Sustainable Prosperity

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Environmental Regulation and Innovation: Select Case Study Evidence of the Porter Hypothesis

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Made up of business, environment, policy and academic leaders, Sustainable Prosperity (SP) is a national green economy think tank/do tank. We harness leading-edge thinking to advance innovation in policy and markets, in the pursuit of a greener, more competitive Canadian economy. At the same time, SP actively helps broker real-world solutions by bringing public and private sector decision-makers to the table with expert researchers to both design and apply innovative policies and programs. We believe that achieving the necessary innovation in policy and markets for a stronger, greener Canadian economy requires a new knowledge base and new conversations. SP's approach is to promote both by generating policy-relevant, expert knowledge to inform smart policy solutions and foster innovative conversations and connections.

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This Policy Brief belongs to a set of three papers on environmental regulation. Environmental Regulation and Innovation: Select Case Study Evidence of the Porter Hypothesis introduces the Porter Hypothesis and explores recent case study analysis of how environmental regulation can induce innovation; Overestimating the Costs of Compliance with Environmental Regulations investigates the extent to which industry and regulators overestimate the costs of environmental regulation prior to the implementation of the regulation. Green Tape Measures Up: Environmental Regulation Comes with Lower Compliance Costs and Greater Innovation than Previously Thought presents the findings of both Policy Briefs in a shorter, high-level summary.

Key Messages

- The "Porter Hypothesis" proposes that well-designed environmental regulation can provide benefits for companies by encouraging innovation and boosting their competitiveness, which in turn can partially or fully offset the costs associated with regulatory compliance. A review of seven recent case studies from four industrial sectors provides real world evidence of "win-win" scenarios, in which environmental regulation can benefit both society (through an improved environment) and private industry (through the returns from innovation). Six of the seven studies reviewed in this Policy Brief found evidence of at least one form of the Porter Hypothesis.
- There is emerging evidence that more stringent and flexible regulations promote more innovation. Canadian policy makers are increasingly adopting these market-based approaches, such as cap-and-trade systems and pollution pricing. The studies reviewed in this Policy Brief that differentiate more flexible regulations from other regulations generally found that the flexible regulations had a stronger track record of encouraging innovation.
- Designing effective environmental policy can be difficult in the face of lobbying pressure from those being regulated. These examples presented in this Policy Brief show that some regulations can in fact deliver private benefits in the form of induced innovation. Understanding the conditions under which this is true can help governments and other regulators implement well-designed environmental regulation.
- Further assessments of the private sector benefits of regulation should be made in order to better understand the conditions under which firms and sectors benefit from environmental regulation, as well as the sectoral and firm-level qualities that determine which sectors and firms will benefit. Increasingly, as newer policies incorporating market-based instruments are adopted, there is opportunity to further study and evaluate their advantages in promoting competitiveness relative to more rigid traditional regulatory approaches.

The Issue

The Porter Hypothesis (PH) states that well designed environmental regulation can benefit regulated firms by spurring innovation, leading to improved efficiency and enhanced competitiveness.[1] This idea is controversial because the PH challenges a long-held paradigm in economics that presumes that, as profit-maximizing entities, firms are already using their resources in the most efficient way to achieve maximum profits, and that regulations merely restrict firms' options, inevitably leading to sub-optimum profits.[2]

Interest in the PH has grown rather than diminished over the past 24 years, due in part to the powerful implications of this hypothesis. If well-crafted regulations can be proven to benefit firms, it could become much easier for government and industry to develop environmental regulations that promote productivity, enhance competitiveness and achieve meaningful environmental targets that benefit society. This is particularly important in Canada, as more jurisdictions transition towards more

[1]Michael Porter and Claas van der Linde , "Toward a New Conception of the Environment-Competitiveness Relationship ", The Journal of
[2]Ambec et al, "The Porter Hypothesis at 20", *Resources for the Future Discussion Paper* 11-01, 1.

flexible and stringent environmental regulatory regimes that could potentially yield more "innovation offsets"[3] for regulated industry.

A large volume of literature has been generated on this subject, evaluating different aspects of the PH, and examining various environmentally regulated industries to explore what the available evidence shows regarding the PH in practice. This Policy Brief aims to shed light on what the most recent real world evidence of the PH shows, through an examination of several recent case-studies focussed on various aspects of the PH in four economic sectors: oil and gas; manufacturing; construction; and environmental goods and services. The case studies included in this Policy Brief were chosen because they represent some of the most recent findings relating to the PH, and focus almost exclusively on studies involving industries in OECD countries, as these are more likely to have direct policy implications for Canadian policy.

The Knowledge Base

The Theoretical Framework

Traditional economic theory views environmental regulation as a drag on competitiveness, and as a trade-off between social benefits and private costs. As profit-maximizing entities, businesses are usually presumed to use their resources in the most efficient way possible, including taking any opportunity to reduce costs or improve efficiency. Regulations thus force firms to deviate from optimal efficiency, instead allocating some of their capital and labour to pollution reduction through paying taxes, purchasing credits or offsets, adopting a mandatorily prescribed technology, substituting more costly inputs and processes for cheaper ones, investing in R&D to find ways to comply, or otherwise complying with government standards.

