different theoretical explanations such as the generation of scarcity rents, the use of environmental regulation by national governments as an instrument of strategic trade policy, the existence of externalities in technology adoption, the interaction with output quality competition and the existence of information incompleteness.

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1 Introduction

This paper presents a review of the theoretical contributions linked to the so-called Porter Hypothesis, placing special emphasis on the strategic and international trade aspects. This controversial hypothesis has challenged some of the common beliefs in the neoclassical paradigm by suggesting the existence of "low hanging fruits" in the sense that some environmental policies may simultaneously benefit the environment and domestic competitiveness. Although this idea had already been suggested by Porter in his book "The Competitive Advantage of Nations" (Porter 1990) and a brief article (Porter 1991), the Porter Hypothesis was more clearly stated, explained and documented with real-life case studies in a joint article by Michael Porter and Claas van der Linde published in the Journal of Economic Perspectives in 1995.

Traditionally, environmental protection and firms' competitiveness have been seen by economists as conflicting elements in the sense that, when firms pursue their corporate objectives, they do not care about the environmental consequences of their actions. Thus, any regulation forcing them to modify their policies can only make them worse-off. In the conventional theoretical framework, this is typically explained as firms solving a profit maximization problem. Any exogenously imposed environmental policy will represent a constraint for the firm or, in other words, a limitation of its feasible set. Since the solution of a constrained problem cannot be superior to that of an unconstrained one, it follows that firms cannot be better off when subject to a tougher environmental regulation.

This is not to say that environmental policy should not be applied. The theory of market failure teaches us that public intervention can be justified to deal with inefficiencies caused by externalities, the presence of public or open access goods or other market failures. In the case of environmental regulation, it may be justified on the grounds of social and environmental interests, in spite of the negative effect they would have on private firm's interests.

The novelty of Porter's contribution is to state that environmental protection policies are not necessarily detrimental for firms' results. Actually, under some circumstances, it may be the other way around since a properly designed environmental policy can help firms become more competitive. According to Porter and van der Linde (1995), the environment-competitiveness debate has been framed incorrectly. The notion of an inevitable struggle

between ecology and the economy grows out of a static view of environmental regulation, in which technology, products, processes and customer needs are all fixed (p. 97) They also claim that the paradigm defining competitiveness has shifted away from this static model and nowadays competitive advantage rests in the capacity for innovation and improvement. Under this new framework, they argue, properly designed environmental policies can trigger innovation that may partially or more than fully offset the costs of complying with them.

If this claim is true, it has important implications regarding the design and implementation of environmental regulation. Particularly, it affects the cost-benefit assessment of environmental policies at the national level, which are often argued to erode domestic competitiveness in international markets. The common argument is that if domestic firms are subject to more stringent regulations that their foreign competitors they will be placed at a competitive disadvantage. Therefore, if the aim of promoting domestic competitiveness is important enough, it may be defensible to apply lax environmental legislations, which is commonly known as ecological dumping (see, e.g., Rauscher, 1994). The implication of the Porter Hypothesis is the opposite: being the first to apply strict environmental regulations can give a first-mover advantage to domestic firms.

Whether one agrees with Porter's claim or not, its impact cannot be denied as it has provoked a lively debate both in the theoretical and the empirical literature.[1] In empirical terms, the challenge is to determine whether the reported evidence supports that environmental regulation tends to erode firm's competitiveness, as it is defended by the orthodox position or, on the contrary, it is likely to foster competitiveness as it is affirmed by Porter and van der Linde (1995). Neither the proponents nor the opponents of the Porter Hypothesis claim that their position holds with probability one. The critics claim that, although some anecdotal empirical evidence in the direction suggested by Porter could be found, it should be seen as the exception rather than the rule. Porter and var der Linde, on the other hand, admit that not every environmental policy will be beneficial for competitiveness, but this is even likely to arise when the regulation is properly designed.

[1] According to Google Scholar, on December 17th 2014, Porter and Van der Linde (1995) had been cited 4238 times. So, including the present one, there are at least 4239 citations! Heyes and Liston-Heyes (1999) make the interesting point that, whether Porter's hypothesis is fully right or not, as it receives a significant credence among a large number of professionals, the environmental authorities should pay attention to it when designing regulations.

So, as pointed out by Popp (2005), the debate over the Porter Hypothesis can be seen as a controversy over the likelihood that complete offsets may occur or not. In this respect, many studies have been conducted to test the effect of environmental regulations on firms' competitiveness and some evidence has been found to support both positions. For a survey of empirical works see Brännlund et al. (2009), Ambec and Lanoie (2008) or Ambec et al. (2013).

The focus of this chapter is rather on the theoretical and conceptual side. On the grounds of standard economic theory, Porter's view has received a skeptical and critical response from many economists. See, for example, Palmer et al. (1995), Jaffe et al. (1995) or Jaffe and Palmer (1997). As a first central criticism, focused on firms' rationality, the Porter Hypothesis implies that firms might systematically overlook opportunities to innovate and improve their own results, and this seems difficult to reconcile with the neo-classical view of the firm as a rational profit-maximizing entity. In short, if environmental innovation were profit-enhancing, firms would be willing to move in that direction on their own without any governmental prompting. As a more policy-oriented criticism, the Porter Hypothesis seems to suggest that the government can make painless or costless decisions, which contradicts the common economic belief that "there is no free lunch".

In other words, in a world with perfectly rational profit-maximizing firms, perfect markets, perfect information and no coordination problems, the idea that risk-neutral firms might benefit from any exogenously imposed obligation, such as a new or a tougher environmental policy, cannot be supported in conceptual terms. As such, this statement is difficult to contradict and, accordingly, the theoretical arguments in favor of the Porter Hypothesis rest on the existence of either incomplete rationality or some market imperfection. In this paper we focus on those issues involving strategic behavior either within the firm, among domestic firms or between domestic and foreign firms. As we show below, different authors have proved that the interaction among rational agents can generate some situations in which the Porter Hypothesis may hold, at least in principle.

Our aim is to identify the main theoretical arguments that have been proposed in the literature to support the validity of the Porter Hypothesis and pick the most significant contributions. Our purpose is not to present a thorough survey of all the literature on the Porter Hypothesis, but simply to identify some of the most plausible channels and provide

a more or less comprehensive and self-contained summary of the key contributions. For a broader literature revision see Wagner (2004), Ambec and Barla (2006), Brännlund et al. (2009) or more recently Ambec et al. (2013).

The structure of the reminder is the following. In Section 2 we present some general issues and different interpretations of the Porter Hypothesis. In Sections from 3 to 7 we review some theoretical explanations based on strategic effects. Specifically, Section 3 explains how environmental policy can benefit firms through the generation of scarcity rents. Section 4 reviews the use of environmental regulation by national governments as an instrument of strategic trade policy. Section 5 focuses on the existence of externalities in technology adoption, both in the output sector and the abatement sector. Section 6 introduces quality-competition considerations both in the domestic and the international framework. The last strategic channel we review, in Section 7, is related to information incompleteness in two different contexts: within the firm and at the output market level. Some relevant contributions, although not specifically linked to strategic effects, are gathered in Section 8. Finally, Section 9 provides some final thoughts and policy implications.

