The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness?

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Introduction

Some twenty years ago, Harvard Business School economist and strategy professor Michael Porter challenged the conventional wisdom about the impact of environmental regulation on business by arguing that well-designed regulation could actually increase competitiveness: "Strict environmental regulations do not inevitably hinder competitive advantage against rivals; indeed, they often enhance it" (Porter 1991, 168). Until that time, the traditional view of environmental regulation, held by virtually all economists, was that requiring firms to reduce an externality like pollution necessarily restricted their options and thus by definition reduced their profits. After all, if profitable opportunities existed to reduce pollution, profit-maximizing firms would already be taking advantage of them.

Over the past twenty years, much has been written about what has since become known simply as the Porter Hypothesis. Yet even today, we continue to find conflicting evidence concerning the Porter Hypothesis, alternative theories that might explain the Porter Hypothesis, and oftentimes a misunderstanding of what it does and does not say.

This article reviews the key theoretical foundations and empirical evidence to date concerning the Porter Hypothesis and identifies research challenges and opportunities concerning the links between environmental regulation, innovation, and competitiveness. Such a careful examination of both the theory and the empirical evidence can yield some useful insights for the

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design of regulatory instruments, as well as a rich research agenda for the future aimed at improving our understanding of the impact of environmental regulations on innovation and competitiveness.We start in the next section with a brief overview of the Porter Hypothesis and the variations on it that have been presented in the literature. Next, we discuss the theoretical arguments that have been proposed over the past twenty years to explain the Porter Hypothesis. Following the review of theory, we examine and evaluate the empirical evidence concerning the Porter Hypothesis and attempt to reconcile and explain some of the conflicting evidence and differing opinions on its validity. Next, we briefly discuss the implications of these theoretical and empirical findings for the design of policies aimed at promoting innovation and competitiveness. We conclude with an agenda for future research on this important policy issue.

An Overview of the Porter Hypothesis

Historically, the conventional wisdom among economists, policymakers, and business managers concerning environmental protection was that it comes at an additional cost to firms that may erode their global competitiveness. According to this traditional view, environmental regulations such as technological standards, environmental taxes, or tradable emissions forces firms to allocate some inputs (labor, capital) to pollution reduction, which is unproductive from a business perspective even if it offers environmental or health benefits to society. Technological standards restrict the choice of technologies or inputs in the production process. Taxes and tradable permits charge firms for emitting pollutants, a by-product of the production process that was previously free. These fees necessarily divert capital away from productive investments.

About twenty years ago, this traditional paradigm was contested by a number of economists, notably Professors Michael Porter (Porter 1991) and Claas van der Linde (Porter and van der Linde 1995a). Relying primarily on case studies, these researchers argue that pollution is often a waste of resources and that a reduction in pollution may lead to an improvement in the productivity with which resources are used. They argue that more stringent but properly designed environmental regulations (in particular, market-based instruments such as taxes or cap-and-trade emissions allowances) can "trigger innovation [broadly defined] that may partially or [in some instances] more than fully offset the costs of complying with them" (Porter and van der Linde 1995a, 98).

Porter was not the first to question mainstream economic views about the cost of environmental regulation. Arguments that pollution controls can spur the reduction of waste by businesses date back to the 1800s (Desrochers and Haight 2012). By the 1980s, some researchers had begun to examine whether environmental regulations could boost technology innovation without necessarily harming competiveness (Ashford 1993). But it is Porter who, building on this foundation, can be credited with bringing these ideas into the mainstream business and policy debate—and inspiring two decades of research into the "Porter Hypothesis."

Causal Links in the Porter Hypothesis

Figure 1 summarizes the main causal links involved in the Porter Hypothesis. As Porter and van der Linde (1995a) described this relationship, if properly designed, environmental regulations

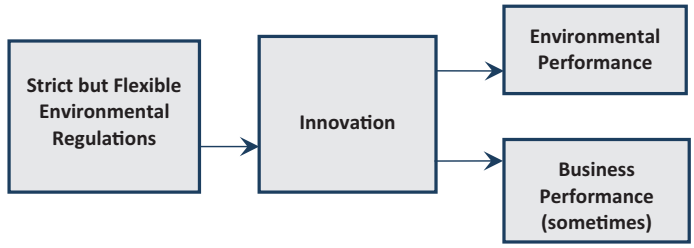

Figure 1 Schematic representation of the Porter Hypothesis

can lead to "innovation offsets" that will not only improve environmental performance, but also partially—and sometimes more than fully—offset the additional cost of regulation.

Porter and van der Linde (1995a, 99–100) go on to explain that there are at least five reasons why properly crafted regulations may lead to these outcomes:

- "First, regulation signals companies about likely resource inefficiencies and potential technological improvements."
- "Second, regulation focused on information gathering can achieve major benefits by raising corporate awareness."
- "Third, regulation reduces the uncertainty that investments to address the environment will be valuable."
- "Fourth, regulation creates pressure that motivates innovation and progress."
- "Fifth, regulation levels the transitional playing field. During the transition period to innovation-based solutions, regulation ensures that one company cannot opportunistically gain position by avoiding environmental investments."

Finally, they note, "We readily admit that innovation cannot always completely offset the cost of compliance, especially in the short term before learning can reduce the cost of innovation-based solutions" (Porter and van der Linde 1995a, 100).

Reactions to the Porter Hypothesis

The Porter Hypothesis has attracted widespread attention in the political arena, especially in the United States (Gore 1992), because it contradicts the widely held view that environmental protection is always detrimental to economic growth. In fact, a summary of a conference sponsored by the Environmental Protection Agency (EPA) in 1992 concluded that "Complying with environmental requirements can lead to a net cost savings for companies [and] . . . improves the international competitiveness of those companies and the U.S. economy in general" (US EPA 1992, iii). The Porter Hypothesis has also triggered extensive scholarly debate and analysis, and Porter and van der Linde (1995a) has become one of the most highly cited articles in the interdisciplinary field of "business and the environment."[1] The Porter Hypothesis has been invoked to persuade the business community to accept environmental

[1]Hoffman (2011) lists Porter and van der Linde (1995a) as the number 5 most highly cited article, followed by a companion piece, Porter and van der Linde (1995b), published in the *Harvard Business Review*.

regulations as something that might ultimately benefit their business or industry.[2] In a nutshell, the argument is that well-designed environmental regulations may lead to a Pareto improvement (i.e., improving the environment while not reducing business profits) or a "win–win" situation in some cases, by not only protecting the environment, but also enhancing profits and competitiveness through the improvement of products or their production processes.

The Porter Hypothesis was also criticized by Palmer, Oates, and Portney (1995) and others for being incompatible with the assumption that firms are profit maximizing. In other words, why would regulation be needed to encourage firms to adopt profit-increasing innovations? In fact, the Porter Hypothesis is based on the idea that firms often ignore profitable opportunities. Indeed, Porter (1991) directly questions the view that firms are always profit-maximizing entities: "The possibility that regulation might act as a spur to innovation arises because the world does not fit the Panglossian belief that firms always make optimal choices."[3]

If systematically profitable business opportunities ("low-hanging fruits") are being missed, then the question is whether environmental regulations can change that reality. Are regulators in a better position than managers to find these profitable business opportunities? Porter argues that environmental regulation may help firms identify inefficient uses of costly resources. They may also produce and disseminate new information (e.g., best-practice technologies) and help overcome organizational inertia.