Since the early 1990s, a growing body of literature has emerged that questions this conventional wisdom that environmental regulation always increases costs for regulated businesses. Among the first and most cited of these works is the 1991 article America's Green Strategy by Harvard economist Michael Porter, in which he suggested that under the right circumstances, private companies can actually benefit from environmental regulation. He appealed to the anxiety of those who worry that regulation constrains American (and other) industries in the face of fierce global competition, arguing that "strict environmental regulations do not inevitably hinder competitive advantage against rivals; indeed, they often enhance it".[4]

For a thorough review of the Porter Hypothesis, refer to "The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness?"[5]

In a subsequent paper published in 1995, Porter and co-author Claas van der Linde fleshed-out the "Porter Hypothesis" (PH), as this idea came to be known. They suggested that pollution generally accompanies a waste of resources or lost energy potential. "Pollution is a manifestation of economic waste and involves unnecessary or incomplete utilisation of resources . . . Reducing pollution is often coincident with improving productivity with which resources are used".[6] Thus, Porter and van der Linde argued, "properly designed environmental regulation can trigger innovation that may partially or more than fully offset the costs of complying with them".[7] In other words, the right regulations can

[3]Michael Porter & Claas van der Linde, "Toward a New Conception of the Environment-Competitiveness Relationship", The Journal of Economic Perspectives, Vol. 9, No. 4 (Autumn, 1995), p 97-118, 98.
[4]Michael Porter, "America's Green Strategy", *Scientific American* 264(4), 168.
[5]Ambec et al, "The Porter Hypothesis at 20", *Resources for the Future Discussion Paper* 11-01
[6]Michael Porter & Claas van der Linde, "Toward a New Conception of the Environment-Competitiveness Relationship", Journal of Economic Perspectives, Fall 1995, Vol.9, num.4, 97-118, p. 98, 105.
[7]ibid

lead to a "win-win" benefit for society and industry, where not only does society benefit from reduced environmental degradation, but industry benefits from increased profits through improvements in efficiency.[8]

Figure 1: Modern View of Environmental Regulation

The Porter Hypothesis relates to the middle arrow in Figure 1; it proposes that there are many circumstances in which "innovation offsets" resulting from environmental regulation at least partially offset the regulated industry's private costs of compliance.

Porter and van der Linde went on to dismiss the traditional paradigm, contending that its founding premise – that all companies are making the best choices and operating at maximum efficiency – is unrealistically optimistic. This is especially true of environmental issues, they argued, since many companies are relatively inexperienced in dealing with novel environmental problems.[9] Rather, productivity is constantly in flux, and firms are continually innovating to survive, using incomplete and asymmetric information to select the best technological opportunities to pursue among a continually shifting array of options. This is further complicated by the fact that the incentives of individual decision makers, corporate departments, and the corporation itself are difficult to align, and organizational inertia and control issues often prevent firms from pursuing the optimal path.[10]

Instead, Porter and van der Linde argued that properly crafted regulations could guide companies towards achieving **"innovation offsets" – that is, triggering innovations that may partially, fully or more than fully offset the costs of complying with regulations.**[11] Regulations could achieve this by

1) Signalling companies about resource inefficiencies and potential technological improvements;

2) Raising corporate awareness through regulation focussed on information gathering;

3) Reducing uncertainty about whether investments to mitigate environmental impacts will be worthwhile;

[8]Paul Lanoie et al, "Environmental Policy, Innovation and Performance: New Insights on the Porter Hypothesis", Journal of Economics & Management Strategy, vol. 20, no. 3, fall 2011, 803-842, 804.
[9]In addition, the absence of a price signal to correct for the externality would mean the firm has less incentive to fully explore the abatement options available to it, including R&D, investment in new practices, fuel-switching, etc.
[10]Michael Porter & Claas van der Linde, "Toward a New Conception of the Environment-Competitiveness Relationship", Fall 1995, Vol.9, num.4, 97-118
[11]ibid

4) Creating pressure to motivate companies to overcome organizational inertia and innovate and;

5) Levelling the playing field by preventing laggards from gaining a strategic advantage while more progressive companies undertake costly efforts to innovate.

Porter and van der Linde do not specify all the characteristics that would be expected of "properly crafted environmental regulation" but note that stringency and flexibility are both key elements of such policies.[12] For this reason, some authors have noted that the PH assumes policies that are performance-based, market-based and more similar to modern policies like cap and trade regimes or pollution pricing than to command-and-control regulations.[13]

What do we mean by "innovation"?

Innovation is defined broadly as used by Porter and van der Linde, and includes how products and services are designed, produced, marketed, supported, and what segments are served by the product or service.

A similar, and widely accepted, OECD definition is: "An innovation is the implementation of a new or significantly improved product (good or service), a new marketing method, or a new organisational method in business practices, workplace organisation or external relations."[14] More simply, innovation means new or better ways of doing valued things.[15]

How is Innovation Measured?

Although Porter and van der Linde define innovation broadly, subsequent studies (including some of those presented in this paper) have generally measured innovation through either R&D expense on environmental technologies, or through the number of successful environmental patent applications.[16] Neither of these measures conforms closely to the broad definition, and both are flawed. R&D expenditures may not translate to actual technological progress, and patents may be held by companies and not used except to constrain competitors. Using patents as a proxy for innovation is also problematic because patents may originate in and be attributed to one industry but principally be used in an entirely different one. Merely comparing total numbers of patents is also problematic, as it implies that all patents are equally significant.[17] Innovations that are not tied to specific technologies – such as those representing management practices or marketing approaches – are generally not captured by either measure. However, due to the difficult nature of measuring abstract and intangible benefits such as innovation, these and a few other measures serve as approximations.