2 General ideas and different versions of the Porter Hypothesis

One difficulty that arises when addressing the Porter Hypothesis from a scientific point of view is to clarify its interpretation. It is not a hypothesis in the statistical sense, as Porter and van der Linde did not write a formal statement to be tested in the form of a null hypothesis versus an alternative one. Rather, what they did is to propose a general idea and offer some real-life examples to illustrate how this general idea can work in practice. The result of this lack of specificity is that different authors have interpreted the Porter Hypothesis in different ways. In other words, apart from (or rather, before than) the debate if the Porter Hypothesis is true or not, there is another debate about what the Porter Hypothesis really says. The main issues that are present in the debate can be summarized in the following questions:

1.- Can environmental regulation foster firm's innovation? If so, is this true in general or just for some kinds of regulation?

2.- Can regulation-induced innovations generate some benefits for the firms that are subject to the regulation?

3.- If those benefits exist, can they be strong enough to (totally or even more than fully) offset the cost of complying with the regulation?

Jaffe and Palmer (1997) distinguished among the "weak," "narrow," and "strong" versions of the Porter Hypothesis. The weak version suggests that environmental regulation is prone to foster some types of innovation. As environmental regulation places constraints on firms, it creates additional costs that will prompt them to innovate in the sense of developing new procedures and activities to soften those cost increases. So, according to the weak version, the answer to questions 1 and 2 would be generally yes and the answer to question 3 would be generally not.

As Porter and van der Linde emphasized, to stimulate innovation, environmental regulation should be properly designed and, more specifically, it should be flexible and focus on outcomes rather than processes.[2] According to this point, the "narrow" version of the Porter Hypothesis argues that certain types of environmental regulation, but not all of them, stimulate innovation. According to this version, the answer to question 1 is yes only for some types of regulations, but not for all of them. The answer to the second question is yes conditional on having a regulation that meets the first requirement. The answer to the third question is, again, generally not.

Finally, the "strong" version is the only one that provides a positive answer to the third question, which implicitly implies a positive answer to the second question, i.e., environmental regulation can generate benefits that offset the costs of compliance and make firms better-off. Nobody (including Porter and van der Linde) claims that this is true for every type of regulation and, therefore, if one is to defend the strong version, inevitably the answer to all three questions would be yes only for some types of regulation.

The core of the controversy around the Porter Hypothesis is related to question 3.

[2]Specifically, Porter and van der Linde (1995) state that "If environmental standards are to foster the innovation offsets that arise from new technologies, they should adhere to three principles: first, they must create the maximum opportunity for innovation, leaving the approach to innovation to industry, second, regulations should foster continuous improvement, rather than locking in any particular technology, and third, the regulatory process should leave as little room as possible for uncertainty at every stage". (p. 110).

Economists would broadly expect some degree of innovation from regulation and, thus a positive answer to questions 1 and 2, at least in some cases (see, e.g., Downing and White, 1986 or Milliman and Prince, 1989), but Porter and van der Linde suggest that, under some circumstances, the answer to question 3 may also be positive and, moreover, it is likely to be positive if the environmental regulation is properly designed. So, the really controversial version of the Porter Hypothesis is the strong one.

According to Jaffe and Palmer (1995), the "strong" version contradicts the profit maximizing paradigm and posits that firms do not pursue all profitable opportunities to develop new products or processes. This is the only case in which a new regulation could induce them to think more broadly and find new opportunities to increase their profits. Under these conditions, environmental regulation turns out to be a free lunch in the sense that it is desirable per se even ignoring the environmental problem it was designed to solve. Jaffe and Palmer's conclusion is based on the belief that, under rational behavior, regulation cannot create profit opportunities, but only economic costs. Thus, if after the regulation the firms find new profit opportunities, it must be the case that they were not acting rationally before the regulation. Another interpretation of the strong version is that, apart from environmental externalities, there might be other problems or market imperfections that limit the firms' possibilities to maximize their profits and the regulation may help to solve those problems. This is the path that a number of theoretical papers in the literature have followed.

In the sequel, when we talk about the Porter Hypothesis, we will be mainly referring to the strong version, according to which environmental regulation can make firms better off as compared with their original situation. But even within the scope of this version, in the literature there are different interpretations of firms becoming "better off". The claim of Porter and van der Linde is that firms become "more competitive" but, as the concept of competitiveness is difficult to pin down, some authors interpret that, after the regulation, the firms will face lower costs, others that they will enjoy higher profits and others that they will have a higher market share.

Gabel and Sinclair-Desgagné (1998) also suggest three different interpretations of the Porter Hypothesis. According to the first interpretation, the regulation can enhance competitiveness of producers of complementary products and services, i.e., those firms that

offer products and services that protect the environment. But, while these firms become better off, firms that are ultimately subject to the regulations, i.e., those that have to contract new services, develop new procedures, etc., will have to bear the costs. This is not really a win-win situation.

The second interpretation has to do with relatively enhanced competitiveness of the regulated firms. The idea is that a tougher domestic environmental regulation will raise the costs of domestic firms but, assuming that the same or similar regulations will also be adopted in the near future in other countries, the costs of foreign competitors will rise by even more. Thus, domestic firms get a first-mover advantage by being the first to develop the technology and achieve experience efficiencies.

The third interpretation involves absolute cost reduction for the regulated firms. In this case, strict regulations will prompt firms to find low hanging fruits that will reduce their private costs while they improve their environmental performance. The third case is roughly the same as what Jaffe and Palmer (1997) call "strong version". According to Gabel and Sinclair-Desgagné, this is the only variant of the Porter Hypothesis that is truly win-win and it is also the really controversial one to economists because it assumes the existence of some organizational failure in the firm.

One value added of the three interpretations proposed by Gabel and Sinclair-Desgagné is to point out the issue of cross-country competitiveness. This idea is very present in Porter and van der Linde's contributions as they claim that implementing a more demanding regulation in a specific country can provide its domestic firms with a competitive advantage versus their foreign competitors. International competition is explicitly considered in some of the papers that we review below, but it is not in others. Similarly, there are other elements of the original Porter's ideas that are not always present in the theoretical developments. For example, although Porter and van der Linde claim that environmental regulations should be flexible, some articles conclude that environmental regulation can be beneficial for firms whether it takes the form of a flexible market-based instrument or a command-and-control standard. Also, although innovation is very central for Porter's idea, some authors also conclude that, under some circumstances, environmental regulation can benefit firms even without the need of innovation. Therefore, in the contributions reviewed below, we can find different degrees of literal proximity to the original Porter's idea.

In the following sections we review some of the theoretical developments related to the Porter Hypothesis paying attention to strategic issues. In each section we focus on a specific theoretical idea, i.e., a channel by which the Porter Hypothesis or a closely related result can emerge, and we identify the most significant contribution(s) exploring this channel. Although the spirit and the basic ideas of the cited articles have been kept as such, the notation has been altered to provide a certain degree of consistency to the chapter. The notation is summarized in the appendix.

3 Scarcity rents

In the economics literature it is well documented that certain regulations might benefit firms by creating scarcity rents and this is also true for the case of environmental policies (see, e.g., Fullerton and Metcalf 2001). Mohr and Saha (2008, example 1) link this effect to the Porter Hypothesis by pointing out that a stricter environmental regulation might have a distributional impact in the sense of increasing firm's profits and passing the cost onto consumers. As Mohr and Saha claim, this is a way to reconcile Porter's idea that environmental policies might be beneficial for firms with the common economists' critique that regulations do have costs.

