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

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CHAIRS' PAPER

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1. INTRODUCTION

Twenty years ago, Harvard Business School economist and strategy professor Michael Porter stood conventional wisdom about the impact of environmental regulation on business on its head by declaring that well designed regulation could actually enhance competitiveness. According to Porter (1991), "Strict environmental regulations do not inevitably hinder competitive advantage against foreign rivals; indeed, they often enhance it." He went on to suggest various mechanisms by which environmental regulations might enhance competitiveness; for example reduction in the use of costly chemicals or lower waste disposal costs. The traditional view of environmental regulation held by virtually all economists until that time was that requiring firms to reduce an externality like pollution necessarily restricted their options and thus by definition reduced their profits. After all, if there are profitable opportunities to reduce pollution, profit maximizing firms would already be taking advantage of those opportunities.

Over the past 20 years, much has been written about what has since become known simply as the Porter Hypothesis ("PH"). Yet, even today, there is conflicting evidence, alternative theories that might explain the PH, and oftentimes a misunderstanding of what the PH does and does not say. However, a careful examination of both the theory and evidence yields some important policy implications for design of regulatory instruments – as well as a rich research agenda to further understand what works, what doesn't, and why.

This paper provides an overview of the key theoretical and empirical insights on the PH to date, and sketches out major research themes going forward. We start in Section 2 with a brief overview of the Porter Hypothesis – as well as the variations that have been expressed in the literature. Next, Section 3 examines the theoretical developments that have taken place over the past 20 years to explain why regulation might indeed improve competitiveness. Section 4 similarly reviews the empirical evidence to date. Section 5 enters the realm of policy recommendations, by examining the implications of our knowledge on the PH for designing regulatory mechanisms that promote innovation and competitiveness. Finally, we end with a section outlining what we see to be the main research gaps that have yet to be filled in this important policy area.

2. THE PORTER HYPOTHESIS

The traditional view among economists and managers concerning environmental protection is that it comes at an additional cost imposed on firms, which may erode their global competitiveness. Environmental regulations ("ER") such as technological standards, environmental taxes or tradable emission permits force firms to allocate some inputs (labor, capital) to pollution reduction, which is unproductive from a business perspective. Technological standards restrict the choice of technologies or inputs in the production process. Taxes and tradable permits charge firms for their emission pollution, a by-product of the production process which was free before. These fees necessarily divert capital away from productive investments.

This traditional paradigm was challenged by a number of analysts, notably Professor Michael Porter (Porter, 1991) and his co-author Claas van der Linde (Porter & van der Linde, 1995). Based on cases studies, the authors suggest 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. More stringent but properly designed environmental regulations (in particular, market-based instrument such as taxes or cap-and-trade emission allowances) can "trigger innovation [broadly defined] that may partially or more than fully offset the costs of complying with them" in some instances (Porter & van der Linde, 1995).

Figure 1 summarizes the main causal links involved in the PH. As Porter and van der Linde (1995) first described this relationship, if properly designed, environmental regulations can lead to "innovation offsets" that will not only improve environmental performance, but will partially – and sometimes more than fully – offset the additional cost of regulation.

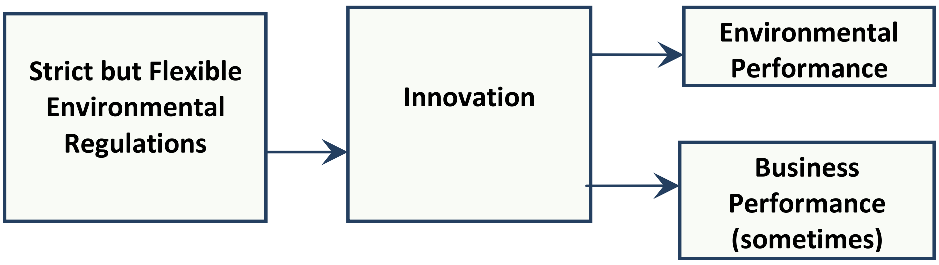

Figure 1. Schematic representation of the Porter Hypothesis

Porter and van der Linde go on to explain that there are at least five reasons that 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.

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."

The Porter hypothesis has met with great success in political debate, especially in the United States, because it refutes the idea that environmental protection is always detrimental to economic growth. It has been invoked to convince the business community to accept environmental regulations since they may benefit from them in addition to other stakeholders. In a nutshell, well-designed environmental regulations might lead to a Pareto improvement or "win-win" situation in some cases, by not only protecting the environment but also enhancing profits and competitiveness through the improvement of the production process or through enhancement of product quality.