In order to test the PH and evaluate the evidence, a prominent paper by Jaffe and Palmer[18] separated the PH into three related but distinct interpretations. In all cases, the underlying premise is that under normal circumstance, firms do not find or pursue all profitable opportunities for new products or processes due to many possible factors including organizational inertia, managers' risk or cost

[12]ibid
[13]See, for instance, Ambec et al, "The Porter Hypothesis at 20", *Resources for the Future Discussion Paper* 11-01
[14]Organization for Economic Cooperation and Development. (2005). "The Measurement of Scientific and Technological Activities: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data: Oslo Manual". Retrieved from http://www.oecd.org/science/inno/2367580.pdf
[15]Canadian Council of Academies. 2013. *Paradox Lost: Explaining Canada's Research Strength and Innovation Weakness*. Ottawa (ON).
[16]Ambec et al, "The Porter Hypothesis at 20", *Resources for the Future Discussion Paper* 11-01, 7.
[17]Smita Brunnermeier & Mark Cohen, "Determinants of environmental innovation in US manufacturing industries", Journal of Environmental Economics and Management 45 (2003) 278–293, 282.
[18]Adam Jaffe & Karen Palmer, "Environmental Regulation and Innovation: A Panel Study", National Bureau of Economic Research, Working Paper 5545, 1997. (Find finished citation)

aversion, and managerial present-biased preferences. When environmental regulations are imposed, firms' adjust their behaviour in order to comply. Three versions of the PH differ in terms of how much innovation could be induced.

Strong PH: Under the strong PH, the shock of new (well designed) environmental regulation induces firms to come up with new ways to comply with the regulation, encouraging innovation that increases business performance and competitiveness so much that it fully or more than fully offsets the costs of complying with the regulations. Jaffe and Palmer suggest that the strong PH implies that environmental regulation is a free lunch, in that regulation induces innovation whose benefits (to the firm) exceed its costs.[19]

Weak PH: As in the strong PH, regulation will stimulate innovation as companies attempt to comply at lower cost. Unlike the strong PH, it is not specified whether the innovation is socially beneficial or not, only that innovation occurs.

Narrow PH: In this interpretation of the hypothesis, regulations that are flexible, stringent, and with minimal uncertainty about their application spur firms to innovate more than those that lack these attributes. For instance, regulations that apply to a performance standard and are always enforced the same way are much more effective at stimulating innovation than regulations that prescribe specific technologies or processes and are likely to become obsolete and replaced by new regulations in the future.

Many other papers examining the PH have adopted this framework introduced by Jaffe and Palmer. The case studies that follow each examine one or more of these aspects of PH. The weak PH at this point is largely uncontested, while a number of recent studies have provided some support for the narrow hypothesis. Consensus has not yet been reached on the strong PH, although studies based on more recent policies – i.e., those most likely to include the use of flexible approaches are less likely to show negative and statistically significant findings.[20]

It is important to note that the Porter Hypothesis does not indicate that environmental regulation will benefit all regulated firms. In fact, it is expected that the poorest performers in a regulated industry would eventually exit. Firms that fail to overcome organizational problems to innovate and comply with regulations should be penalized, and should not continue to operate if their efficiency and environmental performance falls significantly below industry standards. This will in turn free-up capital and human resources that can be put to more productive use by a competitor or new entrant to the industry. A regular rate of firm entry and exit is important to maintaining innovation in industries.[21]

[19] Adam Jaffe & Karen Palmer, "Environmental Regulation and Innovation: A Panel Study", National Bureau of Economic Research, Working Paper 5545, 1997, p 3; Ambec et al. (2011) (pg 4) point-out that Porter and van der Linde do not argue that regulation *always* results in free lunches in the form of increased competitiveness, but only that this is probable and can occur in many cases.
[20] Ambec et al, "The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness?", *Review of Environmental Economics and Policy* (2013), vol 7, issue 1,pp 2-22, 8.
[21] Nick Johnstone, Address (Lecture delivered at 'Accelerating Clean Innovation: How Public Policy Can Drive Greener Growth', Calgary, 31 March 2015) [unpublished], http://www.sustainableprosperity.ca/blog/accelerating-clean-innovation-conference-session-2-public-policy-solutions

Meta-analysis of the Porter Hypothesis

A meta-analysis conducted by Mark Cohen and Adeline Tubb[22] explored over 1000 studies to find approximately 100 that empirically test the relationship between environmental regulation and firm or country-level productivity or competitiveness. These studies vary in data coverage (from as early as 1958 to 2009) and in publication dates (1982 to 2013). The authors conduct a "meta-analysis" – a rigorous statistical methodology to assess the underlying relationship between regulation and productivity/competitiveness.Their analysis thus far has revealed that:

- *At the facility or firm-level, studies are about as likely to find a negative relationship between environmental regulations and productivity or competitiveness as a positive one (and many studies find no significant impact), and*
- *At the state or country level, studies are more than twice as likely to find a positive relationship than a negative one (and again, many find no significant impact).*

Cohen and Tubb [23] also look specifically at the question of how flexible regulations perform. Only 35% of the studies in their meta-analysis differentiate flexible regulations from more command-and-control style ones. When the level of significance is known, flexible regulations are more likely to have a positive and significant relationship than the command-and-control regulations. When disaggregating the data, they find flexible regulation has this positive impact at the state, regional or country level, but not at the firm level. This could be considered qualified support for the Strong PH. They also consider studies that look for innovation that occurs some period of time after the regulation is imposed (i.e., using lagged regulation variables) and find that those studies are more likely to have a significant positive relationship than the others. This is consistent with the innovation benefits from environmental regulation occurring on a longer-time scale than the costs.

Review of Case Studies

Due to the difficult nature of measuring innovation and attributing real world events to policy changes, it remains hard to prove definitively whether or not the PH is correct about the effects of regulation. However, a number of studies shed light on one or more aspects of the PH. The case studies included in this Policy Brief were chosen because they represent some of the most recent findings relating to the PH. Where possible, studies involving industries in OECD countries were favoured, as these are generally more likely to have direct policy implications for Canadian policy than those from non-OECD countries. It should be noted that whatever similarities exist in environmental regulations across these industries, they differ in type and stringency, and are often particular to their respective economic and socio-political contexts. The cases are arranged into four sectors, each focussed on a particular area of the economy that must comply with environmental regulation: oil and gas; manufacturing; construction and buildings; and environmental goods and services.