To illustrate this idea, Mohr and Saha (2008) assume there are N identical competitive firms[3] producing q units of output each, bearing a production cost function $C(q)$ and facing a downward sloping demand $P(Q)$, where $Q = N.q$ is total output. Each unit of output generates one unit of emissions, $e = q$, emissions are taxed at a unit tax rate t and a proportion α of per-firm tax revenues are refunded to the firm as a lump-sum transfer. Then, if taxes are initially set at zero, the marginal effect of the tax on a firm's profit is given by

$$\left.\frac{\partial \pi(t)}{\partial t}\right|_{t=0} = \left[N.P'(Q).q'(t) - (1-\alpha)\right] q(t), \tag{1}$$

where the marginal effect of taxes on firm's output is given by $q'(t) = \frac{1}{N.P'(Q) - C''(q)} < 0$. The first term in (1) is the scarcity rent, which is determined by the fact that a higher

[3]Since the model used by Mohr and Saha (2008) involves perfect competition, strategic interaction is not explicitly modeled. Anyway, we consider that the main argument used by Mohr and Saha has an strategic dimension and, in fact, it can be easily exported to settings with explicit strategic behavior, as is done, for example in André et al. (2009).

cost makes the output price to increase. If the tax is fully refunded to firms ($\alpha = 1$), the net effect of a higher tax on profits is unambiguously positive, which means that scarcity rents themselves are enough to make profits increase even without innovation. If the tax is not fully refunded, then the sign of $\frac{\partial \pi(t)}{\partial t}$ is ambiguous and thus the scarcity rents per se might not be enough to make the firm better off. Anyway, if a firm (or a group of firms) have the possibility to develop a cleaner technology in order to reduce the tax burden, and the cost of innovation is low enough, it is still possible that a tougher policy is beneficial for firms by the joint effect of the scarcity rents and the enhanced productivity due to the technological development.

As a particularly relevant case of scarcity rents, consider a cap-and-trade system in which the firms are allocated emission permits for free by means of grandfathering. Since the permits work as a limited input, the market price of output will reflect the scarcity value of the permits. Moreover, as the emission permits can be traded in the market, some firms can obtain an additional source of revenues. The combination of these effects can provide substantial profit opportunities for some firms, which is commonly known as windfall profits. Empirical work suggests that this phenomenon has been rather important in the first phase of the European Union Emission Trading Systems (EU ETS). For example, Newell et al. (2013) point that power generators extracted rents by receiving carbon allowances for free and then passing along the opportunity costs of these allowances to their customers. For an analysis of this phenomenon, see Ellerman et al. (2010). Ehrhart et al. (2008) identify conditions under which an increase in the price of permits, which in principle represents an additional cost for firms, could generate enough scarcity rents to be ultimately beneficial for them. Moreover, they claim that, in the trading law behind the EU ETS, there are loopholes by which firms could collude to push the price of permits upwards. Hinterman (2011) claims that this type of price manipulation can be responsible for the price oscillations observed during the first phase of the EU ETS.

Summing up, the existence of scarcity rents is one mechanism by which firms could benefit from a more stringent environmental policy, and this could happen even without any innovation or any improvement of domestic competitiveness in output markets. International competition is more explicitly addressed in the following section.

4 Strategic trade policy

Another branch of research addresses the use of environmental policy by domestic governments as a vehicle to foster the competitiveness of their firms vis-a-vis their foreign competitors. In this group, we review the works by Simpson and Bradford (1996) and Greaker (2003).

In one of the earliest theoretical works addressing the Porter Hypothesis, Simpson and Bradford (1996) consider a standard model of strategic trade similar to those by Spencer and Brander (1983) and Brander and Spencer (1985), with two firms, one domestic (labelled as D) and one foreign (F) that produce a polluting good and sell it in a third country's market. The model has three stages: in the first stage, the domestic regulator sets an effluent tax rate t. In the second stage the firms decide their levels of a cost-reducing innovation, y_D, y_F. In the third stage, the firms decide their output levels, q_D, q_F, competing in quantities a la Cournot. Domestic production generates an amount e_D of pollution, which in turn causes a damage given by the damage function $d(e_D)$. The cost functions of the firms are given by

$$C_D = c_D(t, y_D, y_F)\, q_D, \qquad C_F = c_F(t, y_F, y_D)\, q_F,$$

where, in general, the unit cost of firm i (for $i = D$, F), c_i, depends on the tax rate, on the own R&D effort, and also on the competitor's R&D, to account for the possibility of technological spillovers. The rationale behind the model is that the domestic government prompts its firm to behave as a Stackelberg leader vis-a-vis its foreign rival by adopting more aggressive cost-reducing investments.

Simpson and Bradford note that the effluent tax has three effects. First, it raises the domestic firm's marginal cost, making it less competitive; second, it induces cost-reducing innovation and, third, it (partially, totally or even excessively) internalizes the externality. The regulator chooses the value of the tax to maximize social surplus given by

$$P.q_D - C_D - y_D - d(e_D) + t.e_D.$$

where P is the market price of output. The direct effect of increasing the domestic firm's cost causes its best-response function to shift inward, so that foreign production replaces domestic production. This effect can be at least partially offset if cost-reducing innovations

are induced. In that case, the best-response function shifts outward again and profit shifting from domestic to foreign firms would be mitigated.

The authors adopt a skeptical position regarding the Porter Hypothesis, as they conclude that tougher environmental regulation does not necessarily increase domestic profits, output, or even innovation expenditure and, therefore, while strict environmental policies (those that go beyond the point of internalizing environmental externalities) might be sometimes justified, it does not seem reasonable to suppose that this is usually the case. They conclude that the use of environmental regulation as a strategic trade policy is generally inferior to other instruments.

Greaker (2003) explores the effect of a domestic environmental policy (also in the form of a tax rate) on domestic firms' competitiveness as well as the optimal strategic trade policy of the government (which could be either "eco-dumping" or "green"). The results crucially depend on the nature of environmental services for production as normal or inferior inputs. A domestic (D) and a foreign (F) firm pollute and compete in quantities by selling in a third country market products that are assumed to be strategic substitutes. The profits of both firms are given by

$$\begin{aligned} \pi_D(q_D, q_F, t_D) &= R_D(q_D, q_F) - C_D(q_D, t_D), \\ \pi_F(q_F, q_D, t_F) &= R_F(q_D, q_F) - C_F(q_F, t_F), \end{aligned}$$

where R_i and C_i stand for the revenue and the cost function of firm $i \in \{D, F\}$ respectively, and t_i is the tax rate set by country i. Most articles about eco-dumping assume that both total cost and marginal cost are increasing in the stringency of environmental policy, but Greaker (2003) argues that although total cost increases, marginal cost does not necessarily increase. In fact, if the environment is an inferior input, marginal production cost will decrease. The effect of an increase in the domestic tax rate, t_D, on domestic and foreign output has a sign given by