Variations on the Porter Hypothesis

The literature contains conflicting accounts of what the Porter Hypothesis actually says, and different versions of the hypothesis have been proposed and tested. As we noted earlier, the Porter Hypothesis does *not* say that *all* regulations lead to innovation—only that well-designed regulations do. This is consistent with the growing trend toward performance-based and/or market-based environmental regulations. Second, it does *not* state that this innovation *always* offsets the cost of regulation. Instead, the Porter Hypothesis claims that in many instances, these innovations will more than offset the cost of regulation.

Researchers have generally disaggregated the Porter Hypothesis into its component parts in order to test the theory and the empirical evidence for the hypothesis. Jaffe and Palmer (1997) first distinguished among the "weak," "narrow," and "strong" versions of the Porter Hypothesis. First, properly designed environmental regulation may spur innovation (as shown in the first two boxes of Figure 1). This has often been called the "weak" version of the Porter Hypothesis because it does not indicate whether that innovation is good or bad for firms. Of course, the notion that regulation may spur technological innovation is not a new idea in economics and would not itself have led to the controversy about the Porter Hypothesis.[4] The

[2]Closely related to the Porter Hypothesis, in the early and mid 1990s, business and strategy leaders began to argue that firms can enhance their bottom lines by voluntarily reducing pollution *beyond* legal requirements (see Elkington 1997; Esty and Porter 1998). Anecdotal evidence cited by these authors as well as Porter and van der Linde (1995a, 1995b) indicates that companies—often prodded by government or nonprofits—that went beyond legal requirements saved money and increased profits. An examination of these voluntary actions is beyond the scope of this article, but such actions have been analyzed previously in this journal (see Portney 2008; Reinhardt, Stavins, and Vietor 2008).

[3]As discussed later, firms might not appear to be making optimal choices for many reasons, such as imperfect information or organizational or market failures.

[4]In fact, 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).

second part of the Porter Hypothesis (the lower right-hand side of Figure 1) is that in many cases this innovation more than offsets any additional regulatory costs—in other words, environmental regulation can lead to an increase in firm competitiveness. This has often been called the "strong" version of the Porter Hypothesis. Finally, in what has been called the "narrow" version of the Porter Hypothesis, it is argued that flexible regulatory policies give firms greater incentives to innovate and thus are better than prescriptive forms of regulation. Indeed, Porter (1991) challenges regulators to examine the likely impacts of their actions and to choose those regulatory mechanisms, particularly economic instruments, that will foster innovation and competitiveness. Thus the "narrow" version of the Porter Hypothesis is largely a restatement of the economist's preference for performance-based or market-based regulation over command-and-control approaches.

The Theory Underlying the Porter Hypothesis

Over the last twenty years, this controversy over what the Porter Hypothesis actually says and means has given rise to a large economics literature on the theoretical arguments underlying it. Among the theoretical approaches taken to explain the Porter Hypothesis are behavioral arguments, market failures (market power, asymmetric information, research and development [R&D] spillovers), and organizational failure. This section briefly reviews each of these approaches.

Behavioral Arguments

One set of studies relies on the emerging behavioral economics literature to depart from the assumption of profit-maximizing firms. This literature argues that the rationality of the firm is driven by its manager, who has motivations and objectives other than profit maximization. More specifically, the manager may be risk averse (Kennedy 1994), resistant to any costly change (Aghion, Dewatripont, and Rey 1997; Ambec and Barla 2007), or rationally bounded (i.e., limited by information or cognitive ability to process options and make good decisions) (Gabel and Sinclair-Desgagné 1998). Thus the manager misses good investment opportunities (from the point of view of the firm's profit) because they are either too risky, too costly (for the manager but not for the firm), or out of the manager's habits and routines. For example, in Ambec and Barla (2006), the manager has present-biased preferences that cause her or him to put off investment in profitable but costly opportunities ("low-hanging fruits"). Because the cost of innovating occurs "now" but the benefit occurs "later," a present-biased manager tends to postpone any investments in innovation. By making those investments more profitable or requiring them, environmental regulations help the manager overcome this self-control problem, which enhances firm profits.[5] Thus this literature justifies the existence of "win–win" opportunities based on the notion that regulation requires certain behaviors that are ultimately profit maximizing for the firm but might not otherwise be chosen by the manager.

[5]See also Chowdhury (2010) and Kriechel and Ziesemer (2009) on timing issues.

Market Failures

A second set of studies reconciles the apparent contradiction between the Porter Hypothesis and profit maximization by assuming there is a "market failure" in addition to the environmental externality problem. Unlike the previous case, here firms are assumed to seek profit maximization; however, market failures prevent them from fully realizing their profit potential—something that might be partially overcome through regulation.

Market power

The first market failure assumption is market power. Simpson and Bradford (1996) show that when there is imperfect competition among firms, a government may provide a strategic advantage to its domestic industry by imposing a more stringent environmental regulation. This paper formalizes the popular idea that a firm or a country can enjoy a first-mover advantage by becoming "green" sooner than its competitors (Lieberman and Montgomery 1988). As noted by Barrett (1994), the environmental regulation may even be too strong if it leads to more pollution abatement than in the first-best case. In this way, countries can use stringent environmental regulations as a strategic device to increase domestic firms' market share.[6] In a related paper, Rege (2000) examines the role of government in monitoring and regulating product claims to ensure that consumers who want environmentally friendly products will be able to purchase them rather than buying products falsely claiming to be green.

Mohr and Saha (2008) argue that when there are barriers to entry, environmental regulations may benefit existing firms by creating "scarcity rents." That is, prices will increase as firms reduce production in reaction to limits or fees on pollution emissions. For example, emissions permits that are allocated freely to existing polluters will make entry into the industry relatively more costly as incumbent firms will have lower costs, thus decreasing overall competition among firms.[7] Finally, André, González, and Portiero (2009) show that with imperfect competition but differentiated products, a minimum standard for environmental product quality may benefit all firms by solving a coordination problem (i.e., allowing them to reach a Pareto-improving equilibrium).

Asymmetric information

Asymmetric information in markets is another market failure that might reconcile profit maximization with the Porter Hypothesis. As emphasized by Ambec and Barla (2007), asymmetric information about environmental quality creates a "market-for-lemons" result where only "brown" (i.e., dirty) products are supplied under fierce competition among firms. Environmental regulations such as green labels reveal information that benefits firms supplying high environmental quality products. These regulations may also benefit firms specializing in "brown" products by vertically differentiating products, thereby reducing competition among firms. In Constantatos and Herrmann (2011), the lag between the time that firms invest in green products and when consumers observe the environmental quality of goods reduces the

[6]As discussed in Ulph and Ulph (1994), this result depends on many factors, including the nature of competition (e.g., Cournot versus Bertrand—output versus price competition), and how the R&D process impacts abatement and production costs.

[7]Note that unlike the Porter Hypothesis, the rent scarcity argument does not require that innovation occur for firms to benefit from environmental regulation.

profitability of producing a green product. Thus environmental regulations that force firms to produce green products help them reach a Pareto-improving equilibrium where there is no first-mover disadvantage from investing in this new innovation. In Mohr and Saha (2008), consumers' willingness to pay for products increases with the environmental performance of the entire industry, not the environmental performance of individual firms. Thus, with limited entry, reducing the industry's pollution raises prices, which benefits all firms in the industry.