Oil and Gas

The global oil and gas (O&G) industry is a major contributor to greenhouse gas (GHG) emissions, not only indirectly through the eventual combustion of oil and gas products by the end user, but directly, though extraction and refining processes that emit large amounts of GHGs. O&G extraction also

[22]Mark Cohen & Adeline Tubb, "The Impact of Environmental Regulation on Firm Competitiveness: A Meta-Analysis of the Porter Hypothesis", CIGI-INET Working Paper.
[23]Mark Cohen & Adeline Tubb, "The Impact of Environmental Regulation on Firm Competitiveness: A Meta-Analysis of the Porter Hypothesis", CIGI-INET Working Paper.

creates other environmentally hazardous by-products, such as non-GHG air pollutants and mining tailings, and can have a significant impact on surrounding landmass and species. Jurisdictions have introduced various regulations to mitigate these impacts, and in some cases O&G operators have often gone beyond the mandated emissions reductions in response to non-regulatory factors such as public pressure. A number of O&G companies have recently called for governments to put a price on carbon in order to end the current uncertainty over how carbon will be priced and the effects this will have on O&G operations.[24] Two studies that explored the Porter Hypothesis in the context of O&G sector regulations were identified – one in Australia and one in Canada.

Australian Oil & Gas Industry **Source:** Jerad Ford, John Steen & Martie Louise Verreynne, "How environmental regulations affect innovation in the Australian oil and gas industry: going beyond the Porter Hypothesis"[25]	
Industry Context	Australia's O&G industry contributed roughly 2% to the country's GDP in 2012[26] and is expected to contribute over 3.5% to GDP by 2020.[27] However, along with Australia's heavy reliance on coal-fired electricity-generation, emissions from oil and gas extraction contribute to making Australia the second-most GHG-intensive country in the OECD (measured in GHG per unit of GDP).[28]
Study Description	Analysis was based on data collected from a telephone survey of Australian O&G industry executives, representing over a quarter of the firms in the industry. To approximate regulatory stringency, the executives were asked whether a) regulation and compliance in general (red-tape), b) environmental regulation and compliance (green-tape), and c) environmental regulatory uncertainty, "acted as a significant limitation or barrier on your ability to meet your business objectives." The executives answered questions about six innovation types, and whether these innovations were new to the whole industry, or merely new to the firm, to serve as proxies for innovation. In addition, the authors also collected qualitative data from a number of firm case studies of Queensland Natural Gas companies.
Hypothesis	The authors posit that the need for O&G firms to maintain social licence and competitive edge is leading to over-compliance with environmental regulation.[29] A motivation for this over compliance in the industry offered by the authors is that this allows firms to gain an edge over their competitors, as well as influence the nature of future environmental regulation.[30]
Results/ Findings	1) The study found a positive correlation between the presence of "green-tape" (environmental regulation) limitations on business and innovation, and no significant relationship between "red-tape" or regulatory uncertainty and innovation. Firms that cited green-tape were 3 times more likely to self-report the introductions of novel innovations (i.e. new to the whole industry), and 4 times more likely to report introducing innovations relating to their products/services.

[24] http://www.theglobeandmail.com/report-on-business/industry-news/energy-and-resources/europes-top-oil-firms-jointly-call-for-carbon-pricing/article24719324/
[25] Journal of Cleaner Production 84 (2014) 204e213.
[26] http://www.appea.com.au/media_release/oil-and-gas-one-of-australias-top-value-adding-industries/
[27] http://www.appea.com.au/oil-gas-explained/benefits/economic-benefits/
[28] http://www.theguardian.com/environment/2014/jan/10/carbon-emissions-australias-growth-puts-it-near-top-of-oecd-rankings.
[29] Ford, Steen, Verreynne; How environmental regulations affect innovation in the Australian oil and gas industry: going beyond the Porter Hypothesis, Journal of Cleaner Production 84 (2014) 204e213
[30] *Ibid* at 204.

	2) Firms' capabilities to conduct projects and access technology are strongly correlated to innovation in models where the environmental regulatory burden is high. "This means that technological breadth and depth, the ability to conduct projects and a strong reputation in tandem could provide either the capacity for dealing adeptly with environmental regulatory constraints, or supports the 'beyond compliance' hypothesis." The authors offer two possible explanations for this. The first is that firms with strong capabilities are better equipped to innovate in response to new regulations. The second, which the authors find more compelling, is that over-compliance is a competitive strategy used to gain technological advantage over competitors while bolstering social license to operate.[31] 3) Where green-tape was high, maintaining formal collaborations and conducting R&D were even more important to innovation than firm capabilities. 4) The relationships between environmental regulations, capabilities, collaboration and R&D are robust and apply to the entire supply chain (not just tail end).[32]
Porter Implications	Evidence supports **weak PH** and **narrow PH:** Weak: "we find that firms faced with high levels of regulatory burden are more likely to introduce product and service innovations, as well as innovations that are both new-to-the-industry and new-to-the-firm".[33] Narrow: "Our tentative evidence suggests that the less prescriptive nature of the regulatory approach taken by the Queensland government is supporting innovation."[34]

Regulation & Innovation

3: Firms in the Australian oil and gas industry that face environmental regulation are 3 times more likely to self-report the introductions of novel innovations (i.e. new to the whole industry).

4: They are 4 times more likely to report introducing innovations relating to their products/services.