$$\text{Sign}\left[\frac{d\,q_D}{d\,t_D}\right] = \text{Sign}\left[-\frac{d\,q_F}{d\,t_D}\right] = \text{Sign}\left[-\frac{\partial^2 C_D(q_D, t_D)}{\partial q_D \partial t_D}\right] = \text{Sign}\left[-\frac{\partial e_D}{\partial q_D}\right],$$

where e_D denotes domestic emissions. In words, if the domestic marginal cost is increasing in the emission tax rate, the domestic firm would like to supply less the higher the domestic emission tax rate and, in equilibrium, the foreign firm would supply more. This situation

corresponds to the case in which emissions are a normal input for production, i.e., $\frac{\partial e_D}{\partial q_D} > 0$ (emissions depend positively on output). If, on the contrary, emissions are an inferior input, i.e., $\frac{\partial e_D}{\partial q_D} < 0$, then marginal cost is decreasing in the domestic tax rate and, as a consequence, an increase in t_D would entail that the domestic firm will produce more and the foreign firm less. The occurrence of the latter case (i.e., that emissions are an inferior input) requires that the domestic firm is able to abate emissions and the technology is such that the firm chooses to abate more the higher the output. Greaker argues that this is a plausible case and he illustrates this with an example based on the Norwegian aluminium industry.

If emissions are an inferior input, making the domestic environmental policy more stringent could be beneficial for the domestic firms, which is in line with the Porter Hypothesis. Greaker also shows that, in this event, in order to maximize domestic surplus, the domestic regulator would choose a so-called "green" strategy, in which the tax rate is set a value higher than the marginal damage of domestic emissions, $t_D > d'_D(e_D)$, rather than eco-dumping, which involves $t_D < d'_D(e_D)$.

Greaker also gets the somewhat paradoxical result that, under the inferior input assumption, the environment is better protected when countries decide non-cooperatively instead of coordinating their environmental policies. The reason is that the lack of cooperation will lead them to be more aggressive and make their environmental domestic policies tougher.

5 Externalities in technology adoption

In the economics literature it has been widely acknowledged that, due to the public-good nature of knowledge, technology adoption is subject to spillovers among firms in the sense that research and development efforts made by one firm can benefit other firms. In the growth literature, this effect has been reported as a key element for economic growth. Some papers have noticed that the presence of spillovers can open a way for a Porter-type result to arise. The idea is that firms may refrain from making R&D efforts as they cannot perfectly appropriate the resulting innovations and, instead, it could be more profitable to wait for other firms to pay the initial cost and then take advantage of the spillovers. All the

firms (or a large number of them) acting like this can stop or at least slow down technical progress, which is ultimately bad for them, but also for the society and the environment. We now review two contributions that have reported such a mechanism both in the output production sector and the pollution abatement sector: Mohr (2002) and Greaker (2006).

5.1 Technology adoption in output production

Mohr (2002) provides rational support for the Porter Hypothesis within the framework of a learning-by-doing general equilibrium model. The idea is based on the public-good nature of knowledge and technical progress (this idea is also modelled in Mohr and Saha 2008, example 4). Developing a new technology involves a fixed cost in terms of time and resources devoted to R&D. At an early stage such an adoption might not be profitable enough to recover the initial investment. After some time, when some firms have adopted it, the technology matures and it is easier to jump in and benefit from it. In this context, all the firms may remain locked in an old (less productive and dirtier) technology because no one wants to assume the investment cost, although they would be better off if all of them jointly adopted the new technology. The mechanism suggested by Mohr to back the Porter Hypothesis is parallel to the argument commonly used to support the infant-industry hypothesis, based on the idea that trade restrictions can benefit domestic consumers.

To model these ideas, Mohr (2002) considers that production requires, as inputs, labor (l), waste or emissions (e) and production experience (K). This experience is accumulated as a result of different firms devoting labor to a same technology over time. Assume there is an "old" technology (with associated production function f) and a "new" technology (with production function g) that is more productive than the former in the sense that it allows more to be produced for the same amount in inputs, i.e.,

$$f(l, e, K) < g(l, e, K).$$

This condition can also be interpreted as g being cleaner than f, in the sense that for the same amount of labor and experience it can produce the same amount of output using less waste. Nevertheless, for some initial period of time, we have $K_f \gg K_g$, i.e., there is much more experience accumulated for the old technology than for the new one and, as a consequence, the productivity of g is initially lower than that of f:

$$f(l, e, K_f) > g(l, e, K_g).$$

The implication of this assumption is that each firm has a second-mover advantage in the sense that it is profitable to switch to the new technology only if enough firms have done it first and so, everyone has an incentive to wait for someone else to bear the short-term adoption costs and jump in afterwards. By inducing, or even forcing firms to adopt the new technology, regulation can solve the coordination problem. Once all the firms have moved to the new technology, all of them become better off although this is not true individually.

Mohr argues that Porter's hypothesis does not provide a tool for setting government policy. The reason is that his model predicts that environmental policy would probably improve technology and increase output, but not decrease environmental impact. More explicitly, although the new technology would make it possible to produce more and pollute less, it is unlikely that this combination of effects takes place in equilibrium. The reason is that, having a more productive technology, the opportunity cost of abatement increases and firms would have an incentive to produce more and, therefore, also to pollute more. In the literature this idea is sometimes labelled as rebound effect (see, e.g., Greening et al. 2000).

Mohr's (2002) model generates a couple of empirically testable implications: first, while individual businesses may oppose new regulations, industry as a whole should support them. Second, environmental regulations could induce particularly large benefits in developing nations, which have more to gain from a shift to a more advanced technology developed by other countries. This suggests, first, that empirical evidence for Porter's hypothesis may be strongest in these nations and, second, that the possibility of leapfrogging exists.

The second-mover advantage idea suggested by Mohr (2002) is also illustrated by Farmer et al. (2001) in a partial equilibrium setting by means of a Cournot model with two firms in which, before engaging in output competition, both of them can invest in developing a new technology whose impact on production costs is unknown ex ante. If one firm takes the risk of leading the new technology adoption, then the information is publicly disclosed and the second firm can make its decision with full information. Thus,

the second firm will adopt the new technology if it decreases production costs (in which case the benefit is shared) and will not adopt if it is the other way around (in which case the leading firm bears all of the costs of acquiring the information). Therefore, it can be the case that the expected benefits of the new technology exceed the expected costs for all the firms if they simultaneously adopt, but no firm has the incentive to be the first.

Kriechel, B., & Ziesemer, T. (2009) explicitly model the timing of technology adoption by domestic and foreign firms in a dynamic setting and show that environmental policy may destroy a non-adoption equilibrium. They show that the introduction of a small tax establishes an order of adoption and therefore a precommitment situation that produces higher profits for the domestic firms than without the tax.

5.2 Technology adoption in pollution abatement

Similar to Mohr (2002), Greaker (2006) suggests a Porter-like result based on a coordination failure, but while Mohr uses an abstract learning curve, Greaker is more explicit and includes the market for new pollution abatement techniques in his model. The argument is that a stringent environmental policy induces higher demand for abatement equipment, which will spur entry of new firms in the abatement sector, promote competition among them and allow for a lower mark-up. Another important difference between Mohr (2002) and Greaker (2006) lies in the interpretation of the Porter Hypothesis: while Mohr focuses on productivity improvements, which, arguably, would come along with profit increases, Greaker does on market shares: the argument is that domestic firms could export more if they are subject to a more stringent environmental policy, which does not necessarily imply that they would make higher profits.