The PH has been criticized for being incompatible with the assumption of profit-maximizing firms (see Palmer, Oates and Portney, 1995). Indeed, the hypothesis rests on the idea that firms often ignore profitable opportunities. In other words, why would regulation actually be needed for firms to adopt profit-increasing innovations? In fact, Porter directly questions the view that firms are profit-maximizing entities: "The possibility of regulation might act as a spur to innovation arises because the world does not fit the Panglossian belief that firms always make optimal choices." As discussed below, there are many reasons why firms might not appear to be making optimal choices – such as imperfect information, organizational or market failures.

Moreover, even if there are systematically-profitable business opportunities that are missed ("low hanging fruit"), the next question is how could environmental regulations 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.

There is much confusion in the literature about the Porter Hypothesis actually says. As we note above, it does *not* say that all regulation leads to innovation – only that well designed regulations do. This is consistent with the growing trend towards performance-based and/or market-based environmental regulations. Second, it does *not* state this innovation necessarily offsets the cost of regulation – i.e. it does not claim that regulation is *always* a free lunch. Instead, it does make the claim that in many instances, these innovations will more than offset the cost of regulation – i.e. there may be a free lunch in many cases.

Previous authors have disaggregated the PH into its component parts in order to test the theory and evidence. First, (as shown in the first two boxes of Figure 1), properly designed environmental regulation may spur innovation. This has often been called the "weak" version of the PH (see Jaffe and Palmer, 1997) because it does not tell us whether that innovation is good or bad for firms. Of course, the notion that regulation might spur technological innovation is not a new idea in economics, and would not itself have brought about such controversy. The second part of the PH (the lower right hand side of Figure 1) is that this innovation often more than offsets any additional regulatory costs – in other words, environmental regulation often leads to an increase in firm competitiveness. This is often called the "strong" version of the PH. (Note, however, that the PH never goes so far as to suggest that environmental regulation will *always* lead to either innovation or increased competitiveness.) Finally, in what has been called the "narrow" version of the PH, it is noted that flexible regulatory policies give firms greater incentives to innovate and thus are better than prescriptive forms of regulation. Indeed, Porter challenges regulators to examine the likely impacts of their actions and choose regulatory mechanisms that will foster innovation and competitiveness, particularly economic instruments. Thus, the PH is as much a normative prescription for regulatory policy as it is a positive assessment of current policy.

3. NEW DEVELOPMENTS IN THE THEORY

This controversy gave rise to an abundant economics literature on the theoretical bases underlying the Porter hypothesis over the last 20 years. We can distinguish among two approaches. A first set of papers departs from the assumption of profit-maximizing firms in light of the emerging organizational and behavioural economic literature. The rationality of the firm is driven by its manager who has other motivations and objectives than profit maximization. He or she might be risk-averse (Kennedy, 1994), resistant to any costly change (Aghion, et al. 1997, Ambec and Barla, 2007) or rationally bounded (Gabel and Sinclair-Desgagné, 1998). He or she therefore misses good investment opportunities (from the point of view of the firm's profit) because they are too risky, too costly (for the manager but not for the firm) or out of the manager's habits and routines. In Ambec and Barla (2006), the manager has present-biased preferences that make her or him procrastinate profitable but costly investment opportunities ("low hanging fruit"). Since the cost of innovating is for "now" while the benefit is "later", a present-biased manager will tend 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. Regulation essentially becomes a mechanism to overcome incentive incompatibility between the principal and agent within the firm.

A related approach relies on an "organization failure" to reconcile the PH with a profit-maximizing firm. For example, Ambec and Barla (2002) cite two potential inefficiencies that support the PH: informational asymmetries inside the firm and a deficient governance structure. More precisely, managers may have private information about the outcome of an R&D investment. Thus, in order to ensure productivity enhancement and less pollution from an R&D investment, the manager will extract an informational rent (i.e. bonus). Instead, if the government imposes environmental regulations, managers lose their informational rent. The model is one way to formalize Porter's idea that environmental regulation may overcome organizational inertia.

A second set of papers reconcile the PH with profit maximization by assuming a 'market failure.' Under imperfect inter-firm competition, Simpson and Bradford (1996) show that a government may provide a strategic advantage to its domestic industry by imposing a more stringent environmental regulation. Also, with imperfect competition but differentiated products, André et al (2009) show that a minimum standard for environmental product quality might benefit all firms by solving a coordination problem - allowing them to reach a Pareto improving equilibrium. Mohr (2001) provides a similar coordination failure argument with technological spillovers. When the return on a firm's R&D investment is partly captured by its competitors, firms under-invest in cleaner and more productive technologies. An environmental regulation forcing adoption may thus switch the industry from an equilibrium with low investment in R&D to a Pareto improving equilibrium with higher investments in R&D. Greaker (2006) also relies on technological spillovers as a market failure to provide a theoretical foundation to the PH but with an upstream market for innovation. In the same vein, Xepapadeas and Zeeuw (1999) analyze the impact of environmental regulations on the dynamic of capital. They show that an emission tax may lead to retirement of older vintage capital, thereby increasing average productivity. [5] However, despite this productivity gain, the impact on profit is negative in their study.