R&D spillovers

The public good nature of knowledge is another market failure that lends support to the Porter Hypothesis. Mohr (2002) models investment in R&D with technological spillovers in a dynamic framework. Thus, in each period, firms learn about new technologies implemented by their competitors. Mohr (2002) finds that when the return on a firm's R&D investment is partly captured by its competitors, firms underinvest in cleaner and more productive technologies. Thus an environmental regulation that forces adoption may switch the industry from an equilibrium with low investment in R&D to a Pareto-improving equilibrium with higher investments in R&D.[8] Greaker (2003) also cites technological spillovers as a market failure that provides a theoretical foundation for the Porter Hypothesis.[9]

Some economists have argued that although environmental regulations lead to investment in innovation and technological change, thereby improving productivity, this comes at a cost to firms. Xepapadeas and Zeeuw (1999) analyze the impact of environmental regulations on capital and find that an emissions tax may lead to the retirement of older vintage capital, thereby increasing average productivity. However, they also find that there is a negative impact on profit. In contrast, Feichtinger et al. (2005) show that an emissions tax may increase the average age of capital. In a related article, Popp (2005) argues that uncertain returns to R&D can help explain why researchers observe individual firms or industries for which the cost of environmental regulation is completely offset, but economy-wide studies typically find that environmental regulation has a net cost. That is, because the returns to R&D are highly skewed, some innovations will result in significant cost savings even if the average innovation does not.

Organizational Failure

A related approach uses the notion of "organizational failure" to reconcile the Porter Hypothesis with the assumption of a profit-maximizing firm. This literature formalizes Porter's argument that environmental regulation may overcome organizational inertia. Ambec and Barla (2002) find that informational asymmetries within the firm concerning technologies might lend support to the Porter Hypothesis. For example, if managers have private information about the real costs of new technologies that enhances both productivity and environmental performance, they may use the information opportunistically by exaggerating these costs, thereby extracting some rent from the firm. In this situation, if the government imposes an environmental regulation, the rent that managers extract is lowered, thus benefiting the firm. The regulation will be profitable for the firm if the rent saved offsets the cost of

[8]For a counterargument, see Gans (2010), who shows that more stringent climate change policies will not necessarily lead to more innovation. Indeed, it is demonstrated that a tighter emissions cap will reduce the scale of fossil fuel usage, which diminishes incentives to improve fossil fuel efficiencies.
[9]However, Greaker (2003) includes an upstream market for innovation.

complying with the regulation. Thus the regulation may help the head of the firm to increase profits by fostering technological innovation at lower organizational costs (i.e., by overcoming some of the informational advantage of firm managers).

Empirical Evidence for the Porter Hypothesis

Numerous researchers have also tested the Porter Hypothesis empirically. Generally, these studies fall into three categories: those testing the "weak" version, those testing a "strong" version focused on firm-level performance, and those testing a "strong" version focused on country-level competitiveness. This section reviews the findings of these three empirical approaches.

Testing the "Weak" Version of the Porter Hypothesis

There is a large body of literature that analyzes the "weak" version of the Porter Hypothesis—that properly designed environmental regulation may spur innovation (the link between the first and second steps in the chain presented in Figure 1). In practice, innovation is generally assessed through R&D expenses (input) or through the number of registered patents (the product of R&D activity). However, as Porter and van der Linde (1995a, 98) emphasize, innovation is more than just technological change and can take various forms including "a product's or service's design, the segments it serves, how it is produced, how it is marketed and how it is supported."

An example of the literature that assesses innovation through R&D expenditures or patents is Jaffe and Palmer (1997), who estimate the relationship between pollution abatement costs (a proxy for the stringency of environmental regulation) and total R&D expenditures (or the number of successful patent applications). They find a positive link with R&D expenditures (an increase of 0.15 percent in R&D expenditures for a pollution abatement cost increase of 1 percent), but no statistically significant link with the number of patents. However, examining only environmentally related successful patent applications, Lanjouw and Mody (1996), Brunnermeier and Cohen (2003), Popp (2003, 2006), Arimura, Hibiki, and Johnstone (2007), Johnstone, Hascic, and Popp (2010), Lanoie et al. (2011), and Lee, Veloso, and Hounshell (2011) all find a positive relationship with environmental regulation. Johnstone, Hascic and Popp (2010) also find evidence that both the stability and flexibility of environmental regulations have distinct effects on innovation (i.e., impacts that are separate from those due to the regulation's stringency).

Concerning the relationship between environmental regulations and the firm's technological choices, two older studies emphasize a negative relationship between environmental regulations and investment in capital. Nelson, Tietenberg, and Donihue (1993) find that air pollution regulations significantly increased the age of capital in US electric utilities in the 1970s.[10] According to Gray and Shadbegian (1998), more stringent air and water regulations had a significant impact on paper mills' technological choice in the United States. However, their

[10]However, as discussed later, this finding should not be surprising given that US regulations imposed more stringent requirements on new sources and are thus likely an example of regulations that are not properly designed to encourage innovation.

results suggest that such regulations tend to divert investment from productivity to abatement, which is consistent with the standard paradigm (i.e., that regulation is costly).

To summarize, there is a relatively large literature that has examined the link between environmental regulation (oftentimes measured as compliance costs) and innovation (measured as either R&D expenditures or patents). On balance, these studies conclude that there is a positive link between environmental regulation and innovation, although the strength of the link varies.

Testing a "Strong" Version of the Porter Hypothesis (Firm-Level Performance)

The second empirical approach assesses the impact of environmental regulation on the business performance of the firm (the link between the first and last steps in the chain presented in Figure 1). However, this "strong" version of the Porter Hypothesis, which is often measured by the firm's productivity, is tested without looking at the cause of any variation in business performance (i.e., whether it is linked to innovation or another cause).

This second approach, which is reviewed in Jaffe et al. (1995), has a long tradition in the economics literature. Most of the studies reviewed in Jaffe et al. (1995) find that environmental regulation has a negative impact on productivity. For instance, Gollop and Roberts (1983) estimate that sulfur dioxide (SO_2) regulations slowed down productivity growth in the United States in the 1970s by 43 percent. However, several more recent studies find more positive results. For example, Berman and Bui (2001) report that refineries located in the Los Angeles area enjoyed significantly higher productivity than other US refineries despite the more stringent air pollution regulation in Los Angeles. Similarly, Alpay, Buccola, and Kerkvliet (2002) find that the productivity of the Mexican food-processing industry is increasing with the pressure of environmental regulation, which leads them to conclude that more stringent regulation is not always detrimental to productivity.