Greaker (2006) considers a representative firm in the export sector. The amount of emissions, e, emitted by such a firm depends on the amount of (export) output, q, and the units of abatement equipment, x. The government sets an emission quota $\bar{e}$, so that $e \leq \bar{e}$, which in equilibrium holds with strict equality. From this condition, we can obtain the demand for abatement equipment as $x = x(q, \bar{e})$ and then the (downstream) cost of abatement is given by $w.x(q, \bar{e})$, where w is the price of each unit of equipment. Profit maximization of the representative exporting firm renders the optimal amount of output as a function of the standard and the price of abatement, $q(w, \bar{e})$, and hence we can write

the (direct) demand for pollution abatement equipment $x = x\left(q\left(w, \bar{e}\right), \bar{e}\right)$ and the inverse demand $w = w\left(\bar{e}, x\right)$, where it can be shown that $\frac{dw}{dx} < 0$.

In the upstream pollution abatement market, to start supplying a new pollution abatement equipment, the firms have to incur a development cost, β, which constitutes a fixed entry cost. Once the fixed cost is paid, each unit of abatement equipment is produced at a constant marginal cost. The presence of a fixed entry cost prevents the price of abatement equipment from being equal to the marginal cost and a mark-up is required to avoid losses. Due to the presence of spillovers the fixed cost depends negatively on the number of active firms n. Competition in the pollution abatement sector is modelled as Cournot-Nash with free entry and so, in equilibrium, each firm gets zero profit. This condition determines the number of active upstream firms in equilibrium as well as the required mark-up.

If the standard becomes tougher ($\bar{e}$ decreases), downstream firms need to abate more and, hence, the demand for abatement equipment shifts upwards. This allows the entry of more upstream firms (n increases), which reduces the entry cost and hence a lower mark-up is required. The final effect on the price of abatement equipment, $\frac{\partial w}{\partial \bar{e}}$, is ambiguous, but Greaker argues that it is plausible that w decreases, which in turn might induce an increase in output for the exporting firm. Specifically, the effect of a tougher standard on export market share is shown to have the same sign as $w\frac{\partial^2 x_q}{\partial q \partial \bar{e}} + \frac{\partial x}{\partial q}\frac{\partial q}{\partial \bar{e}}$. The first term is the direct effect on output while keeping the price constant, and the second is the indirect effect via the price. The first effect is negative but the second is ambiguous and, if it is positive, it could make the whole effect to be positive, which would imply that a tougher standard increases export output, although this increase may come along with an increase in abatement cost.

6 Quality competition

Although the Porter Hypothesis literature is more focused on the supply side, involving technology and costs, there are also some papers underlining the role of market demand and consumer preferences. To frame this part of the literature, we build on the standard vertical differentiation model by Gabszewick and Thisse (1979) and Shaked and Sutton (1982). For applications of this model to the study of environmental quality see, for instance, Amacher

et al. (2004) or Lombardini and Riipinen (2005).

Consider a good that is produced by competing firms. The good can be produced with different levels of environmental quality. There is a continuum of consumers indexed by the parameter θ, which is uniformly distributed over the interval $[\underline{\theta}, \overline{\theta}]$. This parameter determines how much every consumer is willing to pay for environmental quality. Each consumer buys at most one unit of the commodity and his/her indirect utility (or surplus) is given by $U = \theta s - P$ if he/she buys a good of environmental quality s at price P, and zero if he/she buys nothing at all. The model involves a two-stage game. In the first stage the firms simultaneously decide the quality level of the product. In a second stage, the firms engage in either price competition (a la Bertrand) or quantity competition (a la Cournot). Within this rather standard setting, some papers have explored the possibility to obtain a Porter-like result. We review two groups of papers: while in the first group quality competition is modelled just at the domestic level, the second addresses cross-country competition.

6.1 Within-country competition

André et al. (2009) consider a version of the basic model with two firms that compete in prices in the second stage. Environmental quality is treated as a discrete variable with two alternative values: s_H (high) and s_L (low). One plausible interpretation is that L represents the standard variant of a good and the firms have to take the decision of whether to stick to this traditional variant or to shift to produce a new, more environmentally friendly one, H. Production costs are quadratically increasing with the amount of output and dependent on the quality level. If one firm chooses quality $s_i \in \{s_H, s_L\}$ and produces and amount of output q, its cost will be given by $C_i(q) = a_i + c_i q^2$, with $a_H \geq a_L = 0$ and $c_H \geq c_L$. Hence, the high-quality variant is assumed to be more costly than the standard one and this difference can take two forms: either $a_H > 0$, where a_H can be seen as an adoption cost, or $c_H > c_L$, which implies that the high-quality variant entails higher marginal costs.

To some extent, the mechanism reported by André et al. (2009) is qualitatively similar to the coordination problem described by Mohr (2002): since the environmentally friendly variant entails higher production costs, each firm is reluctant to shift individually to produce it, as this may place the firm at a disadvantage when competing in prices versus

low-quality rivals providing cheaper products. Under some conditions, supplying the environmentally friendly variant is not profitable enough for a single firm, and thus both of them remain stuck to the low-quality version, although they could benefit if both jointly shifted to produce high quality products. This jump can be prompted by the environmentally regulation.

In formal terms, the firms face the following simultaneous game in normal form in the first stage:

Firm 2

Firm 1		s_H	s_L
	s_H	(π^*_{HH}, π^*_{HH})	$(\pi^*_{HL}, \pi^*_{LH} - T)$
	s_L	$(\pi^*_{LH} - T, \pi^*_{HL})$	$(\pi^*_{LL} - T, \pi^*_{LL} - T)$

(2)

where π^*_{ij} is the equilibrium profit (gross of taxes) of a firm that sets quality s_i while its rival sets s_j. For simplicity, it is assumed that the environmental policy takes the form of a lump-sum tax (T) on the standard variant of the good, although the same qualitative results can be obtained with other policy instruments. The version of (2) with $T = 0$ is referred to as the unregulated game. André et al. (2009) show that the model renders a Porter-like result if the following pair of conditions hold:

$$(1)\ T > \max\{\pi^*_{LL} - \pi^*_{HL},\ \pi^*_{LH} - \pi^*_{HH}\},$$
$$(2)\ \pi^*_{HL} < \pi^*_{LL} < \pi^*_{HH}.$$

Under (1) and (2), (s_L, s_L) is a Nash equilibrium of the unregulated game, the environmental regulation induces (s_H, s_H) as the unique equilibrium of the regulated game and both firms are better off in the new equilibrium. Two particular cases can be found: in the first one, which requires $\pi^*_{LH} > \pi^*_{HH}$ as an additional condition, (s_L, s_L) is a unique equilibrium of the unregulated game. In this case, the firms face a typical prisoner's dilemma as they are initially locked in a low-quality equilibrium and the environmental policy pushes them to a high-quality alternative that entails a higher profit for them. If, on the contrary, we have $\pi^*_{HH} > \pi^*_{LH}$, both (s_L, s_L) and (s_H, s_H) are equilibria of the unregulated game. In the second case, the role of the environmental policy is to solve the coordination failure by eliminating the multiplicity of equilibria and ensuring that the "right" equilibrium will prevail.