[5] Notice that Feichtinger et al. (2005) show that the opposite may occur: an emission tax may increase the capital's average age.

4. THE EMPIRICAL EVIDENCE

Many researchers have attempted to test the Porter hypothesis empirically. Three approaches emerge from this empirical literature. The first intends to analyse the "weak" version of the PH - the link between the intensity of environmental regulation and innovation (that is to say the first link in the chain described in Figure 1). Operationally, 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 (1995) make clear, innovation is not 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."

A summary of many of these studies is contained in an Appendix (adapted and updated from Ambec and Barla, 2006; Ambec and Lanoie, 2008). As an illustration of this first set of papers, Jaffe and Palmer (1997) estimate the relationship between total R&D expenditures (or the number of successful patent applications) and pollution abatement costs (a proxy for the stringency of environmental regulation). They found a positive link with R&D expenditures (an increase of 0.15% in R&D expenditures for a pollution abatement cost increase of 1%), but no statistically significant link with the number of patents. However, restricting themselves to environmentally-related successful patents, Brunnermeier and Cohen (2003), Popp (2003, 2006), Arimura (2007), and Lanoie et al. (2007) found a positive relationship with environmental regulation.

For the firm's technological choices, two older studies emphasize a negative relationship between environmental regulations and investment in capital. Nelson et al. (1993) found that air pollution regulations significantly increased the age of capital in the U.S. electric utilities in the seventies. As discussed later, however, this finding might not be surprising given the fact that U.S. regulations imposed more stringent requirements on new sources – likely an example of regulations that are not well designed to encourage innovation. According to Gray and Shabegian (1998), more stringent air and water regulations have a significant impact on paper mills' technological choice in the U.S. However, their results suggest that it tends to divert investment from productivity to abatement, consistently with the standard paradigm.

Altogether, these works deduce that there is a positive link, although varying in strength, between environmental regulation and innovation.

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 described in Figure 1). The "strong" version of the Porter hypothesis is tested, however, without looking at the cause of this variation in performance (linked to innovation or to another cause). The firm's business performance is often measured by its productivity.

This second approach has a long tradition in the economic literature (see Jaffe et al., 1995, for a review). The second half of the Appendix lists many of these studies. Most papers reviewed in Jaffe et al. (1995) highlight a negative impact of environmental regulation on productivity. For instance, Gallop and Robert (1983) estimated that SO_2 regulations slowed down productivity growth in the U.S. in the seventies by 43%. However, several more recent papers (see Table 1) find more positive results. For example, Berman and Bui (2001) report that refineries located in the Los Angeles area enjoyed a significantly higher productivity than other U.S. refineries despite a more stringent air pollution regulation in this area. Similarly, Alpay et al. (2002) estimated the productivity of the Mexican food processing industry to be increasing with the pressure of environmental regulation. They therefore suggest that a more stringent regulation is not always detrimental to productivity.

Lanoie et al. (2007) combines both approaches, assessing for the first time the whole Porter causality chain. The data come from a unique OECD survey carried out with more than 4,000 companies located in seven industrialized countries. The method consists of assessing three equations by proceeding in two stages with adequate instruments ("two-stage least squares"). Following Figure 1, the three dependent variables are environmental innovation, environmental performance and business performance. The results first show a positive and significant link between the perceived severity of environmental regulations and environmental innovation; this is consisitent with the weak version of the PH. 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 PH – that regulation spurs innovation, which further enhances business performance. However, Lanoie et al. also note that environmental regulation has a direct negative effect on business performance. On balance, they find that the net effect is negative – that is, the positive effect of innovation on business performance does not outweigh the negative effect of the regulation itself. On balance, regulation appears to be costly – but less so than if one were to consider only the direct costs of regulation itself.

One important caveat to this negative finding is that most previous studies have not adequately taken into account the dynamic dimensions of the Porter Hypothesis. Porter argues that more stringent environmental policies will lead to innovations to reduce inefficiencies and this, in turn, will eventually reduce costs. This process may take some time. In previous studies on the determinants of productivity, researchers have often regressed productivity at time 0 on proxies of environmental regulation stringency at time 0 as well, which does not allow time for the innovation process to occur. By introducing lags of three or four years between changes in the severity of environmental regulations and their impact on productivity, Lanoie et al. (2008) have found that stricter regulations led to modest long-term gains in productivity in a sample of 17 Quebec manufacturing sectors – first reducing productivity in year one, a slightly positive effect in year two, and then more positive outcomes in years three and four – more than offsetting the first year's loss. Furthermore, they show that this effect is more important in industries highly exposed to outside competition. Further research should focus on these more dynamic impacts.