Testing Both the "Weak" and "Strong" Versions of the Porter Hypothesis

Lanoie et al. (2011) examine both the weak and strong versions of the Porter Hypothesis, for the first time assessing the whole Porter causality chain. The data come from a unique Organisation for Economic Co-operation and Development (OECD) survey of more than four thousand companies located in seven industrialized countries.[11] Lanoie et al. (2011) conduct a regression analysis of three equations,[12] using the three dependent variables from Figure 1: environmental innovation, environmental performance, and business performance. The results indicate a positive and significant link between the perceived stringency of environmental regulations and environmental innovation, which is consistent with the weak version of the Porter Hypothesis. Furthermore, the "predicted" environmental innovation from the first regression has a positive and significant impact on business performance. This provides evidence of the causal link suggested by the strong form of the Porter Hypothesis—that regulation spurs innovation, which further enhances business performance. However, Lanoie et al. (2011) also find that environmental regulation has a direct negative effect on business performance. They conclude that the net effect is negative—that is, the positive effect of innovation on

[11]Details of the OECD survey are available at www.oecd.org/env/cpe/firms.
[12]The equations are estimated using two-stage least squares.

business performance does not outweigh the negative effect of the regulation itself. These results suggest that environmental regulation is costly, but less so than if one was to consider only the direct costs of the regulation itself.

Static versus Dynamic Tests of the Porter Hypothesis

It is important to note that most previous studies have not adequately accounted for the *dynamic* dimensions of the Porter Hypothesis. Porter argues that more stringent environmental policies will lead to innovations to reduce inefficiencies, which, in turn, will eventually reduce costs. However, this process may take some time. Most previous studies of the determinants of productivity have regressed productivity at time 0 on proxies of the stringency of environmental regulation at time 0 as well, which does not allow time for the innovation process to occur. In contrast to earlier studies, by introducing lags of three or four years between changes in the stringency of environmental regulations and any resulting changes in productivity, Lanoie, Patry, and Lajeunesse (2008) find that stricter regulations led to modest long-term gains in productivity in a sample of seventeen Quebec manufacturing sectors.[13] They show that this effect is more important in industries that are highly exposed to outside competition. Future research should focus more on these dynamic impacts.

Summary of Empirical Findings on Business Performance ("Strong" Version)

To summarize, the empirical evidence on the impact of environmental regulation on business performance (generally measured as firm- or industry-level productivity) suggests a negative relationship, contrary to the strong version of the Porter Hypothesis. However, these studies are generally cross-sectional or two-period models. The only study to date that attempts to measure this relationship over long time periods (Lanoie et al. 2008) produces results that support the strong version of the Porter Hypothesis (i.e., that there is a positive relationship between environmental regulation and firm-level performance). Further research is clearly needed in this area.

Testing a "Strong" Version (Country-Level Competitiveness)

A third empirical approach to evaluating the Porter Hypothesis is to examine competition among nations, which returns to the original hypothesis (Porter 1991) that environmental regulation will enhance a country's competitiveness. Much of the empirical literature on this issue turns the Porter Hypothesis on its head by examining the "pollution haven" hypothesis—that stringent environmental regulation will induce firms to leave the country for less strict (and hence less expensive) regulatory regimes. Of course, firms might move polluting facilities abroad for reasons other than to avoid environmental regulation, such as access to markets or differences in the cost of labor, land, transportation, and other inputs.

Much of the early literature on the pollution haven hypothesis (e.g., Jaffe et al. 1995) found evidence that is consistent with the Porter Hypothesis—that industries with more stringent regulations (generally proxied by higher pollution abatement costs) have lower net trade flows,

[13]More specifically, they find that stricter regulations reduced productivity in year 1 had a slightly positive effect in year 2, and resulted in even more positive outcomes in years 3 and 4, more than offsetting the first year's loss.

consistent with the Porter Hypothesis. However, as Copeland and Taylor (2004) and Brunnermeier and Levinson (2004) note in their literature reviews, both endogeneity and unobserved variables that are correlated with regulation may explain these results. Indeed, citing more recent literature, these authors conclude that while much work still needs to be done, the weight of the evidence supports the pollution haven hypothesis. Nevertheless, the magnitude of the effect of environmental regulation does not appear to be "strong enough to be the primary determinant of the direction of trade or investment flows" (Copeland and Taylor 2004, 48). Perhaps more important from the perspective of the Porter Hypothesis, few of the pollution haven hypothesis studies have distinguished among the types of regulatory mechanisms employed (e.g., countries that use command-and-control versus more market-based standards). Instead, they generally use pollution control costs or emissions levels (see, e.g., Quiroga, Persson, and Sterner 2009) as proxies for regulatory stringency. Although these variables may be reasonable measures of stringency, they do not provide information about whether countries with more stringent policies are using "good" (e.g., market-based) or "bad" (e.g., command-and-control) forms of environmental regulation.

To summarize the empirical findings concerning environmental regulation and country-level competitiveness, although more recent evidence suggests that countries with more stringent environmental regulations (generally measured as pollution abatement costs) become less competitive (which contradicts the Porter Hypothesis), this finding of a "pollution haven" is not the primary driver of trade flows. More importantly, to date, empirical studies have not been able to distinguish between "good" and "bad" regulation. Thus additional studies are needed that compare the competitiveness of nations based on their approach to environmental regulation.

Designing Policies to Enhance Innovation and Competitiveness

It is clear from both Porter's original writings and the empirical evidence that the impact of environmental regulation on innovation and competitiveness depends critically on the type of environmental policies that are implemented. The Porter Hypothesis is premised on flexible market-based environmental regulation, not rigid command-and-control regulation. Thus if the competitiveness or innovation benefits promised by Porter are to be realized, it is important that the right type of regulations be implemented (e.g., flexible, market based). However, government policies other than environmental regulations can also have an impact on the relationship between environmental policies and innovation or productivity. In this section, we briefly examine how the type of environmental (and nonenvironmental) policies can affect innovation and competitiveness.

Environmental Policies

Porter (1991) noted that the type of regulatory instrument is an important premise for the Porter Hypothesis. More specifically, Porter and van der Linde (1995a, 110) argue:

> If environmental standards are to foster the innovation offsets that arise from new technologies and approaches to production, they should adhere to three principles.

> First, they must create the maximum opportunity for innovation, leaving the approach to innovation to industry and not the standard-setting agency. Second, regulations should foster continuous improvement, rather than locking in any particular technology. Third, the regulatory process should leave as little room as possible for uncertainty at every stage.

Market-based and flexible instruments such as emissions taxes. tradable allowances, or performance standards are more conducive to innovation than technological standards because they leave more freedom to firms to find a technological solution to minimize compliance costs. Some researchers (e.g., Jaffe and Palmer 1997) call this the narrow version of the Porter Hypothesis. However, as noted earlier, this is not the main contribution of Porter because economists have long advocated market-based and flexible instruments. Nevertheless, there has been much research in this area that provides support/evidence for this "narrow" version of the Porter Hypothesis. For example, Burtraw (2000) finds evidence that the switch in US environmental regulations for SO_2 emissions in 1990 from a technological standard with emissions caps to an allowance trading program considerably reduced compliance costs (40 to 140 percent lower than projected), although the net effect was still a net cost. However, Burtraw (2000) also concludes that the switch from a command-and-control approach to a more flexible emissions trading program enhanced innovation and fostered organizational change and competition in the upstream input market. That is, the program gave firms the flexibility to select the best strategy for reducing emissions including a switch to coal with lower sulfur content. The industry also experienced innovation in fuel blending and in the scrubber market.[14] In addition, the switch from technological standard to tradable emissions allowances transferred responsibility for compliance from engineers or chemists, typically in charge of environmental issues, to top executives such as financial vice presidents, who are trained to treat SO_2 emissions allowances as financial assets. Thus market-based approaches appear to have spurred innovation in both technology as well as organizational processes.

