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How MNEs respond to environmental regulation: integrating the Porter hypothesis and the pollution haven hypothesis

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Abstract The Porter hypothesis claims that well-designed environmental regulation stimulates innovation and contributes to firms' competitive advantage towards international rivals. Multinational firms face the opportunity not to comply with environmental regulation and to escape towards countries with lax environmental regulation (i.e. the pollution haven hypothesis). However, the studies on how firms respond to environmental regulation fail to take into account the specific behaviour of multinational firms. Accordingly, I advance a conceptual framework based on the international business literature to guide future research agenda on how multinational firms respond to environmental regulation. In particular, by integrating the Porter hypothesis and the pollution haven hypothesis in an international business context, I suggest that multinational firms are attracted to countries with lax environmental regulation when they lack the capabilities to respond creatively to environmental regulation in advanced countries.

Keywords Environmental regulation · Porter hypothesis · Pollution haven hypothesis · Multinational enterprises · Innovation · Literature review

JEL Classification Q5 · O3

1 Introduction

The effects of environmental regulation (ER) on competitiveness are highly debated (Palmer et al. 1995; Porter and van der Linde 1995). The so-called *Porter hypothesis* proposes that the ER improves competitiveness. Empirical studies have overall

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confirmed this relation. However, most of these studies rarely focus explicitly on multinational enterprises (MNEs); in particular, it is still debated whether MNEs can be great contributors to a sustainable development or instead they are easily tempted to move to low-regulated locations (i.e. *the pollution haven hypothesis*).

The conventional economic view posits that requiring firms to internalize pollution externalities would rise their costs and lower their profits (e.g. Palmer et al. 1995); this view was challenged by Porter (1991) who argued that a well-designed ER might create an incentive to innovate in resource-efficiency and emission-reduction, and eventually enhances firm competitiveness (Porter and van der Linde 1995). Jaffe and Palmer (1997) have proposed three versions of the Porter hypothesis. The weak version claims that ER induces innovation and the strong version posits that ER affects the overall competitive advantage; in addition, a narrow version proposes that only certain policies spur innovation.

After about 20 years, the available empirical evidence on the Porter hypothesis has provided puzzling results; a quite strong empirical evidence exists on the linkage between ER and innovation (i.e. the weak version of the Porter hypothesis) (Brunnermeier and Cohen 2003), while more swinging effects are observed for the linkage between ER and competitiveness (i.e. the strong version of the Porter hypothesis) (e.g. Lanoie et al. 2011). Indeed, the support of the Porter hypothesis depends on the level of observation, the type of regulation, and the indicators of innovation and competiveness (Iraldo et al. 2011). Therefore, more recent contributions have moved towards a more systematic investigation of the conditions under which such positive linkages arise (e.g. Wagner 2007) and—especially at the industry level—how ER-induced innovation are diffused across sectors and countries (e.g. Corradini et al. 2014).

Many of the empirical studies on the Porter hypothesis cover a single country or a limited group of nations, perhaps because of data constraints (except e.g. Kalamova and Johnstone 2011) but also because the effects of ER on competitiveness have strong implications for policies, most of which are formulated at national level. In this respect, the uni-national firms (usually small in size) and the small-medium enterprises (SMEs) (usually low internationalized) are crucial actors for the adoption and the diffusion of eco-innovation, as they constitute the majority of business in many countries and their numerousness rather than their size might have a significant impact on the environmental (del Brío and Junquera 2003). However, the increasing integration of global economy requires a transnational perspective on the environmental issues (Kolk and Van Tulder 2010). In this sense, the MNEs can either act as link between locations and disseminate eco-innovation across countries through trade and foreign direct investments (FDI), or locate their polluting-activities where more favourable regulation is present.