A third approach to evaluating the PH is to examine competition among nations – which returns to the original hypothesis of Porter that environmental regulation will enhance a country's competitiveness. Much of the empirical literature turns the issue on its head – 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. The PH would suggest just the opposite. Of course, there are other reasons why firms might move polluting facilities abroad – such as differences in the cost of labour, land, transportation and other inputs (not just pollution).

Much of the earlier literature on the pollution haven hypothesis found a positive impact – industries with more stringent regulations (generally proxied by higher pollution abatement costs) had less net trade flows – consistent with the PH. However, as Copeland and Taylor (2004) and Brunnermeier and Levinson (2004) explain in their literature reviews, both endogeneity and unobserved variables that are correlated with regulation may explain these results. Indeed, they cite more recent literature accounting for these issues – and conclude that while much work still needs to be done, the weight of the evidence supports the pollution haven hypothesis. Nevertheless, the magnitude of this effect does not appear to be "strong enough to be the primary determinant of the direction of trade or investment flows." (Copeland and Taylor, 2004)." Perhaps more importantly from the perspective of the PH, few of these studies have been able to distinguish between the type of regulatory mechanism employed – instead, they often use pollution control costs or emission levels (see e.g. Quiroga, Persson and Sterner, 2009) as proxies of regulatory stringency. While these might be reasonable measures of stringency, we do not know whether countries with more stringent policies are using "good" or "bad" forms of environmental regulation.

5. DESIGN OF POLICIES TO ENHANCE COMPETITIVENESS

It is clear from both the original Porter writings and empirical evidence to date that both innovation and competitiveness outcomes depend significantly on the context. The PH itself was premised on flexible, market-based regulation – not rigid command and control regulation. Beyond environmental regulations, other government policies can interact with the link between environmental regulation and innovation or competitiveness. In this section, we briefly explore the implications of policy design for the PH.

Environmental Policies

As mentioned by Porter, the type of regulatory instrument is an important premise of the PH. As Porter and van der Linde (1995) 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 emission taxes or tradable allowances, or performance standards, are more favourable to innovation than technological standard since they leave more freedom to firms on the technological solution to minimize compliance costs. Some authors, like Jaffe and Palmer (1997), refer to that as the narrow version of the PH. In this vein, Burtraw (2000) provides evidence that the switch in environmental regulations for SO_2 emissions in the U.S. from a technological standard with emission caps to an allowance trading program in 1990 considerably reduced compliance cost (40% to 140% lower than projection) – although the net effect was still a net cost. However, the switch to an emission cap enhanced innovation and fostered organizational change and competition on the upstream input market. The program left enough flexibility for the firm to select the best strategy for reducing emissions, including a switch to coal with lower sulphur content. The industry also experienced innovation in fuel blending and in the scrubber market.[6] In addition, the switch from a technological standard to tradable emission allowances led to a transfer of responsibility 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.

Along the same lines, Hoglund Isaksson (2005) looks at the impact of a charge on nitrogen oxides (NOx) emissions introduced in Sweden in 1992. She examines the impact on abatement cost functions of 114 combustion plants during the period 1990 – 1996. Her findings suggest that extensive emission reductions have taken place at zero or very low cost, and that effects of learning and technological development in abatement have been present during the analyzed period.

Lanoie et al. (2007) also provides indirect evidence on this issue, showing that performance standards are leading to more innovation than more prescriptive technological standards. Driessen (2005) reviews the literature and argues that environmental taxes provide a stronger incentive for innovation than do traditional regulations or emissions trading.

Finally, 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,

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[6] The former "command-and-control" did not provide incentives to increase SO_2 removal by scrubbers from more than the 90% (for high-sulphur coal) or 70% (for low-sulphur coal) standard. With the new program, the incentives are such that upgrading of existing scrubbers through improvements is likely to occur.

Andersen et al (2007) analyzed environmental tax revenues in seven EU countries that are recycled into other tax cuts (labour or income), and found that the result is a neutral or slightly positive net impact on GDP.

Industrial and Patent Policies

Industrial and patent policies might complement environmental regulation to protect the environment at lowest cost to firms. In particular, well-defined property rights on innovations might help to reduce R&D spillovers to the benefit of all innovating firms while slowing diffusion. Mandatory licences might 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 might make technological change as a strategy for environmental compliance more attractive. Popp (2006) provides evidence that the timing of the introduction of more stringent environmental regulations impact the number of patents issued on pollution abatement technology. This suggests that innovation policy is strongly related to environmental policy. Maskus (2010) contains a recent review of the literature and finds that the relationship between patent policy and innovation is complex – suggesting that there are no simple answers that fit all circumstances.