Along the same lines, Hoglund Isaksson (2005) examines the impact of Sweden's decision in 1992 to impose a charge on nitrogen oxides (NO_x) emissions. Looking at the impact on the abatement cost functions of 114 combustion plants during the 1990–96 period, she finds that extensive emissions reductions occurred at zero or very low cost, primarily due to learning and technological developments that occurred during the period analyzed.

Lanoie et al. (2011) also provide indirect evidence on this issue, showing that performance standards are leading to more innovation than more prescriptive technological standards. Driesen (2005, 303) reviews the literature and concludes:

> Pollution taxes have a greater potential to promote innovation than either emissions trading (at least when permits are given away, rather than sold) or traditional regulation. Both emissions trading and performance standards produce incentives only to attain the standards government sets, rather than to go further. While trading does provide incentives for low cost sources to produce some "extra" credits, it does so only to the extent that high cost sources need credits to meet their limits. Once the high cost sources have purchased enough credits to attain

[14]The previous command-and-control regulation did not provide incentives to increase SO_2 removal by scrubbers. However, the new program provided incentives to upgrade existing scrubbers.

their limits, no further incentive to go beyond compliance exists. Pollution taxes, however, provide a continuous incentive for polluters to deploy innovations costing less than the marginal tax rate.

Moreover, if market-based instruments generate revenues (e.g., from taxes or permit auctioning), then the efficient recycling of those revenues can improve competitiveness outcomes. For example, Andersen et al. (2007) analyze environmental tax revenues in seven European Union countries that are recycled into other tax cuts (labor or income) and find a neutral or slightly positive net impact on gross domestic product.

Finally, Lankoski (2010, 6) reviews the empirical evidence to date on the impact of the type of policy instrument on competitiveness and reaches conclusions that are similar to those in Porter and van der Linde (1995a), that regulatory "policy should strive to be win–win compatible. This speaks in favour of policies that provide incentives to innovation, are stable and predictable, make use of suitable transition periods, focus on end results rather than means, and economic policy instruments."[15]

Industrial and Patent Policies

Industrial and patent policies may complement environmental regulation to protect the environment at the lowest cost to firms. For example, well-defined property rights for innovations can help reduce R&D spillovers that benefit all innovating firms while slowing diffusion. Mandatory licenses may also foster technological adoption—but at the risk of reducing the incentive to invest in R&D. Subsidies and tax credits for R&D spending may make technological change aimed at environmental compliance a more attractive strategy. Popp (2006) provides evidence that the timing of the introduction of more stringent environmental regulations has an impact on the number of patents issued for pollution abatement technology. More precisely, he finds that the introduction of stringent SO_2 and NO_x standards in the United States, Germany, and Japan has led to a large increase in the number of patents issued on related abatement technologies in each of the three countries. Interestingly, the transfer of technologies occurs across countries, although indirectly: earlier patents issued in other countries are cited in the new patent applications. Lee et al. (2011) found similar evidence that stringent automobile emissions standards implemented in the United States induced domestic firms to increase their patenting activities relative to foreign competitors. In the same vein, Dechezlepêtre, Glachant, and Ménière (2011) examine the international transfer of technologies related to climate change mitigation policies, such as wind and solar power, and find that more stringent intellectual property rights in a country seem to encourage the diffusion of green power technologies.[16]

Training

Under the Porter Hypothesis, improved productivity or competitiveness depends heavily on the possibility of low-hanging fruit, although new technological innovations are also important. Because busy managers, especially in small and medium enterprises (SMEs), may not always have the time and the technical expertise to identify these profitable opportunities, training

[15]See also the discussion in Wagner (2006).

[16]Maskus (2010) provides a discussion of intellectual property rights for environmental and climate technologies.

programs may be helpful. Rochon-Fabien and Lanoie (2011) investigate the benefits of a unique Canadian training program, the Enviroclub initiative, which was developed to help SMEs improve their profitability and competitiveness through enhanced environmental performance. An Enviroclub consists of a group of ten to fifteen SMEs, each of which is required to carry out one profitable pollution prevention project. Support is provided to the SMEs through workshops on various themes related to environmental performance and consultant services. The consultant analyzes the operations of the firm and recommends specific measures to prevent pollution and enhance business performance. The participating firm must then adopt at least one of these recommendations. Rochon-Fabien and Lanoie (2011) examined the first 187 projects produced through this program and conclude that all of them were profitable for the participating firms (i.e., they reduced both costs and pollution). Lyon and van Hoof (2009) find similar results for Mexico.

Organizational or Governance Issues

As noted earlier, Porter (1991) argues that organizational inertia may provide an explanation for firms missing profitable opportunities to both reduce pollution and increase profits. This is more likely to occur in firms with deficient governance structures including asymmetric information and misaligned incentives between firm owners and managers. Such organizational or governance failures either constrain the ability of managers to pursue profit-maximizing objectives or otherwise distort incentives within the firm. Environmental regulations may help firms overcome this organizational inertia by forcing them to review the organization of production and their business model. For example, based on the results of three case studies, Arjalies and Ponssard (2010) argue that the potential benefits envisioned by Porter were more likely to be realized in firms that viewed the treatment of environmental issues as an opportunity, and thus incorporated environmental management into their organizational processes and management system, than in firms that viewed environmental issues as a compliance-oriented task. Similarly, Burtraw (2000) argues that firms were more likely to take advantage of cost-reducing opportunities available to them under the US SO_2 trading program once responsibility for trading was shifted from environmental managers to financial officers. These examples illustrate the impact that organizational design can have on a firm's ability to reap some of the benefits of the well-designed regulations envisioned by Porter.

Recent efforts to increase corporate transparency and reporting (e.g., the Carbon Disclosure Project[17] and Global Reporting Initiative[18]), provide training on sustainability issues, hire corporate responsibility officers who often report directly to the board of directors, and appoint individuals with sustainability experience to firms' boards of directors all reflect actions that might further reduce organizational inertia, thus moving firms toward more strategic opportunities that might reduce costs or increase profits.

[17]The Carbon Disclosure Project is an investor-led organization that annually requests, reports, and widely circulates detailed information from the largest global companies concerning their carbon emissions and water use. See www.cdproject.net.

[18]The Global Reporting Initiative is a nonprofit international multi-stakeholder organization that sets guidelines for reporting on economic, environmental, social, and governance issues. As more firms use the common GRI framework for sustainability reporting, both internal and external stakeholders are better able to compare nonfinancial performance across firms. See www.globalreporting.org.