Alberta Oil Sands Industry **Source:** Alain-Désiré Nimubona, Ujjayant Chakravorty & Andrew Leach, "The Search for Abatement Technologies in the Alberta Oil Sands"[35]	
Industry Context	Alberta's oil sands industry accounted for nearly 52% of Canadian crude oil production in 2010.[36] The energy sector accounted for over 22% of Alberta's GDP in 2012 and one in sixteen jobs were directly related to energy prior to the drop in crude oil prices in 2014.[37] Despite

[31] *Ibid* at 212.
[32] *Ibid* at 208-209.
[33] *Ibid* at 211.
[34] *Ibid*.
[35] Center for Economic Studies and Ifo Institute Working Paper No. 4781, May 2014.
[36] http://www.nrcan.gc.ca/publications/statistics-facts/1239
[37] http://oilsands.alberta.ca/economicinvestment.html; http://www.energy.alberta.ca/oilsands/791.asp

	decreases in the per barrel emissions intensity of oil sands production, growth in the sector has led to absolute emissions growth.[38] The environmental impacts of the Alberta oil sands are not limited to GHG emissions, but affect the surrounding water systems, landmass, and species. This paper focuses in particular on the tailings generated by Alberta's oil sands industry, and how effective different types of environmental policy are in encouraging tailings-reduction innovation.
Study Description	The paper presents a theoretical, three-stage model (search, adoption, and deployment) that demonstrates how polluting firms implement new abatement technologies in an environment of uncertainty regarding the performance of these technologies. They use this to compare how well three different types of pollution control regulatory instruments ("command and control", "carbon tax", and "tradable permit system") incent firms to innovate. This search model is framed in the context of firms with operations in the Alberta oil sands, and their response to environmental regulations limiting tailings generation. The authors also use their model to examine whether increasing a regulation's stringency leads to the adoption of profit-increasing technologies, and compare the likelihood that each of the three regulatory instruments will lead to lower total compliance costs.
Hypothesis	"The polluting firm always has more incentives to search for and adopt a more efficient abatement technology under either an emissions tax or a tradeable permit system than under an equivalently stringent emissions standard."
Results/ Findings	Theoretical results indicate that polluting firms have more of an incentive to innovate under an emissions tax or a tradable permit scheme than an equally stringent "command and control" emissions standard. The results also indicate that a tradable permit scheme is more likely than a tax to reduce compliance costs for the firms over time – thus making cap and trade schemes most likely to yield a "win-win" strong Porter scenario. The paper also suggests that for an industry such as Alberta's oil sands with high search and adoption costs for new technologies and a significant degree of uncertainty regarding how abatement technologies will perform in practice, stringent (market-based) environmental regulations are needed to prompt companies to innovate. From the results of their model, the authors extrapolate that, in the context of tailings abatement, "in adopting a regulatory standard as opposed to a price-based mechanism, [Alberta] may have reduced the potential for new technologies to be discovered and adopted."
Porter Implications	Evidence supports **Narrow PH**; further, the model indicates that there is a greater likelihood that future compliance costs will be lower under a tradable permit regime than under an equally stringent emissions tax, possibly indicating that the overall productivity gains implied by the **Strong PH** are more likely to be realized under the tradable permit system.

Manufacturing

Unlike the oil and gas sector, which produces a relatively limited set of products, the manufacturing sector includes a very heterogeneous set of businesses producing a wide variety of products. Rather than producers of energy, they are generally consumers of energy, using it as an input in the

[38]Government of Alberta: Oil Sands GHG Emissions- Fact Sheet, http://www.oilsands.alberta.ca/FactSheets/Greenhouse_Gas_factsheetNov_2014.pdf

production of other products. In addition to energy, manufacturing uses a number of different inputs, including raw materials, labour, intermediate products and services—again, varying widely across different manufacturing sub-sectors. Two studies explore the Porter Hypothesis in the context of manufacturing – one in Europe, one in the United States.

European Manufacturing Industry **Source:** Yana Rubashkina , Marzio Galeotti & Elena Verdolini, "Environmental regulation and competitiveness: Empirical evidence on the Porter Hypothesis from European manufacturing sectors" [39]	
Industry Context	Most of the manufacturing industries[40] involved in this study have been covered by the European Union Emissions Trading System (EU ETS)[41] since its introduction in 2005. The EU ETS sets a cap on total CO_2 emissions, and requires emitters to comply with their emissions cap or purchase offsetting credits. The system appears to be working. Since 2005, the EU 28's total CO2 emissions have fallen from 4.2 billion tonnes to 3.7 billion in 2013 – a reduction of nearly 12%. Europe's mitigation achievements are likely at least partially owed to clean innovations discovered by private industry. This case study compares regulatory stringency levels between European jurisdictions to see whether environmental regulations play a role in inducing this innovation, and if so, to what extent.
Study Description	The PH was tested by using data from the manufacturing sectors of 17 European countries between 1997 and 2009, looking at overall trends in innovation to see if more stringent regulations do in fact lead to more innovation (weak PH), and looking at productivity impacts of stringent regulation (strong PH). Data on R&D expenditures and patent applications were used to proxy innovation in each sector when testing the weak PH, and total factor productivity[42] data were used to proxy for sectoral economic performance when testing the strong PH. Firms' pollution abatement and control expenditures (PACE) were used to indicate the stringency of environmental policy in each region. Rather than focus on "green" R&D and patent applications, the study examines trends in overall R&D and patent applications, in part to control for the "crowding-out effect" where green innovation displaces other forms of innovation in response to environmental regulations.
Hypotheses	A) More stringent regulations lead to more innovation. B) More stringent regulations lead to boosted productivity.
Results/ Findings	A) Innovation The authors find no statistically significant impact for environmental regulation on R&D, but do find regulation to have a consistent positive and significant effect on patent applications. A 10% increase in PACE was associated with a 0.3-0.9% increase in patent applications. The authors' explanation for this is that "in the EU more stringent regulation does not seem to provide enough stimulus to one important input to the production of knowledge, but it does favor a more efficient combination of all the inputs involved which results in a higher