Training

Improved productivity or competitiveness under the PH relies heavily on the possibility of low-hanging fruit – although new technological innovations themselves are also important. 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 may help them. Rochon-Fabien and Lanoie (2010) investigate the benefits of an original Canadian training program, the Enviroclub initiative. This initiative was developed to assist SMEs in improving their profitability and competitiveness through enhanced environmental performance. An Enviroclub consists of a group of 10–15 SMEs, each of which carries out one profitable pollution prevention project. To support this practical experience, business participants attend 4 days of workshops on various themes related to environmental performance. They also receive the services of a consultant for 90 hours. This consultant analyzes the operations of the firm and, after a thorough diagnosis, recommends different measures to prevent pollution and enhance business performance. The participating firm is committed to adopt at least one of the recommendations of the consultant. Rochon-Fabien and Lanoie (2010) examine the first 187 projects emerging from this program and conclude that all of them were profitable for the participating firms, i.e. reducing costs and pollution at the same time. Lyon and van Hoof (2009) provide similar results for Mexico.

Organizational or Governance Conditions

As noted, Porter argued that organizational inertia can be one reason why firms are missing profitable opportunities to both reduce pollution and increase profits. In the same vein, environmental regulations might help firms to overcome their organizational inertia by forcing them to review the organization of production and their business model. This is more likely in firms with deficient governance structures, including asymmetric information with firms among divisions, lack of commitment by the hierarchy, costly communication, contractual incompleteness, etc. Such organizational or governance failures either constrain the ability of managers to pursue their objectives or distort incentives within the firm. The results from Burtraw (2000) showing how SO_2 allowances were handled by financial officers instead of environmental managers is a good example – as financial officers presumably had more of an incentive to reduce pollution (which would either increase the value of allowance they could sell or reduce the need to buy allowances). Recent trends to increase corporate transparency and reporting (e.g. the Carbon Disclosure Project and Global Reporting Initiative), hire Corporate Responsibility Officers who oftentimes report directly to the Board of Directors, and to appoint members of the Board of Directors with sustainability experience – all point to actions that might reduce organizational inertia further.

6. THE FORWARD RESEARCH AGENDA

After 20 years, the PH continues to stimulate academic research and policy debates. While we have learned a lot, findings are often very context specific. With changes in globalization, industry structure, and social expectations, the research agenda over the next 20 years is already full. We have categorized the future research agenda into four major themes:

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 PH does not posit that higher abatement costs will lead to innovation. Indeed, higher compliance costs might simply be attributable to older plants, for example, not more stringent regulatory standards. Instead, the PH suggests that more stringent environmental standards lead to investment in R&D (or changes in processes, organizations, etc.), which in turn leads to innovation. The challenge for researchers is to find appropriate data to fully understand and test these mechanisms.

Another reason we might be observing conflicting results is that firm, industry or environmental characteristics affect the extent to which innovation offsets and productivity or competitiveness enhancements occur. What is it about manufacturing industries in Canada between 1985- 1994 (Lanoie et al., 2008) or the U.S. petroleum industry between 1987-1995 (Berman and Bui, 2001) that causes them to have an increase in productivity when faced with stricter environmental standards – while just the opposite was found in U.S. pollution-intensive industries from U.S. paper mills between 1979-1990 (Gray and Shadbegian, 2003)?

These type challenges abound in the literature on the PH. Lankowski (2010) provides a nice summary of these issues and notes that authors have identified 50 or more methodological or measurement problems that make it difficult to compare and draw conclusions. Future research is not only needed to refine and improve upon these issues, but perhaps a serious meta-analysis would help uncover some of the underlying effects and shed more light on these issues.

Non-regulatory Policies

As noted above, there is some evidence that training programs may provide knowledge 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 U.S. as well as elsewhere. While these programs are generally designed to provide companies with knowledge and/or incentives to go beyond compliance – either to reduce costs or to increase demand for their products – they may have significant ancillary benefits of increasing compliance with existing regulations.

In addition, there is growing evidence that mandatory disclosure programs have resulted in improvements in environmental performance – even when not mandated. For example, while Hamilton (1995) found that on average, firms lost market value on the day that the first TRI numbers were made public, Konar and Cohen (1997) found firms with the largest stock price declines subsequently reduced their emissions most. More importantly, Konar and Cohen (2001) found that subsequent reductions in TRI increased the intangible asset value of firms. These and other similar findings raise the interesting question of whether indirect forms of regulation such as mandatory disclosure yield positive or negative impacts on balance.

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

Longitudinal Studies

As noted, one reason we might continue to see mixed results on the regulation- competitiveness effect is the inability of previous studies to adequately capture the lag structure of innovation. While Brunnermeier and Cohen (2003) found a positive relationship between lagged compliance costs and innovation, and Lanoie et al. (2008) found a positive relationship between lagged regulatory stringency and productivity, most authors have relied upon contemporaneous comparisons. Innovations might take several years to develop – and capital expenditures are often delayed for a few years through normal budgetary cycles and building lags. Thus, future studies that carefully examine the dynamic structure of the PH would be welcome.