The shift from (s_L, s_L) to (s_H, s_H) comes along with an increase in the price due to

the higher willingness to pay of consumers and the difference in marginal cost if it exists. Output in the final equilibrium is greater than in the initial one if $\frac{s_H}{c_H} > \frac{s_L}{c_L}$, where these ratios can be interpreted as a measure of the cost-effectiveness of each quality. If the latter condition holds, consumer's surplus is higher in the high-quality than in the low-quality equilibrium, and thus the environmental regulation may simultaneously benefit the environment, firms and consumers.

Lambertini and Tampieri (2012) revisit the model by André et al. (2009) by considering Cournot instead of Bertrand competition. They conclude that in this case the Porter-type result can only take the form of a prisoner's dilemma. This result precludes the possibility that the environmental policy simultaneously benefit both firms and the consumers.

Constantatos and Herrmann (2011) develop a qualitatively similar model, with a different modelling strategy and with quantity competition at the second stage. They point out that consumers perceive a new product's environmental quality with a time lag and there may exist "market inertia" resisting the introduction of a cost-efficient green product that, if adopted, would provide both higher consumer surplus and profits. In a similar spirit, Farzin (2003) develops a model with quantity competition and free entry in which a stricter environmental standard increases firm's costs but also shifts the demand outwards. Farzin's main message is that a stricter environmental standard can lead to a larger number of firms in industry and a greater industry output along with lower pollution.

6.2 International competition

The papers reviewed in the previous subsection focus on competition among domestic firms and basically address the question of whether environmental policy can solve a coordination failure among them. It can be argued that, by fostering domestic firms' innovation and making them produce with higher quality, environmental regulation can put them in an advantageous position with respect to foreign firms. Constantatos and Hermann (2011) explicitly considers international competition by presenting a modified version of their model with four firms, two domestic and two foreign, that export their products to an international market. They conclude that, under certain parameter combinations, the model confirms Porter's conjecture that unilateral adoption of environmental regulation by one country increases the long-run market share and profits of its domestic firms.

Rothfels (2002) explicitly addresses international competition by building a version of the vertical differentiation model with a domestic firm and a foreign firm. Unlike the papers reviewed in the previous subsection, Rothfels assume continuous rather than discrete quality. This assumption, which is actually the usual one in the vertical differentiation literature, implies that, in equilibrium, there is always a certain degree of product differentiation. As André et al. (2009), and unlike Lambertini and Tampieri (2012), Constantatos and Herrmann (2011) and Farzin (2003), she assumes price competition in the second stage. Costs are assumed to depend quadratically on quality but not on output.[4] So, the cost of country j is given by

$$C_j(s) = c_j s^2 \qquad \text{with } j = D, F,$$

where s is the endogenously decided level of quality and c_j is a country-specific parameter, D stands for domestic and F for foreign. If $c_F > c_D$ the domestic firm enjoys a cost advantage with respect to the foreign firm and the opposite happens if $c_F < c_D$. Both cases are studied separately. The starting point is a situation in which the domestic firm produces the low quality good, whereas the foreign firm supplies the high quality good ($s_D < s_F$) and the central question is if a properly designed environmental policy can induce 'leapfrogging' in the sense that, after the regulation is implemented, the domestic firm will produce a higher quality than its competitor.

If the domestic firm enjoys a cost advantage over the foreign competitor ($c_F > c_D$) it is shown that leapfrogging can be induced by imposing a binding minimum quality standard. This results in higher profits for the domestic firm and the exit of the foreign firm from the domestic market. Moreover, this policy can enhance environmental quality and welfare. In the case that the domestic firm has a cost disadvantage ($c_F < c_D$) instead of an advantage, a minimum quality standard does not induce leapfrogging but the same result can be induced if, instead of a standard, the government introduces a subsidy in the form of a proportional reduction of the costs of providing high quality.

[4] This is justified by assuming that quantity dependent costs are equal for both firms and have constant marginal costs and, then, they can be neglected for the purposes of the study.

7 Information problems

One of the basic assumptions in standard perfect competition models is the existence of perfect information that is fairly widespread among all economic agents. It is well-known that information asymmetries among economic agents is a source of market inefficiencies (see, for example, Macho-Stadler and Pérez-Castrillo 2001). Some authors have claimed that these inefficiencies open up the possibility that an environmental regulation provides a win-win result. The idea is that regulation can alleviate information asymmetry and enhance profit opportunities. This effect can take place under information asymmetries within the firm and information asymmetries in the output market. Both cases are addressed below.

7.1 Information asymmetries within the firm

Mainstream neoclassical economics has traditionally considered the firm as a perfectly rational, profit-maximizing black-box without paying enough attention to the mechanisms by which firm's decisions are internally taken. A large body of research in the management literature has pointed out that firms' final decisions are the result of complex internal interactions between different agents or groups, which have different and usually conflicting interests.

In the so called principal-agent literature it is common to differentiate between the owner of the firm (the "principal"), who is interested in maximizing the firm's profit, and the manager (the "agent"), who works for the firm, but has his own objectives such as maximizing his welfare, increasing his leisure time, etc. The fact that the principal cannot perfectly control the manager, due to imperfect observability, results in additional efficiency costs for the firm and the possibility that, if these costs are alleviated, an environmental policy could be profit-enhancing.

Gabel and Sinclair-Desgagné (1998) point out that the decisions that determine the firm's performance are not directly made by the principal, but they result from a network of necessarily imperfect systems and procedures. As a consequence, the link between environmental regulatory policy and the allocation of environmental resources is complex, multistep, and imperfect. By altering the external rules to which the corporate principal is

subject, the regulatory policy will commonly induce the principal to change the management systems, to which the agents must respond, and this latter response is the one that will really have an environmental impact. These organizational constraints can prevent the firm from seeing and reacting to opportunities or threats and this is what the authors call 'organizational failure'. These authors highlight the fact that a firm's management system involves some routines that increase its organization's efficiency but also reduce its adaptability to changing circumstances. Changes in management systems are typically revolutionary, in the sense that old systems are destroyed and replaced by new ones. They also tend to be disruptive, because agents must abandon traditional patterns of behavior and learn new routines in their place. Since this learning and unlearning process is costly for managers, it is reasonable that they have a personal motive to resist this change. And it is more so given that the benefits of the change may be external to them.

Ambec and Barla (2002) model a specific mechanism by which the combination of intra-firm asymmetric information and environmental regulation can result in a win-win result for the environment and the firm. They consider a setting in which the firm makes an investment in R&D, the result of which is uncertain and can be perfectly observed a posteriori by the manager but not by the firm's owner. For each realization of the investment project there is an associated optimal output level. The firm must offer the manager a contract with two aims: first, to induce him to reveal the true result of the investment and, second, to make him accept the contract and exert enough effort to produce the optimal amount of output associated to each realization.

The fact that the manager has private information forces the firm to pay some informational rents, i.e., some extra money to induce him to tell the truth. These informational rents add to the firm's cost and, therefore, decrease its profit. The more severe the informational problem is, or in other words, the more different the optimal levels of output associated to different realizations are, the more informational rents the firm has to pay. In this framework, Ambec and Barla (2002) show that an environmental standard in the form of an upper bound on the amount of output, apart from inducing more R&D effort, also has the effect of reducing the difference between the optimal values of output for different realizations and, hence, to reduce the required amount of informational rents. Ambec and Barla claim that, under some parameter combinations, the latter effect is strong enough

to offset the compliance cost and, hence, to increase the firms' profit with respect to the non-regulated situation.