[39] Energy Policy 83 (2015) 288–300.
[40] The manufacturing industries were (1) food products, beverages and tobacco; (2) textiles and leather products; (3) wood products; (4) paper and pulp products; (5) coke, refined petroleum, and nuclear fuel; (6) chemicals, rubber and plastic products; (7) other non-metallic mineral products ; (8) basic metals; and (9) fabricated metal, machinery and equipment, electrical and optical equipment, transport equipment, manufacturing n.e.c. (pg 299 Table A1)
[41] http://ec.europa.eu/clima/policies/ets/index_en.htm
[42] TFP indicates how productively inputs are combined to generate gross output.

	knowledge output, as proxied by patents." B) Productivity While the costs associated with regulatory compliance are essentially immediate (indicated by PACE), the authors cite an earlier study stating that R&D induced by the new regulations generates productivity growth with a lag of one to three years.[43] However, after regressing TFP against one and two-years lagged PACE, and various settings of the other controlling factors, the authors found "no evidence of a statistically significant effect of environmental policy stringency on factor productivity. Regardless of the controls used, the PACE variable always remains insignificant." The authors also tested the impact of innovation on competitiveness, finding no significant relationship between R&D and TFP, and the relationship between patent applications and TFP to be negative, but only weakly significant. They concluded, "higher R&D investments over time do not bring any productivity gain to a certain country-sector, whereas more patent applications might decrease its productivity."
Porter Implications	Evidence supports **Weak PH** "When looking at the weak PH we conclude that environmental regulation leads to an increase in patent applications, but has no impact on R&D expenditures…Our evidence suggests the following: environmental regulation stimulates environmental R&D spending which displaces non-environmental R&D, but does not result in lower overall R&D levels. This increased environmental R&D is applied as an input in the production of knowledge resulting in more patent applications." **Strong PH**: Not Supported "On the whole, potential positive effects on firms' innovation activity appear not to be able to offset the negative effect of additional compliance costs. We thus fail to find support in favor of the strong Porter Hypothesis."

USA Manufacturing Industry **Source:** Smita Brunnermeier & Mark Cohen, "Determinants of environmental innovation in US manufacturing industries"[44]	
Industry Context	The American industrial sector emitted 21% of the country's GHGs in 2013.[45] Within this industrial sector, the manufacturing industry accounts for over one quarter of the country's total energy use.[46] Emissions from the industrial sector have been in decline since the late 1990s, as the US economy has undergone a structural shift away from energy-intensive manufacturing.[47]
Study Description	The study used a panel data-set covering 146 American manufacturing industries between 1983 and 1992, to test whether and to what degree environmental regulations pressure firms to innovate. Regulatory pressure/stringency was proxied by PACE and by the number of

[43] Griffith et al. 2004 (get full citation from paper)
[44] Journal of Environmental Economics and Management 45 (2003) 278–293.

[45] http://www.epa.gov/climatechange/ghgemissions/sources/industry.html.
[46] http://energy.gov/sites/prod/files/2013/11/f4/energy_use_and_loss_and_emissions.pdf, pg 1.
[47] http://www.eia.gov/environment/emissions/ghg_report/ghg_carbon.cfm.

	pollution-related government inspections conducted on the respective industries. The number of successful environmentally related patent applications[48] granted to the industry served as a proxy for innovation.[49]
Hypothesis	More stringent environmental policy will lead to more environment-related innovation.
Results/ Findings	According the study, (1) there is a small but statistically significant positive relationship between pollution abatement expenditures and environmental patents. Each $1 million increase in industrial abatement expenditures was associated with a .04% increase in mean patents; and, (2) there is no evidence that the frequency of government monitoring affects innovative activity. The authors also revealed some empirical evidence that environmental innovation is more likely to occur in industries that are internationally competitive. This is consistent with the findings of the Australian O&G industry study regarding firm capabilities. The authors acknowledge that they were unable to distinguish between PACE that resulted from compliance with government regulation vs. that which was the product of over-compliance (due to public pressure, among other factors) with this regulation.
Porter Implications	Evidence supports **Weak PH** These findings contribute supporting evidence for the weak PH. Although the measured effects on innovation of increasing PACE are relatively small, the authors note that they are significant, and that innovations that would have occurred in academia or in non-manufacturing sectors were excluded.

Construction and Buildings

Unlike Globally, the buildings sector consumes more energy than any other sector, and accounts for over one-third of total final energy consumption and carbon dioxide (CO2) emissions.[50] In Canada, commercial and residential buildings together accounted for 29% of the country's secondary energy use (12% and 17%, respectively).[51]

Two studies that explore the PH in the context of the construction/building industries were identified, one from Europe and one from China. While it could be argued that the Chinese study is less likely to provide immediate policy implications for Canada, it has the potential to be an informative case study because China is developing rapidly and investing in innovation.

[48] "Patents involving hazardous or toxic waste destruction or containment, recycling or reusing waste, acid rain prevention, solid waste disposal, alternative energy sources, air pollution prevention and water pollution prevention were counted as "environmental patents." (pg 282)

[49] Unlike Rubashkina, Galeotti & Verdolini, the authors do not use a lag structure in their model, stating that the literature indicates only a minor time-gap between R&D and patent application.