Lankoski (2010) suggested that this difference in treating lag structures was one reason why earlier studies are more likely to reject the PH, while more recent studies appear more favourable. However, another potential reason that more recent studies are more likely to find positive results is simply that the world is changing over time. We have more experience with market-based regulation of the form advocated by Porter. Also, there is a heightened social consciousness around sustainability – both green products and corporate social responsibility. Thus, the “value” of improving environmental performance may have increased over time. Capturing these effects in a longitudinal study might be difficult, but could provide some interesting insights.

Global Studies

As datasets become more global and we increase our ability to make cross-country comparisons with meaningful detailed data, more research might focus on the competitiveness across nations. As mentioned above, there is growing (but still not conclusive) evidence that countries with more stringent environmental regulations are less competitive in those sectors. However, future research might distinguish between command-and-control, performance-based and market-based instruments to whether the form of regulation has an impact on these findings.

REFERENCES

Aghion P., M. Dewatripont et 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.

André J. F., González P. and Portiero N. (2009), "Strategic Quality Competition and the Porter Hypothesis", *Journal of Environmental Economics and Management*, vol. 57, pp.182-194.

Ambec S. and P. Barla (2002), "A Theoretical Foundation of the Porter Hypothesis," *Economics Letters*, 75(3), 355–60.

Ambec, S. and P. Barla (2006), "Can Environmental Regulations Be Good for Business? An Assessment of the Porter Hypothesis," *Energy Studies Review*, 14(2), 42–62.

Ambec, S. and Barla P. (2007), "Quand la réglementation environnementale profite aux pollueurs. Survol des fondements théoriques de l'hypothèse de Porter", *L'Actualité économique*, vol. 83, n°3, pp. 399-414.

Ambec S. and Lanoie P. (2008). "Does it Pay to be Green? A Systematic Overview ", *Academy of Management Perspectives*, vol. 22, pp 45-62.

Andersen, M.S. et al. (2007), *Competitiveness Effects of Environmental Tax Reforms (COMETR): Publishable Final Report to the European Commission, http://www2.dmu.dk/cometr/*

Arimura, T., Hibiki, A., and N. Johnstone (2007), "An Empirical Study of Environmental R&D: What Encourages Facilities to be Environmentally-Innovative?" in Johnstone, N. (Ed.) *Corporate Behaviour and environmental Policy*. Cheltenham, UK: Edward Elgar in association with OECD.

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., Constantatos C. and Herrmann M. (2008), "Environmental Regulation as a Coordination Device for Introduction of a Green Product: The Porter's Hypothesis Revisited", *Document de travail,* Université Laval, Québec, Canada.

Berman, E. and L.T.M. Bui (2001), 'Environmental regulation and productivity: evidence from oil refineries' *The Review of Economics and Statistics* 83(3), 498-510.

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

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, Resources For the Future (RFF), Washington.

Copeland, B.R. and M.S. Taylor (2004), "Trade, Growth and the Environment." *Journal of Economic Literature*, 42, 7-71.

Driesen, D. "Economic Instruments for Sustainable Development," Chapter 9 in *Environmental Law for Sustainability: A Critical Reader* (S. Wood, B. Richardson eds., Hart Publications 2005), http://law.syr.edu/Pdfs/0osgoodehallboo.pdf .

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

Esty, Daniel C. and Michael E. Porter (1998), "Industrial Ecology and Competitiveness: Strategic Implications for the Firm", *Journal of Industrial Ecology*, 2(1), 35-44.

Esty, Daniel C. and Michael E. Porter (2002), "Ranking National Environmental Regulation and Performance: A Leading Indicator of Future Competitiveness?" in *The Global Competitiveness Report 2001-2002* (Michael E. Porter, Jeffrey Sachs et al). New York: Oxford University Press, 78-100.

Esty, Daniel C. and Michael E. Porter (2005), "National Environmental Performance: An Empirical Analysis of Policy Results and Determinants", *Environment and Development Economics*, 10(4).

Fare R., S. Grosskopf, C.A.K. Lovell and C. Pasurka (1989), 'Multilateral productivity comparison when some outputs are undesirable: a nonparametric approach', *The Review of Economics and Statistics*, 71, p. 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), 434-446.

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*, editors: H. Folmer and T. Tietenberg, Edward Elgar.

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), 654-674.

Gray, W.B., (1987), 'The Cost of Regulation: OSHA, EPA and the Productivity Slowdown', *The American Economic Review* 77(5), 998-1006.

Gray, W.B. and R.J. Shadbegian (1998), 'Environmental regulation investment timing, and technology choice', *The Journal of Industrial Economics* XLVI(2), 235-256.

Gray, W.B. and R.J. Shadbegian (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 Releaase Inventory Data," *Journal of Environmental Economics and Management 28, 98-113.*

Hoglund Isaksson, L. (2005), “Abatement Costs in Response to the Swedish Charge on Nitrogen Oxide Emissions” *Journal of Environmental Economics and Management* 50, 102-120.