Indeed, while SMEs have limited financial resources and they might lack the managerial and technological capabilities to purse a successful environmental strategy (del Brío and Junquera 2003), MNEs have vast technological capacities (Cantwell 1989) and they are likely to respond promptly to ER with path-breaking innovations. In addition, the impact of MNE eco-innovation on the economy can occur at a large scale (Blomström and Kokko 1998) and foreign-owned plants have been found to be greener than local firms (Eskeland and Harrison 2003). Moreover,

MNEs often follow social and environmental responsible corporate strategies (Kolk and Van Tulder 2010). Also, in comparison to uni-national firms, MNEs have the capabilities to diffuse green technologies from home to foreign countries, and vice versa (Dasgupta et al. 2002). At the same time, MNEs are among the greater greenhouse gas emitters (UNCTAD 2010) and they may escape to pollution havens (Eskeland and Harrison 2003). The empirical evidence is mixed and the ambiguous results might be due to a small importance of host ER in comparison to other location determinants and to methodological issues (Kalamova and Johnstone 2011).

This paper contributes to the existing literature on the Porter hypothesis and the pollution haven hypothesis by reviewing the most relevant empirical evidence (52 empirical studies are reviewed) and by proposing a conceptual framework to switch the focus from a single country or limited geographical areas to an international business (IB) prospective. To achieve this aim, this study integrates the Porter hypothesis and the pollution haven hypothesis in order to guide future research agenda on how MNEs respond to ER. In particular, this review proposes that the Porter hypothesis should be addressed taking into consideration the firm-specific intangible assets and the location choices at disposal of MNEs. Most likely, MNEs favour pollution havens *only* in the case they have not the capabilities to respond with additional innovation to more stringent ER at home. In other words, the reaction of the MNE to ER depends on the firm-level resources, the investment motivations, and the location characteristics (both home and host) (Cantwell 1989; Rugman and Verbeke 1992; Dunning 1993, 1998; Kogut and Zander 1993).

The study is organized as follows. Section 2 presents the Porter hypothesis and the pollution haven hypothesis in the context of the IB literature. Section 3 reviews the empirical evidence. Section 4 provides a conceptual framework on the three possible responses of the MNEs to more stringent ER at home. Finally, Sect. 5 draws some conclusion.

2 The Porter hypothesis: is ER bad for business?

2.1 Conventional view on ER

The conventional view on the effects of ER on the economy is that it imposes some costs to firms, thus reducing their profits and slowing their productivity growth (Jaffe and Palmer 1997). At the level of industry and countries, greater ER might hamper international competitiveness with declining exports, increasing imports and—from the point of view of advanced countries—a shift of manufacturing capacity to countries with less stringent regulation (Jaffe et al. 1995). Environmental policies are usually in the form of command-and-control or market-based approaches (Jaffe et al. 2002). Command-and-control policies set technological or performance-based standards (such as "end-of-the-pipe" pollution control), while market-based approaches encourage firms to undertake pollution-reducing actions through market incentives such as pollution fees, or tradable emission permits (Jaffe et al. 2002). In both forms of ER firms are required to devote some inputs to pollution prevention or abatement, or to reduce production, which necessarily

reduce productivity, because otherwise the profit-maximizing firms would have already adopted these actions, even in the absence of ER (Jaffe et al. 1995; Ambec et al. 2013; Koźluk and Zipperer 2013).

2.2 The Porter hypothesis

Michael Porter's work (Porter 1990; 1991; Porter and van der Linde 1995) highlights that international competiveness is based on rising productivity through constant and continuous innovation; innovation can reduce costs, or can lead to higher-valued products. In this context, firms are not profit-seeking agents that always make the optimal choice in a world of perfect information about the profitable opportunities. Instead, firms face highly incomplete information and uncertainty. In contrast to the "static" conventional view, in such "dynamic" perspective, ER stimulates innovation which may compensate for the cost of conforming to regulation, or may even bring to an absolute advantage over foreign firms not exposed to ER. Therefore, properly designed ER can enhance competitiveness through an incentive to innovate more.

Porter and van der Linde (1995) highlight that only a stringent regulation would lead to innovation offsets, i.e. innovation that offsets partially or fully the cost of complying with regulations, because it would force the firms to more fundamental solutions. In alternative, relatively lax regulation, such as the introduction of pollution control systems or other "end-of-pipe" solutions, would stimulate incremental innovation or no innovation at all, which lower the chances to offset the costs of compliance.