7.2 Information asymmetries in the output market

From Akerloff's (1970) groundbreaking article, we know that imperfect information in the output market is another source of market inefficiency. In a nutshell, the problem arises when a physically uniform good can be produced with different qualities, which may come along with different production costs. Consumers are aware that different qualities are present in the market but, when faced with a specific product, they are not able to distinguish its quality. As a result, they are reluctant to pay what would be a fair price for a high-quality product since they fear that the true quality is not what the seller claims it to be.

Rege (2000) presents a model to support the idea that, under imperfectly observable quality, an environmental regulation can improve national industry's competitiveness. The analysis is carried out in a long-run general equilibrium model involving a world industry which consists of firms from a given number of identical countries with price-taking firms. The firms produce physically identical products with differentiated quality, where producing with high quality involves an extra cost (a_H) with respect to producing low quality.

Three groups of firms are considered: those firms producing and claiming to produce low quality, those producing and claiming to produce high quality and, finally, cheating firms that produce low quality but claim to produce high quality. Consumers are not able to distinguish between firms in the second and the third group. Cheating firms can be inspected, caught and fined with a positive probability that depends on the share of honest high-quality firms. In equilibrium, this share increases with the severity of the expected fine (A) and decreases with the extra cost of producing high quality, a_H.

The analysis shows that, in the market equilibrium, production of high environmental quality products is lower than in the Pareto optimal solution and it could even be zero if A is low enough or a_H is high enough. On the other hand, if a country's monitoring policy gets tougher relative to the world industry in the sense that either the fine or the probability of getting caught cheating increases, then (I) domestic industry's competitiveness will improve

and (II) the market-share of high-environmental-quality goods will increase, which is a consistent result with the Porter Hypothesis.

Mohr and Saha (2008, example 3) tell a similar story. Consumers are willing to pay a premium for goods that are produced using "green" technologies, but they cannot observe the production process and hence they rely on total industry emissions as a proxy for environmental quality. As regulation reduces overall industry emissions, it alleviates the informational problem and makes firms enjoy a premium paid by consumers for their products. Mohr and Saha also raise one important issue related to the reasons why consumers are willing to pay a premium. If they are willing to do so only temporarily, in order to induce a change, but not once the regulation is established, then regulation-induced profits might be temporary rather than permanent.

Tietenberg (1998) notes that a recent trend in environmental regulation involves disclosing firms' environmental information to the public.[5] The rationale behind this strategy is to push firms to reduce their environmental impact to avoid being punished by the markets. Kriström and Lundgren (2003) show that the purpose to improve their environmental image among consumers can explain why firms can voluntarily reduce their emissions. André et al. (2011) show that, under some circumstances, an environmental information disclosure policy can be profit-enhancing for firms.

8 Other (non-strategic) mechanisms

As we have shown in the preceding sections, a large proportion of the theoretical articles on the Porter Hypothesis rest on strategic links among economic agents. Nevertheless, there are a few papers suggesting otherwise, not specifically strategic, channels by which an environmental policy could be profit-enhancing for firms. In this section we summarize some of the most significant ones.

Xepapadeas and de Zeeuw (1999) focus on the effect of environmental policy (in the form of a tax on emissions) on the composition of the firm's capital stock. They present a model in which the capital of the firm is made of machines of different ages. Younger machines are more productive and less polluting but also more costly to buy and to install,

[5] This trend is also related to the increasing importance of Eco-labels. See, for example, Amacher et al. (2004) or Mason (2006).

as compared to older machines. A more stringent policy (i.e., a higher tax rate) will represent a higher cost for firms that will encourage them to restructure their capital stock. Specifically, two effects are identified: a "downsizing effect", involving a reduction in the number of machines of all ages and therefore the size of the whole capital stock, and a "modernization effect", which accelerates the removal of older machines and reduces the average age of the capital stock. These effects alleviate, but are not strong enough to offset the direct impact of a tougher regulation on costs. Therefore, the authors conclude that, in this framework, we should not expect a win-win situation as such, but the trade-off between improving the environment and the competitiveness of the home industry is not as grim as is sometimes suggested because of favorable changes in the composition of the capital stock. Feichtinger et al (2005) revisit the analysis of Xepapadeas and de Zeeuw (1999), allowing for nonlinearities and focusing on learning and technological progress. They show that, under some circumstances, the results by Xepapadeas and de Zeeuw (1999) do not hold. In particular, they conclude that in the presence of learning, implementing a stricter environmental policy with the aim of reaching a certain target of emissions reduction has a stronger negative effect on industry profits, which renders results which are in sharp contrast to the Porter Hypothesis.

Popp (2005) offers an interpretation of the Porter Hypothesis based on the uncertain nature of R&D. In a 2-period simulation, a firm can perform R&D in the first period and it produces output using a dirty input, together with capital and labor, in the second period. The result of R&D is assumed to be uncertain to capture the fact that, in reality, some research projects are successful and others end in failure. In a benchmark situation without a (tough enough) environmental policy in place, the firms can be reluctant to undertake R&D projects. Once a tougher environmental regulation is enacted, the firms can find out that, in the new situation, R&D is profitable enough and, with a positive probability they can discover, a posteriori, that the project would have been profitable even without the policy prompting. Similarly, Kennedy (1994) shows that the cost of environmental regulation can be negative when innovation is subject to some uncertain element. If the firm is risk neutral, regulation necessarily raises expected costs but costs can be lower ex post for some realizations of the innovation process. If the firm is risk averse, regulation might reduce expected costs because it can induce the firm to undertake a level of research

closer to the cost-minimizing one.

Hart (2004) presents a growth model in which final output depends on different vintage intermediate goods that differ in their productivity and environmental damage. Skilled labour can be allocated between production vintages and research to develop new designs. This model provides support for a Porter-related hypothesis, according to which a tax on final goods produced using dirty intermediates could lead to an increase in research effort and, at least possibly, an increase in the long-term growth rate. The main drivers of these results are the possibility of research under-provision in the market economy and the possibility of developing environmentally friendly new designs.

9 Concluding remarks

It is not surprising that the Porter Hypothesis has generated some controversy because the idea itself is controversial as it challenges some central beliefs of the neoclassical paradigm. Certainly, such controversy is not due to Porter's claim that environmental policy can foster some types of innovation. This statement is not difficult to accept and, actually, is not new in economics. As noted by Ambec et al (2013), the idea that regulation can spur technological innovation is based on the concept of induced innovation, which goes all the way back to Hicks (1932). The controversy stems from the idea that, under some circumstances, such innovation is likely to result in gains that could (perhaps more than) offset the costs of compliance.