Jaffe, A.B. and K. Palmer (1997), “Environmental Regulation and Innovation: A Panel Data Study”, The Review of Economics and Statistics 79(4), 610-619.

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.*

Konar, S., and M. A. Cohen (2001), “Does the Market Value Environmental Performance?” *Review of Economics and Statistics 83(2), 281-89.*

Lankoski, L. (2010), "Linkages between Environmental Policy and Competitiveness", *OECD Environment Working Papers*, No. 13, http://www.oecd.org/dataoecd/0/8/44392874.pdf.

Lanoie, P., J. Lucchetti, N. Johnstone, and S. Ambec (2007), *Environmental Policy, Innovation and Performance: New Insights on the Porter Hypothesis*, GAEL Working Paper 2007-07, http://www.grenoble.inra.fr/Docs/pub/A2007/gael2007-07.pdf.

Lanoie, P., Patry, M., Lajeunesse, R. (2008), “Environmental Regulation and Productivity: New findings on the Porter Hypothesis”, *Journal of Productivity Analysis* 30: 121-128.

Lyon, T.; Van Hoof, B. (2009) *Evaluating Mexico Green Supply Chains Program*, mimeo, University of Michigan (August).

Maskus, K. (2010), “Differentiated Intellectual Property Regimes for Environmental and Climate Technologies,” OECD Environment Working Papers, No. 17, OECD Publishing. www.oecd.org/dataoecd/38/11/45198038.pdf.

Mohr R.-D. (2002), “Technical Change, External Economies, and the Porter Hypothesis,” *Journal of Environmental Economics and Management*, 43(1), 158–68.

Nelson R.A., T. Tietenberg and M.R. Donihue (1993), ‘Differential Environmental Regulation: Effects on electric utility capital turnover and emissions’ *The Review of Economics and Statistics* 75(2), 368-373

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), 641-660.

Popp, D. (2006), “International Innovation and Diffusion of Air Pollution Control Technologies: The Effects of NOX and SO2 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 (1995), “Toward a New Conception of the Environment-Competitiveness Relationship,” *Journal of Economic Perspective*, 9(4), 97–118.

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., Earnhart, D. (2010) “The Effect of Clean Water regulation on Profitability: Testing the Porter Hypothesis” *Land Economics* 86 (2): 329-344.

Repetto, Roberts, Dale Rothman, Paul Faeth et Duncan Austin (1996), *Has Environmental Protection Really Reduced Productivity Growth?*, World Resources Institute.

Rochon-Fabien, A., Lanoie, P. (2010) “Promoting Pollution Prevention in Small Businesses: Costs and Benefits of the “Enviroclub” Initiative”, Mimeo, HEC Montreal.

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’, *The Rand Journal of Economics* 16(3), 410-423.

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, 165-182.

APPENDIX
EMPIRICAL STUDIES ON THE PORTER HYPOTHESIS

STUDY	DATA	METHODOLOGY	MAIN RESULTS
I. Impact of Environmental Regulations (ERs) on Innovation and Technology			
Jaffe and Palmer (1997)	▪ Panel of U.S. manufacturing industries – 1973-1991.	▪ Reduced form model. ▪ Innovation proxy: R&D investments and number of successful patent applications. ▪ ERs proxy: Pollution control capital costs.	▪ R&D significantly increases with ERs. Elasticity: +0.15. ▪ No significant impact of ERs on number of patents.
Brunnermeier and Cohen (2003)	▪ Panel of 146 U.S. manufacturing industries 1983-1992.	▪ Reduced form model. ▪ Innovation proxy: number of environmentally-related successful patent applications. ▪ ERs: Pollution control operating costs and number of air and water pollution control inspections.	▪ Small but significant impact of pollution operating cost on number of patents. ▪ No impact of inspections.
Nelson et al. (1993)	▪ 44 U.S. electric utilities over the 1969-1983 period.	▪ Three-equation model: i) age of capital; ii) emissions; and iii) regulatory expenditures. ▪ Model includes two ER proxies: air pollution cost and total pollution control costs per KW capacity.	▪ ERs significantly increase age of capital (elasticity: +0.15). ▪ Age of capital has no statistically-significant impact on emissions. ▪ Regulation has impacted emission levels.
Arimura et al. (2007)	▪ Survey of 4 000 manufacturing facilities in seven OECD countries.	▪ Bivariate probit model with (1) Environmental R&D dummy regressed on various measures of environmental policy (perceived stringency, standards, taxes), an environmental accounting dummy and other management practices control variables. (2) Environmental accounting dummy regressed on same variables.	▪ The perceived ER stringency has a positive and significant impact on the probability to a run an environmental R&D program. ▪ The type of ER (standard or tax) has no significant effects on environmental R&D.
Popp (2003)	▪ Patent data and performance measures of flue gas desul-furization units ("scrubbers") of 186 plants in US (1972-97).	▪ SO2 removal efficiency of new scrubbers regressed on the flow of knowledge (measured by patents) and policy variables. ▪ Operating and maintenance cost of scrubbers regressed on same variables.	▪ The new SO2 emission permit regulation introduced in 1990 increased SO2 removal efficiency and lowered operating and removal costs.