2.2.1 The three versions of the Porter hypothesis

Jaffe and Palmer (1997) proposed three different articulations of the original Porter hypothesis in Porter and van der Linde (1995), which are known as the weak version, the strong version and the narrow version. The weak version contends that when firms are subjected to ER, they bear some costs of compliance additional to their financial costs. At the same time, to face the increasing costs, firms are forced to search new ways to reduce such compliance costs; in other words, they are forced to innovate. These particular types of innovation are aimed at dealing with additional regulation-induced costs, and not necessarily increase overall innovation capacity of firms (Jaffe and Palmer 1997).

The strong version posits that firms operate in imperfect markets, in which profitable opportunities are not always detected by firms. Thus, ER forces firms not only to find new products and processes that comply with the regulation (weak version) but they are also pushed towards new modes of thinking and new technological opportunities that increase their profits. Hence, ER is "free-lunch", since it spurs innovation and leads to higher productivity (Jaffe and Palmer 1997).

Finally, Jaffe and Palmer (1997) introduce the narrow version, which is based on the idea that *certain* types of regulation introduce innovation. In particular, flexible and market-based instruments are more likely to stimulate firms to innovate processes and products, rather than merely setting standards at which they have to comply.

2.3 The Porter hypothesis in the IB field: the pollution haven hypothesis

2.3.1 The location determinants of MNE activities

IB literature has investigated the geography of MNE activities by taking into account the firm-specific characteristics of firms, but also the motivations of the investment (Dunning 1993) which eventually influence the location choices; for example, MNEs seeking for natural resources would be attracted to countries with abundance, availability and low prices of natural resources, while R&D facilities would require skilled workforce and scientific infrastructures, and investments in after-sales support would be more sensitive to labour costs (Dunning 1998).

Within the knowledge-based view of the firm (Kogut and Zander 1992), the most recent IB literature has been mainly related to strategic asset-seeking FDI which have the aim to exploit existing firm resources or augmenting those resources (Kuemmerle 1999; Le Bas and Sierra 2002; Cantwell and Mudambi 2005). This type of strategic asset-seeking FDI requires specific locational advantages in terms of skilled labour force (with scientific and technical knowledge) (e.g. Chung and Alcacer 2002), opportunities for information and learning (with other firms, universities, or public research centres) (e.g. Andersson et al. 2002), and institutions that would ease the knowledge production (e.g. a legal system that protects intellectual property rights) (e.g. Kumar 1996). The strict relation between knowledge-related location advantage and FDI is observed also for the service sector (e.g. Marek 2012). Since intangible assets are recognized as major determinants of MNE competitiveness, strategic asset-seeking FDI acquires crucial importance and the MNE is constantly engaged in efficiently transferring and replicating those assets within the organization across borders (Kogut and Zander 1993); as part of the knowledge is tacit and difficult to transfer at distance, MNEs implement proper mechanisms to deal with intra-firm knowledge transfer across countries (Björkman et al. 2004; Minbaeva 2007; Pérez-Nordtvedt et al. 2008).

IB literature has also acknowledged the deterrents to FDI. First of all, when the MNEs establish facilities in foreign locations, they expose themselves to the risks of imitation by local competitors (Mansfield et al. 1981), although the possibility to transfer technologies to third parties depend—among other factors—on the degree of knowledge codification and the absorptive capacities of recipient (Zander and Kogut 1995). In addition, MNEs are less likely to locate value-creating activity in countries characterized by a greater cultural distance or weak formal institutions (Flores and Aguilera 2007; Slangen and Beugelsdijk 2010); in particular, political instability, corruption and low protection of property rights constitute an unfavourable context for foreign investors (Kumar 1996; Wei 2000; Smarzynska and Wei 2001).