Conclusions and Directions for Future Research

More than twenty years ago, Michael Porter generated enormous interest among scholars, policymakers, businesses, and interest groups in the idea that well-designed regulation could actually enhance competitiveness. Indeed, much has been written since then about what has become known as the Porter Hypothesis. This article has provided an overview of the theoretical and empirical literature on the Porter Hypothesis. First, we find that the theoretical arguments for the Porter Hypothesis appear to be more solid now than when they were first discussed as part of the heated debate in the *Journal of Economic Perspectives* in 1995 (see Palmer et al. 1995). On the empirical side, the evidence for the "weak" version of the Porter Hypothesis (that stricter environmental regulation leads to more innovation) is fairly clear and well established. However, the empirical evidence on the strong version of the Porter Hypothesis (that stricter regulation enhances business performance) is mixed, but with more recent studies providing clearer support.[19]

Porter's suggestion that more stringent environmental protection may lead to "win–win" outcomes for society overall has stimulated extensive academic research and policy debates over the last twenty years and has no doubt contributed to significant environmental and economic improvements through better designed regulation. We owe Porter great thanks for this. The Porter Hypothesis continues to raise important issues and questions for both researchers and policymakers about how to design and implement policies that will induce environmental innovation and how to protect and diffuse these innovations among firms. We conclude with a discussion of the research challenges and opportunities concerning the relationship between environmental regulations, innovation, and competitiveness, which we have divided into four major categories.

Data and Methodological Issues

Much of the existing literature necessarily uses proxies for the key variables of interest. For example, in studies of innovation, environmental regulations are often proxied by environmental compliance costs. Yet the Porter Hypothesis does not argue that higher abatement costs will lead to innovation. Indeed, higher compliance costs might simply be attributable to older plants, for example, rather than more stringent regulatory standards. In fact, the Porter Hypothesis suggests that more stringent environmental standards lead to investment in R&D (or changes in processes, organizations, and so on), which in turn leads to innovation. The challenge for researchers is to find appropriate data that can be used to help us more fully understand and test the mechanisms by which regulation leads to innovation, and, ultimately, determine when these innovations increase or decrease costs.

One explanation for the conflicting empirical results concerning the Porter Hypothesis is that firm, industry, or environmental characteristics may affect the extent to which innovation offsets and productivity or competitiveness enhancements occur. What is it about manufacturing industries in Canada between 1985 and 1994 (Lanoie et al. 2008) or the US petroleum industry between 1987 and 1995 (Berman and Bui 2001) that caused them to increase their

[19]Brännlund and Lundgren (2009) reach similar conclusions about the more recent evidence on the strong version of the Porter Hypothesis.

productivity when faced with stricter environmental standards while just the opposite occurred among US paper mills between 1979 and 1990 (Gray and Shadbegian 2003)?

These types of inconsistencies and challenges abound in the literature on the Porter Hypothesis. Lankoski (2010) provides a helpful summary of these issues and notes that previous studies have identified fifty or more methodological or measurement problems that make it difficult to compare results across firms, industries, countries, time periods, and so on, and thus to draw conclusions. Future research is needed to refine and address these issues. In addition, an extensive meta-analysis might help uncover some of the underlying effects and thus shed more light on these issues.

Nonregulatory Policies

As noted earlier, there is some evidence that training programs can provide helpful information to environmental managers about more productive (and perhaps even profitable) approaches to environmental protection. Related to direct training on better compliance approaches are the growing number of voluntary programs such as the 33/50 and ENERGY STAR programs in the United States.[20] Although these programs are generally designed to provide companies with information and/or incentives that encourage them to go beyond compliance—either to reduce costs or to increase demand for their products—they may have the significant ancillary benefits of increasing compliance with existing regulations.

There is also growing evidence that mandatory disclosure programs have resulted in improvements in environmental performance. For example, although Hamilton (1995) finds that on average, firms lost market value on the day that the first Toxic Release Inventory (TRI)[21] numbers were made public in the United States, Konar and Cohen (1997) find that firms with the largest stock price declines have subsequently reduced their emissions the most. More importantly, Konar and Cohen (2001) find that subsequent reductions in TRI numbers have increased the intangible asset value of firms. These and other similar findings raise the interesting question of whether the net impacts of indirect forms of regulation such as mandatory disclosure are positive or negative.

There are other actors besides the government whose policies might interact with the regulation-innovation-competitiveness links. As mentioned earlier, the trend toward increased transparency, whether through voluntary corporate reporting, quasi-mandatory requirements from stock exchanges or other agencies, or third-party reporting such as the Carbon Disclosure Project or www.scorecard.org, might reduce organizational inertia. This would also appear to be a fruitful area for future research.

Longitudinal Studies

As noted earlier, one reason for the mixed empirical results concerning the link between environmental regulation and competitiveness is the inability of previous studies to adequately

[20]The 33/50 program was designed by the US EPA to encourage firms to reduce their toxic emissions voluntarily by 33 percent in 1992 and 50 percent in1995. See http://www.epa.gov/oppt/3350/. The ENERGY STAR program (a joint program of EPA and the US Department of Energy) provides product labels to manufacturers that meet energy efficiency guidelines. See www.energystar.gov.

[21]The TRI program requires facilities to disclose to the EPA (and ultimately to the public) their disposal practices and emissions of hundreds of toxic chemicals. See www.epa.gov/TRI.

capture the lag structure of innovation. Although Brunnermeier and Cohen (2003) find a positive relationship between lagged compliance costs and innovation and Lanoie et al. (2008) find a positive relationship between lagged regulatory stringency and productivity, most previous studies have relied on contemporaneous comparisons. Because innovations may take several years to develop, and capital expenditures are often delayed for a few years through normal budgetary cycles and building lags, future studies that carefully examine the dynamic nature of the relationship between regulation, innovation, productivity, and competitiveness would be helpful.

Lankoski (2010) suggests that this difference in treating lag structures is one reason why earlier studies were more likely to reject the Porter Hypothesis; recent studies have been more favorable. However, another possible explanation for more recent studies finding empirical support for the Porter Hypothesis is simply that the world has changed over time. We now have more experience with market-based regulation of the form advocated by Porter. There is also a heightened social consciousness around sustainability, in the form of both green products and corporate social responsibility. Thus the "value" of improving environmental performance may have increased over time, which means that firms are more able to profit from their environmental initiatives than in the past, and that the Porter Hypothesis may be more relevant today. Although capturing these effects in a longitudinal study would be a challenge, it could provide important and more current policy-relevant results and help reconcile some of the conflicting evidence from previous studies.

Global Studies

As data sets become more global and our ability to make cross-country comparisons with meaningful detailed data increases, future research should also focus on competitiveness across nations. As mentioned earlier, there is growing (but still not conclusive) evidence that countries with more stringent environmental regulations are less competitive in those regulated sectors (see the reviews in Esty [2001] and Ederington [2010]). Future research might distinguish among command-and-control, performance-based, and market-based instruments to determine whether the form of regulation has an impact on these findings.

References

Aghion, P., M. Dewatripont, and P. Rey. 1997. Corporate governance, competition policy and industrial policy. *European Economic Review* 41: 797–805.

Alpay, E., S. Buccola, and J. Kerkvliet. 2002. Productivity growth and environmental regulation in Mexican and U.S. food manufacturing. *American Journal of Agricultural Economics* 84 (4): 887–901.

Ambec, S., and P. Barla. 2002. A theoretical foundation of the Porter Hypothesis. *Economics Letters* 75 (3): 355–60.

———. 2006. Can environmental regulations be good for business? An assessment of the Porter Hypothesis. *Energy Studies Review* 14 (2): 42–62.

———. 2007. Quand la réglementation environnementale profite aux pollueurs. Survol des fondements théoriques de l'hypothèse de Porter. *L'Actualité économique* 83 (3): 399–414.

Ambec, S., and P. Lanoie. 2008. Does it pay to be green? A systematic overview. *Academy of Management Perspectives* 22: 45–62.