[50] International Energy Agency (2014): "Transition to Sustainable Buildings: Strategies and Opportunities to 2050," available at: https://www.iea.org/media/training/presentations/etw2014/publications/Sustainable_Buildings_2013.pdf

[51] http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=F60DB708-1; http://www.nrcan.gc.ca/energy/efficiency/buildings/4261: http://www.nrcan.gc.ca/energy/efficiency/housing/research/13628.

European Buildings **Source:** Joëlle Noailly, Improving the energy-efficiency of buildings: The impact of environmental policy on technological innovation[52]	
Industry Context	Building energy efficiency is highly regulated in Europe[53] compared to many other industries. Eichhammer and Schlomann (1999) argue that this is due to the absence of a strong lobby in the building sector to campaign against (or in favour) of regulation.
Study Description	The paper examines the impact of three types of energy policy instruments on energy-efficiency innovation in buildings: (1) regulatory energy standards, (2) energy taxes, and (3) specific government spending on R&D. It relies on data from several European nations on energy-saving patent counts, regulatory energy standards for new buildings, energy prices (affected by the energy tax), and public energy R&D expenditures.
Hypotheses	(1) Environmental regulations do have a positive impact on innovation related to energy-efficiency in buildings. (2) Regulatory standards, energy taxes, and government spending on R&D have different effects on innovation.
Results/ Findings	The author found that of the three policy tools, energy standards had the largest impact on innovation. A 10% increase in the stringency of these standards led to an average increase in the likelihood to patent by 3%.[54] By contrast, the study found the variance of energy price (serving as proxy for energy taxes), had an insignificant effect on the number of patents.[55] They also found that when the government spends 10% more on specific energy R&D expenditures in a given year, then 2 years later, firms will apply for 0.3% more patents.
Porter Implications	Evidence Supports **Weak PH** Some support for **Narrow PH**: Increasing stringency boosts innovation (as measured by likelihood to patent).

Chinese Construction Industry **Source:** G.Y. Qi et al., "The drivers for contractors' green innovation: an industry perspective"[56]	
Industry Context	More than a third of all of the buildings being constructed in the world are in China.[57] China's construction industry thus serves as both a potentially huge opportunity to mitigate environmental impact through green construction practices and the use of energy-efficient materials, as well a testing ground for green innovations in construction and building design.
Study	The study uses survey data to examine the factors that influence the adoption of green

[52] Nota Di Lavoro, 106.2010.
[53] ibid
[54] *Ibid* at 16.
[55] The author acknowledged that the insignificant effects of the energy tax could be particular to the European building sector for two reasons: (1) principal/agent issues in the building sector and (2) the fact that energy was relatively cheap throughout the course of the years covered by the study (1989-2004).

[56] Journal of Cleaner Production (2010) 1-8.
[57] http://www.constructcanada.com/wp-content/uploads/2014/08/report_the_construction_sector_in_china.pdf, pg 2.

Description	construction practices by Chinese contractors, attempting to discern which of four factors (managerial environmental concern, environmental regulations, stakeholder demands, and firm size) are most influential in the adoption of green practices by contractors.
Hypothesis	Some factors may have more influence than others in encouraging contractors to adopt green practices in construction.
Results/ Findings	Results indicated that managerial environmental concern was the biggest factor in firms adopting green practices, and that government regulations were the next most important factor. The authors suggested that Chinese regulations needed to be made more stringent for them to have a real effect: "Environmental regulations have also significant effect on the adoption of green construction innovation. However, it is appreciated that these are not considered stringent enough as to be the major driving force for adopting green construction practices."[58] The authors suggest that fines and penalties for non-compliance with regulations might have encouraged contractors to adopt more positive attitudes towards the environment. No evidence was found of stakeholder pressure impacting the adoption of green practices. This finding however, may be more particular to China than to countries like Canada that have stronger presence of civil society. Finally, larger firms were found to adopt greener practices than smaller firms, perhaps as a result of greater firm capability.
Porter Implications	(Mild) evidence supports **Weak PH**, although it is acknowledged that in this case, environmental regulations play a secondary role to managerial attitudes. The authors have highlighted an opportunity for Chinese policy-makers to mitigate the environmental impact of the construction industry through the introduction of more stringent regulation.

Environmental Goods and Services across Multiple Industries

A study using data from multiple industries is included to illustrate whether an overall relationship between regulation and innovation is detected when looking at the environmental goods and services economy as a whole. Environmental goods and services, while not thought of as a sector of the economy like those previously discussed, can be considered a cross-cutting sector, with activities that service other sectors and contributions to GDP found throughout the economy.

German Economy **Source:** Jens Horbach, "Determinants of environmental innovation—New evidence from German panel data sources"[59]	
Industry Context	Germany is home to one of the world's largest environmental industries, employing nearly two million people in this industry as of 2012. Based on the trajectory of the economy, some consultants estimate that green technologies will account for 14% of Germany's GDP by 2020.[60]

[58] *Ibid* at 7.
[59] Horbach, Jens. Determinants of environmental innovation—New evidence from German panel data sources. Science Direct, Research Policy 37 (2008) 163–173.
[60] Deutschland (December 19, 2012), "Green technology – world market leader with innovative ideas" https://www.deutschland.de/en/topic/business/innovation-technology/green-technology-world-market-leader-with-innovative-ideas