2.3.2 The ER and the location choice by MNEs

The literature on whether ER favours or hamper investment by MNEs has proposed two competing views. The *pollution haven hypothesis* (or *industrial flight*) is based on the idea that the introduction of an ER in a certain location raises the costs of firms operating in that location and consequently firms would imports polluting-

intensive goods from and/or would locate production plants in foreign countries, where regulation is less stringent (Jaffe et al. 1995). Accordingly, trade and FDI would geographically concentrate polluting industries or functions in countries with weak environmental standards (mostly developing economies) (Kalamova and Johnstone 2011). In the IB field, lax ER can constitute a locational advantage for foreign firms; the pressures of global competition can motivate the MNEs to choose countries with less stringent ERs for those polluting activities that would be more costly in high-income economies with relatively high environmental standards (Dasgupta et al. 2002).[1] The attraction force of lax ER in developing countries can work for entire "dirty industries" (e.g. paper, chemicals, petroleum), or for dirty production stages of firms (Zarsky 1999). Also, firms with poor environmental performance or with great tolerance for pollution as a legitimate source of competitive advantage might be attracted to developing countries (Zarsky 1999).

The alternative view is that once MNEs locate in a certain country, they perform differently than local firms. MNEs, especially from advanced countries, might have cleaner technologies and better environmental management systems, being or not the results of more stringent regulation at home (Zarsky 1999). In addition, MNEs are more exposed worldwide to meet the demand for more social and environmental responsible corporate strategies; usually, the bulk of their markets is in large advanced countries, when consumers are demanding greener products and more sustainable practices at home and worldwide (Kolk and Van Tulder 2010). Moreover, MNEs from advanced countries are usually larger than firms in host developing countries; this aspect implies that the MNEs can embark the risk of green investments and that the impact of resulting eco-innovation on the economy can occur at a larger scale than uni-national firms or SMEs (Blomström and Kokko 1998). Indeed, foreign-owned plants have been found to be more energy efficient and use cleaner types of energy than local firms (Eskeland and Harrison 2003); this latter trait might be due also to the fact that once the MNE has developed certain technological and management standards, it is very likely that they are applied in each of its foreign plants. Also, because MNEs operate in multiple countries, they have developed capabilities to transfer knowledge from home to foreign countries, and vice versa (Dasgupta et al. 2002); accordingly, if a certain technology or organizational practice has been revealed successful at home, the MNE is able to easily transfer these assets to foreign subsidiaries.

3 Empirical evidence

3.1 Weak version of the Porter hypothesis: innovation effects of ER

Studies on the ER-innovation relation generally validate the weak version of the Porter hypothesis by using mostly R&D, patents and innovation counts as proxy for

[1] This study focuses on the FDI location choice by MNEs; when trade is investigated to test the pollution havens, the results hardly show a systematic escape to developing countries (Jänicke et al. 1997).

innovation, and an array of ER such as pollution abatement investments and perceived stringency.

3.1.1 Country level

At the country-level, one of the first study to provide evidence of a positive relation between ER and innovation is Lanjouw and Mody (1996). By looking at environmental patents in 1970s and 1980s, they observe an increase correlated to the growing pollution abatement expenditure in countries such as US, Japan, and Germany. Popp (2006) finds positive effects of air pollution control regulation on patents in US, Germany and Japan. In each country, firms respond to stricter environmental standards in home country by increasing innovation. Similarly, Johnstone et al. (2010) find a positive effects of environmental public policies (such as the Kyoto Protocol and rising public R&D expenditure) on patents in renewable energy for OECD countries in 1978–2003. Using patent counts related to environment and survey data on the perceived stringency of ER, Johnstone et al. (2012) confirm a positive relation for a large set of both advanced and developing/emerging countries.