Andersen, M. S., S. Junankar, S. Scott, J. Jilkova, R. Salmons, and E. Christie. 2007. Competitiveness

effects of environmental tax reforms (COMETR): Publishable final report to the European Commission, http://www2.dmu.dk/cometr/.

André, J. F., P. González, and N. Portiero. 2009. Strategic quality competition and the Porter Hypothesis. *Journal of Environmental Economics and Management* 57: 182–94.

Arimura, T., A. Hibiki, and N. Johnstone. 2007. An empirical study of environmental R&D: What encourages facilities to be environmentally-innovative?, In *Corporate behaviour and environmental policy*, ed. N. Johnstone Cheltenham, UK: Edward Elgar in association with OECD.

Arjalies, D. L., and J. P. Ponssard. 2010. A managerial perspective on the Porter Hypothesis: The case of CO_2 emissions. Ecole Polytechnique, Paris, http://hal.archives-ouvertes.fr/docs/00/44/58/47/PDF/2010-02.pdf.

Ashford, N. A. 1993. Understanding technological responses of industrial firms to environmental problems: Implications for government policy. In *Environmental strategies for industry*, ed. K. Fischer, and J. Schot, 277–307. Washington, DC: Island Press.

Barbera, A. J., and V. D. McConnell. 1990. The impact of environmental regulations on industry productivity: Direct and indirect effects. *Journal of Environmental Economics and Management* 18: 50–65.

Barla, P., C. Constantatos, and M. Herrmann. 2008. Environmental regulation as a coordination device for introduction of a green product: The Porter's Hypothesis revisited. *Document de travail.* Québec, Canada: Université Laval.

Barrett, S. 1994. Strategic environmental policy and international trade. *Journal of Public Economics* 54: 325–38.

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

Brännlund, R., and T. Lundgren. 2009. Environmental policy without costs? A review of the Porter Hypothesis. *International Review of Environmental and Resource Economics* 3 (2): 75–117.

Brown, J. B., and P. J. Wilcoxen. 2003. Environmental regulation: Does federally mandated pollution abatement investment lead to less productive investment? Mimeograph. Syracuse University.

Brunnermeier, S. B., and M. A. Cohen. 2003. Determinants of environmental innovation in US manufacturing industries. *Journal of Environmental Economics and Management* 45: 278–93.

Brunnermeier, S. G., and A. Levinson. 2004. Examining the evidence on environmental regulations and industry location. *Journal of Environment & Development* 13 (6): 6–41.

Burtraw, D. 2000. Innovation under the tradable sulfur dioxide emission permits program in the U.S. electricity sector. Discussion paper 00-38. Washington, DC: Resources for the Future.

Chowdhury, P. R. 2010. The Porter Hypothesis and hyperbolic discounting. Indian Statistical Institute.

Copeland, B. R., and M. S. Taylor. 2004. Trade, growth and the environment. *Journal of Economic Literature* 42: 7–71.

Constantatos, C., and M. Herrmann. 2011. Market inertia and the introduction of green products: Can strategic effects justify the Porter Hypothesis? *Environmental and Resource Economics* 50: 267–84.

Crotty, J., and M. Smith. 2008. Strategic responses to environmental regulation in the U.K. automotive sector: The European Union end-of-life vehicle directive and the Porter Hypothesis. *Journal of Industrial Ecology* 10 (4): 95–111.

Dechezleprêtre, A., M. Glachant, and Y. Ménière. 2011. What drives the international transfer of climate change mitigation technologies? Empirical evidence from patent data. CERNA working paper, Mines ParisTech.

Desrochers, Pierre, and Colleen E. Haight. 2012. Squandered profit opportunities? Some historical perspective on industrial waste and the Porter Hypothesis. Mimeograph. Economics Department, San Jose State University.

Driesen, D. 2005. Economic instruments for sustainable development. In *Environmental law for*

sustainability: A critical reader, ed. S. Wood., and B. Richardson. Chapter 9. Oxford, UK: Hart Publications. http://law.syr.edu/Pdfs/0osgoodehall boo.pdf.

Dufour, C., P. Lanoie, and M. Patry. 1998. Regulation and productivity. *Journal of Productivity Analysis* 9: 233–47.

Ederington, J. 2010. Should trade agreement include trade policy? *Review of Environmental Economics and Policy* 4 (1): 84–102.

Elkington, J. 1997. Cannibals with forks: The triple bottom line of 21st century business. Oxford, UK: Capstone.

Esty, D. 2001. Bridging the trade-environment divide. *Journal of Economic Perspectives* 15 (3): 113–30.

Esty Daniel, C., and E. Michael Porter. 1998. Industrial ecology and competitiveness: Strategic implications for the firm. *Journal of Industrial Ecology* 2 (1): 35–44.

———. 2002. Ranking national environmental regulation and performance: A leading indicator of future competitiveness? In *The global competitiveness report 2001-2002*, ed. Porter, Michael E., Jeffrey D. Sachs, John W. McArthur, 78-100. New York: Oxford University Press.

———. 2005. National environmental performance: An empirical analysis of policy results and determinants. *Environment and Development Economics* 10 (4): 391-434.

Fare, R., S. Grosskopf, C. A. K. Lovell, and C. Pasurka. 1989. Multilateral productivity comparison when some outputs are undesirable: A nonparametric approach. *Review of Economics and Statistics* 71: 90–98.

Feichtinger, G., R. F. Hartl, P. M. Kort, and V. M. Veliov. 2005. Environmental policy, the Porter Hypothesis and the composition of capital: Effects of learning and technological progress. *Journal of Environmental Economics and Management* 50 (2): 434–46.

Gabel, H. L., and B. Sinclair-Desgagné. 1998. The Firm, its routines, and the environment. In *The international yearbook of environmental and resource economics 1998/1999: A survey of current issues*, ed. Folmer, H., and T. Tietenberg. Cheltenham, UK: Edward Elgar.

Gans, J. S. 2010. Innovation and climate policy. University of Melbourne, http://works.bepress.com/joshuagans/24/.

Gollop, F. M., and M. J. Roberts. 1983. Environmental regulations and productivity growth: The case of fossil-fuelled electric power generation. *Journal of Political Economy* 91 (4): 654–74.

Gore, A. 1992. *Earth in the balance: Ecology and the human spirit*. New York: Houghton Mifflin.

Gray, W. B. 1987. The cost of regulation: OSHA, EPA and the productivity slowdown. *American Economic Review* 77 (5): 998–1006.

Gray, W. B., and R. J. Shadbegian. 1998. Environmental regulation investment timing, and technology choice. *Journal of Industrial Economics* 46 (2): 235–56.

———. 2003. Plant vintage, technology, and environmental regulation. *Journal of Environmental Economics and Management* 46: 384–402.

Greaker, M. 2003. Strategic environmental policy: Eco-dumping or a green strategy? *Journal of Environmental Economics and Management* 45 (3): 692–707.

Hamilton, J. T. 1995. Pollution as news: Media and stock market reactions to the toxics release inventory data. *Journal of Environmental Economics and Management* 28: 98–113.

Hicks, J. R. 1932. *The theory of wages*, 1st ed. London: Macmillan.