Popp (2006)	▪ Patent data from the U.S., Japan, and Germany (1967-2001).	▪ Impact of SO_2 (US) and NO_X (Germany and Japan) ERs on patenting and patent citations. ▪ ERs: timing of the introduction of new ERs. ▪ Estimate the cross-countries spillovers using patent citation origins.	▪ ERs followed by an increase of patenting from domestic firms but not from foreign firms. ▪ Earlier ERs for NO_X in Germany and Japan are important components of US patents for pollution control technologies to reduce NO_x emissions.
II. Impact of ERs on Productivity			
Gollop and Robert (1983)	▪ 56 U.S. electric utilities, 1973-1979.	▪ Productivity measure: derived from the estimation of a cost function that includes the ERs proxy. ▪ ERs: the intensity of SO_2 regulations based on actual emissions, state standard and the utility estimated unconstrained emission levels.	▪ ERs reduce productivity growth by 43%.
Smith and Sims (1983)	▪ 4 Canadian beer breweries, 1971-1980.	▪ Productivity measure: derived from the estimation of a cost function. ▪ Two breweries were submitted to an effluent surcharge and two breweries were not.	▪ Average productivity growth regulated breweries -0.08% compared to +1.6% for the unregulated plants.
Gray (1987)	▪ 450 U.S. manufacturing industries, 1958-1978.	▪ Change in average annual total factor productivity growth between 1959-69 period and the 1973-78 period regresses on pollution control operating costs.	▪ 30% of the decline in productivity growth in the seventies due to ERs.
Barbera and Mc Connel (1990)	▪ 5 U.S. pollution intensive industries (paper, chemical, stone-clay-glass, iron-steel, non-ferrous metals), 1960-1980.	▪ Derive the direct (abatement cost growth) and indirect (changes in other inputs and production process) effects of pollution control capital using a cost function approach.	▪ Overall, abatement capital requirements reduce productivity growth by 10% to 30%. ▪ Indirect effect sometimes positive.
Dufour, Lanoie and Patry (1998)	▪ 19 Quebec manufacturing industries, 1985-1988.	▪ Total factor productivity growth regressed on changes in the ratio of the value of investment in pollution-control equipment to total cost.	▪ ERs have a significantly negative impact on productivity growth rate.
Berman and Bui (2001)	▪ US petroleum refining industry, 1987-	▪ Comparison of total factor productivity of California South Coast refineries	▪ Stricter regulations imply higher abatement costs. However, these

	1995.	(submitted to stricter air pollution regulations) with other US refineries. ▪ ERs severity is measured by the number of environmental regulations each refinery is submitted to.	investments appear to increase productivity.
Lanoie, Lajeunesse and Patry (2008)	▪ 17 Quebec manufacturing industries, 1985-1994.	▪ Total factor productivity growth regressed on lagged changes in the ratio of the value of investment in pollution-control equipment to total cost.	▪ ERs have a significantly positive impact on productivity growth rate, using lagged results, especially in the sectors highly exposed to outside competition.
Alpay, Buccola and Kerkvliet (2002)	▪ Mexican and U.S. processed food sectors (1962-1994).	▪ Productivity measure obtained through the estimation of a profit function that includes pollution abatement expenditures (US) and inspection frequency (Mexico) as proxies for ERs.	▪ US: negligible effect of ERs on both profit and productivity. ▪ Mexico: ERs have a negative impact on profits but a positive impact on productivity.
Gray and Shadbegian (2003)	▪ 116 U.S. paper mills, 1979-1990.	▪ Regression of total factor productivity on pollution abatement operating costs, technology and vintage dummies and interaction terms between the dummies and the abatement variable. ▪ Estimation of a production function that includes beside input prices, pollution abatement costs and other control variables.	▪ Significant reduction in productivity associated with abatement efforts particularly in integrated paper mills.
Rassier and Earnhart (2010)	73 US chemical firms, 1995-2001	Regression of Returns on sales on permitted wastewater discharge limits	Tighter regulations meaningfully lowers profitability
Lanoie et al. (2007)	4200 manufacturing facilities in 7 OECD countries, 2003	▪ Mail survey ▪ Three equations estimated with dependent variables: (1) presence of Environmental R&D, (2) Environmental performance, (3) Business performance. Key independent variables include perceived regulatory stringency and policy mechanisms.	Tighter ER increases R&D which improves business performance. However, direct effect of ER is negative; combined impact is negative (innovation offsets do not offset cost of ER).