Study Description	The study uses two German panel databases to determine what factors promote innovation, looking at data collected between 1993 and 2004. The databases used covered most firms in Germany, however, the authors analysed only those that could be classified as belonging to the environmental sector.
Hypothesis	The study sought to test a number of hypotheses relating to factors that supposedly promote innovation. Most relevant to the PH is the following hypothesis: Environmental regulation and environmental management tools trigger environmental innovation.
Results/ Findings	Using the two databases and various estimation techniques, the authors find that • Environmental regulation, environmental management tools and general organizational changes and improvements were found to be "highly relevant motivations for environmental innovation."[61] • Greater firm technological capabilities – indicated by R&D spending and highly qualified employees – trigger environmental innovations. • Firms that have innovated in the past (whether environmental innovation or other) are more likely to innovate in the future.
Porter Implications	Evidence supports **Weak PH**

The Porter Hypothesis and Export Performance

Weak Porter Hypothesis

Of the seven case studies presented here, six of them provide evidence supporting the Weak PH. Looking beyond the case studies in this Policy Brief, the literature shows that there is an emerging consensus, particularly amongst more recent papers, that the Weak PH is supported.[62]

Finding empirical evidence supporting the Weak PH is significant. It confirms that environmental regulation forces firms to devote more resources to devise less environmentally harmful ways of generating revenue. This is an essential part of greening the economy, by de-coupling economic growth from environmental degradation.[63]

Strong Porter Hypothesis

The Strong PH goes to the heart of why the Porter Hypothesis was such a revolutionary and controversial idea in the first place. Unfortunately, not nearly as much analysis has been done regarding the Strong PH, and the studies that have been conducted fail to come to a clear consensus.

It may be that, in order to properly assess the veracity of the Strong PH, it will be necessary to look at regulations that involve market-based instruments, as these conform more to the factors that Porter

[61] Horbach, Jens. Determinants of environmental innovation—New evidence from German panel data sources. Science Direct, Research Policy 37 (2008) p 172

[62] See the appendix of "The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness?" by Ambec, Cohen, Elgie and Lanoie. Available at http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-11-01.pdf

[63] For more on this concept, this document is a good reference: https://www.cigionline.org/publications/greening-economic-growth-how-can-environmental-regulation-enhance-innovation-and-compet.

has indicated make-up "properly designed" regulation. If innovation offsets are linked with more stringent and flexible regulation, as Porter and van der Linde suggest, then the carbon taxes and emissions trading systems recently introduced in Canada could introduce an era of Canadian private-sector innovation and competitiveness.

Narrow Porter Hypothesis

The Narrow PH is increasingly accepted. Governments in many jurisdictions are adopting more flexible policy tools such as market based instruments, recognizing this as an efficient way to correct market failures around environmental externalities; additionally, it is common sense that regulations need to be sufficiently stringent to have an effect on behaviour. Not all the studies explored in this Policy Brief compared command-and-control regulatory approaches to more flexible approaches, but those few that did found evidence of the Narrow PH.

The Upside of Flexible, Market-based Policies

The main advantage of regulatory tools that use markets and price signals is that they achieve environmental goals at lower cost than conventional regulations – by allowing firms and people flexibility about how to reduce their impact, and giving an economic reward for doing so. Cohen et al. point out "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." Typical environmental regulations require firms to achieve a certain minimum standard, but provide no incentive to do better (like a speed limit approach). Economic tools, by contrast, provide an economic reward to firms for every unit of pollution they can reduce; so they are encouraged to reduce as much as possible, to make more money.[64] This drives innovation, which is critical to economic success in a greening global marketplace.

This Policy Brief's companion piece "Overestimating the Cost of Compliance with Environmental Regulation" explores how industry and regulators alike often overestimate the costs of compliance with environmental regulations prior to their implementation, in part because we fail to anticipate the innovations that will be developed and implemented. Popp finds this in the US Clean Air Act.[65] He also finds that prior to 1990 Clean Air Act, when plants were required to install scrubbers of minimum 90% removal efficiency, innovation was focused on finding ways to reduce the operating costs of the scrubbers, but there was no incentive to increase efficiency. When the policy changed to a pricing mechanism in 1990 with the introduction of the tradeable permits SO_2 market, innovation changed as well, focussing on improving removal efficiency. This is an important finding: command-and-control regulation led to innovation, but it was innovation focused on reducing costs; pricing-based, flexible policy led to innovation that reduced costs and improved environmental outcomes. Burtraw finds similar and complementary results regarding innovation and evidence of lower compliance costs under the flexible cap and trade regime than under the command-and-control approach.[66]

Implications for Policy Makers

[64] In some cases, a pricing instrument is not appropriate, such as in the case of particularly harmful chemicals for which a regulatory ban on the use of the substance could be warranted. In other cases, a mix of complementary policies may work best.

[65] Popp, D. (2003), Pollution control innovations and the Clean Air Act of 1990. J. Pol. Anal. Manage., 22: 641–660.

[65]: 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, DC.

- While there remains debate regarding how much innovation is induced by environmental regulations, and whether firms are net beneficiaries of this innovation, there is evidence that environmental regulations generally do induce innovation in the regulated firms and industries. It is important to identify and attempt to measure this induced innovation in order to gain a complete picture of the overall private costs and benefits of environmental regulation.

- There is early evidence that the more flexible market tools – when sufficiently stringent – are more likely to induce a greater level of innovation. As there are still many jurisdictions without a price on GHG emissions, and even more which do not put a price on other forms of environmental externalities, policy-makers would be wise to consider flexible, stringent policies and regulations where appropriate.

- Further assessments of the private sector benefits of regulation would be useful in order to better understand the conditions under which firms benefit from environmental regulation and the firm-level qualities that determine which firms will benefit. While firm-level analysis can be difficult to undertake, given proprietary and confidential data, it could be a particularly insightful type of analysis – particularly if done ex-ante, with good pre-policy baseline data available. In addition, as newer policies incorporating market-based instruments are adopted, there is opportunity to expand the knowledge-base for the Narrow Porter Hypothesis.