Hoffman, Andrew J. 2011. Thirty-five years of research on business and the natural environment. Part 2: The 75 seminal articles of the field. July 13. http://oneaomonline.blogspot.com/2011/07/thirty-five-years-of-research-on_13.html.

Hoglund Isaksson, L. 2005. Abatement costs in response to the Swedish charge on nitrogen oxide emissions. *Journal of Environmental Economics and Management* 50: 102–20.

Jaffe, A. B., and K. Palmer. 1997. Environmental regulation and innovation: A panel data study*Review of Economics and Statistics* 79 (4): 610–19.

Jaffe, A. B., S. R. Peterson, P. R. Portney, and R. N. Stavins. 1995. Environmental regulation and international competitiveness: What does the evidence tell us? *Journal of Economic Literature* 93: 132–63.

Johnstone, N., I. Hascic, and M. Kalamova. 2010. Environmental policy characteristics and technological innovations. *Economia Politica* 27 (2): 275–99.

Johnstone, N., I. Hascic, and D. Popp. 2010. Renewable energy policies and technological innovation: Evidence based on patent counts. *Environmental and Resource Economics* 45 (1): 133–55.

Kennedy, Peter. 1994. Innovation stochastique et coût de la réglementation environnementale. *L'Actualité économique* 70 (2): 199–209.

Konar, S., and M. A. Cohen. 1997. Information as regulation: The effect of community right to know laws on toxic emissions. *Journal of Environmental Economics and Management* 32: 109–24.

———. 2001. Does the market value environmental performance? *Review of Economics and Statistics* 83 (2): 281–89.

Kriechel, B., and T. Ziesemer. 2009. The environmental Porter Hypothesis: Theory, evidence and a model of timing of adoption. *Economics of Innovation and New Technology* 18 (3): 267–94.

Lanjouw, J. O., and A. Mody. 1996. Innovation and the international diffusion of environmentally responsive technology. *Research Policy* 25: 549–71.

Lankoski, L. 2010. Linkages between environmental policy and competitiveness. OECD Environment working papers No. 13, www.oecd.org/dataoecd/0/8/44392874.pdf.

Lanoie, P., J. Lucchetti, N. Johnstone, and S. Ambec. 2011. Environmental policy, innovation and performance: New insights on the Porter Hypothesis. *Journal of Economics and Management Strategy* 20: 803–42.

Lanoie, P., M. Patry, and R. Lajeunesse. 2008. Environmental regulation and productivity: New findings on the Porter Hypothesis. *Journal of Productivity Analysis* 30: 121–28.

Lee, Jaegul, Francisco M. Veloso, and David A. Hounshell. 2011. Linking induced technological change, and environmental regulation: Evidence from patenting in the U.S. auto industry. *Research Policy* 40 (9): 1240-52.

Lieberman, M., and D. Montgomery. 1988. First-mover advantages. *Strategic Management Journal* 9: 1–58.

Lyon, T., and B. Van Hoof. 2009. Evaluating Mexico green supply chains program. Mimeograph, University of Michigan. August.

Managi, S. 2004. Competitiveness and environmental policies for agriculture: Testing the Porter Hypothesis. *International Journal of Agricultural Resources and Ecology* 3 (3–4): 310–24.

Maskus, K. 2010. Differentiated intellectual property regimes for environmental and climate technologies. OECD Environment working papers No. 17. OECD Publishing, http://dx.doi.org/10.1787/5kmfwjvc83vk-en.

Mohr, R. D. 2002. Technical change, external economies, and the Porter Hypothesis. *Journal of Environmental Economics and Management* 43 (1): 158–68.

Mohr, R. D., and S. Saha. 2008. Distribution of environmental costs and benefits, additional distortions and the Porter Hypothesis. *Land Economics* 84 (4): 689–700.

Nelson, R. A., T. Tietenberg, and M. R. Donihue. 1993. Differential environmental regulation: Effects on electric utility capital turnover and emissions. *Review of Economics and Statistics* 75 (2): 368–73.

Palmer, K., W. E. Oates, and P. R. Portney. 1995. Tightening environmental standards: The benefit-cost or the no-cost paradigm? *Journal of Economic Perspectives* 9 (4): 119–32.

Popp, D. 2003. Pollution control innovations and the Clean Air Act of 1990. *Journal of Policy Analysis and Management* 22 (4): 641–60.

———. 2005. Uncertain R&D and the Porter Hypothesis. *B.E. Journal of Economic Analysis and Policy*, www.bepress.com/bejeap/contributions/vol4/iss1/art6/.

———. 2006. International innovation and diffusion of air pollution control technologies: The effects of NO_X and SO_2 regulation in the US, Japan, and Germany. *Journal of Environmental Economics and Management* 51 (1): 46–71.

Porter, M. 1991. America's green strategy. *Scientific American* 264 (4): 168.

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

———. 1995b. Green and competitive: Ending the stalemate. *Harvard Business Review* (September-October): 120–34.

Portney, Paul, R. 2008. The (not so) new corporate social responsibility: An empirical perspective. *Review of Environmental Economics and Policy* 2: 261–73.

Quiroga, M., M. Persson, and T. Sterner. 2009. Do countries with lax environmental regulations have a comparative advantage in polluting industries? Working paper..

Rassier, D. G., and D. Earnhart. 2010. The effect of clean water regulation on profitability: Testing the Porter Hypothesis. *Land Economics* 86 (2): 329–44.

Rege, M. 2000. Strategic policy and environmental quality: Helping the domestic industry to provide credible information. *Environmental and Resource Economics* 15 (3): 279–96.

Reinhardt, L. Forest, N. Robert, Stavins, H. K. Richard, and Vietor. 2008. Corporate social responsibility through an economic lens. *Review of Environmental Economics and Policy* 2: 219–39.

Repetto, Robert, Dale Rothman, Paul Faeth, and Duncan Austin. 1996. *Has environmental protection really reduced productivity growth?* Washington, DC: World Resources Institute.

Rochon-Fabien, A., and P. Lanoie. 2011. Promoting pollution prevention in small businesses: Costs and benefits of the "enviroclub" initiative. *Canadian Public Policy* 38: 217–32.

Simpson, D., and R. L. Bradford. 1996. Taxing variable cost: Environmental regulation as industrial policy. *Journal of Environmental Economics and Management* 30 (3): 282–300.

Smith, J. B., and W. A. Sims. 1985. The impact of pollution charges on productivity growth in Canadian brewing. *Rand Journal of Economics* 16 (3): 410–23.

Ulph, A., and D. Ulph. 1994. Trade, strategic innovation and strategic environmental policy—A general analysis. In *Environmental policy and market structure*, ed. C. Carraro, Y. Katsoulacos, and A. Xepapadeas, 181–208. Dordrecht, the Netherlands: Kluwer.

US Environmental Protection Agency. 1992. The clean air market place: New business opportunities created by the Clean Air Act amendments—Summary of conference proceedings. Washington, DC: Office of Air and Radiation.

Wagner, M. 2006. A comparative analysis of theoretical reasoning and empirical studies on the Porter Hypothesis and the role of innovation. Mimeograph, BETA: Strasbourg.

Xepapadeas, A., and A. de Zeeuw. 1999. Environmental policy and competitiveness: The Porter Hypothesis and the composition of capital. *Journal of Environmental Economics and Management* 37: 165–82.