As we have discussed above, the first reaction of economists to Porter's claim was to state that, if those offsets were observed in practice, they should be seen as an anecdote rather than a systematic phenomenon consistent with standard economic theory. Thus, under different formulations, the fundamental question underlying the related literature is: beyond anecdotal evidence, can Porter's claim take place with certain regularity in the framework of rationality? The theoretical contributions that we have reviewed in this chapter, together with other related ones that we have omitted for the sake of brevity, should convince even the most skeptical that it is indeed possible to find situations in which environmental regulation results in some economic benefits, either in the form of lower cost, higher firm's profit, enhanced competitiveness or even higher consumers' surplus,

and this type of result may well be due to strategic interaction between rational economic agents. Moreover, the opportunities to achieve such economic benefits might arise even if some of the conditions set by Porter and van der Linde fail to hold. In fact, under some circumstances, it is possible that firms increase their profits even without undertaking any innovation investment, such increases may happen in a purely domestic framework, without the need of considering international competition and they could arise even if the environmental regulation is not designed according to the principles stated by Porter and van der Linde.

To make this phenomenon compatible with rationality, it is possible to follow basically two lines of reasoning: first, that those opportunities were not present before the policy was applied and thus the opportunities were created by the regulation itself, and second, that the opportunities were present but the firms were not aware or could not take advantage of them. The first line includes the case in which the regulation creates or exacerbates scarcity rents, which allow the firms to obtain a higher profit although this is done at the expense of consumers. Also, the regulation may alleviate the information asymmetry within the firm, which would benefit the firm at the expense of the managers. Finally, the regulation could also alleviate information asymmetry in the output market, which is likely to benefit consumers and high quality firms at the expense of low-quality cheating firms. In the second line, we have explored the existence of coordination problems among firms, which might be locked in to an old technology or a low-quality product equilibrium. While all the firms would benefit if they shifted to a cleaner technology or a high-quality product, they may refrain from doing so because they expect to enjoy a second-mover advantage. Environmental regulation can solve this coordination problem by prompting the firms to jump in altogether.

Having said that, some limitations of the validity of the Porter Hypothesis and its use as an argument to promote environmental regulation should be taken into consideration. The first warning, which was already present in the original Porter's contributions, is that we should not think that every environmental policy will induce the required innovations and even less that such innovations will always offset the compliance costs. Porter and van der Linde caution that, to achieve these aims, the regulation should be properly designed. Broadly speaking, the related literature is even more cautious than Porter and van der

Linde. In fact, the possibility that an environmental regulation generates a win-win situation is seen by most authors as a rather exceptional result that only appears under specific conditions. Apart from the regulation design, and depending on the specific channel by which Porter's result arises, other conditions are required. Basically, there should be some market failure other than the environmental externality, such that the regulation can help to solve both problems simultaneously.

Also, it is not reasonable to assume that the effect of environmental regulation is monotonic. To put this argument in simple and general terms, consider a specific situation involving an activity sector within a country, with a given technology, producing a certain good and working under a specific market structure. Assume that situation is propitious for the Porter Hypothesis to hold, for example, because of the existence of a coordination problem as those reported above. In the terminology commonly used in the literature, there are "low hanging fruits" that the regulation can help to harvest. Assume that, starting from that specific situation, a properly designed regulation is implemented, or the existing regulation becomes more stringent, which provides a win-win result entailing both environmental and economic benefits. Now, take the new situation with the tougher environmental regulation as the starting point and ask the question if the Porter Hypothesis would hold again. In other words, if the environmental regulation gets even tougher, would it render additional economic benefits? At this level of generality nothing can be stated with certainty, but it is reasonable to assume that, in most cases the answer would be probably not, because the low hanging fruits have already been collected and there are no more of them to be harvested. So, the answer to the question "will a more stringent environmental regulation result in economic benefits?" is extremely tricky and dependent on the starting conditions.

Another warning refers to the use of the Porter Hypothesis as an argument to promote environmental regulation. The fact that environmental policy may be beneficial for firms' competitiveness, or at least not as detrimental as is usually suggested, should not lead us to conclude that environmental regulation should be used primarily to pursue economic benefits. Those benefits should be seen as a positive side-effect to support the main objective, which should be to protect the environment. In this respect, Simpson and Bradford [50] conclude that, as a strategic trade policy, environmental regulation is inferior to other

instruments. André et al. (2009) conclude that profit-enhancing environmental regulation will not always make consumers be better off. On the other hand, somewhat paradoxically Mohr (2002) predicts that regulation-induced innovation will probably improve technology and increase output, but not necessarily decrease environmental impact.

The question if the Porter Hypothesis is true or not is difficult to address as such in theoretical terms but it is also difficult to address in empirical terms. Apart from the reasons stated above, the empirical work has additional difficulties such as the data collection, the selection of the statistical methods or the comparison between different socio-economic and geographic circumstances. Moreover, in those cases in which the evidence shows that a specific regulation has not provided the expected economic benefits, before concluding that the Porter Hypothesis should be rejected, it is necessary to make sure that the regulation under consideration has been properly designed according to the principles established by Porter and van der Linde (1995), which is not always easy to test.

Therefore, we cannot categorically affirm that the Porter Hypothesis is true or not in general terms, but still we can get some useful lessons from it. Probably, the most clear message is that, as noted by Xepapadeas and de Zeeuw (1999), the conflict between environmental protection and firms' competitiveness is probably not as grim as conventional economic thinking suggests. Related to this, since firms are likely to be reluctant to tougher regulations, they will probably exaggerate a priori the expected loss that they would face under such regulations. This is, by no means, an argument to use environmental regulation as an instrument to pursue non-environmental objectives, but it is an additional argument to defend the application of environmental policies when the balance between environmental benefits and economic costs is apparently unclear, as the economic costs are prone to be overestimated.

As a final reflection, the fulfillment of the Porter Hypothesis does not necessarily imply that environmental regulation does not entail any costs. What the regulation typically does is to reallocate the costs in a different way than before the regulation. Then, one important policy implication of our analysis is that, when designing environmental regulations, the authorities should pay special attention to the distributive effects and, specifically, they should identify the economic agents that will bear most of the costs. In this sense, the new generation information-disclosure policies may be of particular interest as, by revealing

hidden information to the market, they are likely to benefit the consumers as well as high-quality, efficient and truthfully reporting firms and shift the cost to low-quality, inefficient and cheating firms.

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10 Appendix. Notation

	– Numbers and indexes –
$N,\ n$	Number or downstream and upstream firms resp.
$D,\ F$	Domestic, foreign.
$H,\ L$	High, low (refers to quality).
$f,\ g$	Old (dirty) and new (clean) technology resp.
	– Output, prices and demand –
$q,\ Q$	Individual and market output resp.
$P,\ P(Q)$	Output price, inverse demand function.
s	Quality of output.
$\theta \in [\underline{\theta}, \overline{\theta}]$	Quality preference parameter.
$U = \theta s - P$	Consumer utility when consuming one unit with quality s at price P.
	– Inputs, costs, revenues and profits –
$l,\ K,\ x$	Labor, experience,abatement equipment.
y	Innovation expenses.
$C,\ c$	Total production cost, marginal production cost.
$a,\ a_H$	Fixed production cost, extra cost of producing high quality.
w	Price of abatement equipment.
β	Fixed development cost in the upstream sector.
$R,\ \pi$	Revenue, profit.
	- Emissions, damages and policy -
$e,\ d(e)$	Emissions, damage.
$t,\ T,\ \alpha$	Per unit tax, lump-sum tax, proportional tax refund.
$\bar{e}$	Emissions quota.
A	Fine for cheating.