3.1.2 Industry level

At the industry level, Jaffe and Palmer (1997) find a positive effect of firm pollution control expenditures on R&D expenditures in the US industries, but fail to find the same relation for patenting activities. Similar findings on R&D expenditures are provided by Hamamoto (2006) for Japan and by Yang et al. (2012) for Taiwan. For UK, Kneller and Manderson (2012) find a positive relation between environmental investments (both R&D and capital) and greater pollution abatement pressure, but not in total R&D and capital; moreover, they find that environmental R&D crowds out non-environmental R&D. In this respect, Popp and Newell (2012) fail to detect a crowding-out effect of energy R&D. Using only environmental patents, Brunnermeier and Cohen (2003) estimate a panel of 146 US manufacturing industries in 1983–1992 and find a positive effect of pollution abatement expenditures.

A group of studies at the industry level have taken into account inter-sectoral spillover as a mechanism to explain ER-induced innovation. For EU, Corradini et al. (2014) study the relation between R&D and emission abatement of CO_2 and non-methane volatile organic compounds. They take into account both inter-sector and intra-sector cross-country spillovers. In general, Corradini et al. (2014) find support to the positive reaction across sectors, and this effect is stronger in terms of environmental spillovers than knowledge spillovers; these results are found for both types of emission abatement. Instead, when looking at the intra-sector cross-country spillovers, differences emerge between the types of spillovers and the type of emissions, which suggest that the link between innovation and regulation is heavily dependent on the nature of public good and related externalities. In a similar vein, Costantini et al. (2013) find that environmental and technological inter-sectoral spillovers are crucial determinants of emission intensity at the industry level in Italian regions, and especially environmental spillovers are stronger for greenhouse gases than for pollutants responsible of acidification processes. On the importance

of adoption of environmental innovation in related sectors, Ghisetti and Quatraro (2014) provide evidence on how sectoral environmental productivity (i.e. value added per unit of emission) in Italian regions is positively affected by the introduction of green technologies not only in the same sector, but also in vertically integrated sectors.

3.1.3 Firm level

At the facility level, Johnstone and Labonne (2006) find that the decision to engage in environmental-related R&D is positively affected by the perceived environmental policy stringency in seven OECD countries; by using the same survey, Lanoie et al. (2011) confirm the positive impact on environmental R&D expenditures and observe these effects also on environmental performance and—as discussed below—on business performance; the foreign ownership of firms does not turn to be a significant determinant in their estimations. Also Frondel et al. (2007) use the OECD survey, and they observe that stringent ER are more important for end-of-pipe technologies, while cost savings, general management systems and specific environmental management tools tend to positively affect clean production. On two-country comparison, Horbach et al. (2013) confirm the importance of regulation as drivers for eco-innovations compared to other innovations for German and French firms. Analyses of multiple countries by survey-based data which account for different types of eco-innovation and regulation are difficult to obtain. A recent work by Horbach (2014) corroborate the Porter hypothesis for a large group of EU countries, with a particular novel insight on Eastern European countries.

Many firm-level studies are confined to a single country. Lee et al. (2011) find that domestic US firms in automobile sector in 1978–1998 become more innovative than foreign firms in the early phase of the US program to introduce technology-forcing auto emissions standards. Interestingly, they show that domestic firms became more innovative than foreign firms located in the US, but this effect is confined to the early phase of regulation.

By using a survey on UK firms, Demirel and Kesidou (2011) estimate the internal and external determinants of three types of firms' green investments. Their findings indicate that ERs affect end-of pipeline pollution control technologies and environmental R&D (the latter being in support of a truly Porter hypothesis).

On the adoption of environmental innovation in Emilia-Romagna (Italy), Antonioli et al. (2013) find evidence that firms subject to more stringent ER (i.e. in more polluting sectors) undertake organizational change to deal with CO_2 abatement, controlling—among others—for whether the firm is associated to foreign one. Cainelli et al. (2012) estimate the determinants of eco-innovation (i.e. process and product innovation in several fields) of firms in Emilia-Romagna region; along with cooperation, they find that sectoral investments in air and waste are positive drivers, while the ratio between greenhouse gases and value added is detrimental of environmental innovation. Moreover, they control for foreign ownership and they show that MNEs have an advantage over domestic firms when they are embedded in the local context. In services, the drivers of environmental innovation in CO_2 abatement and energy efficiency are found different across Italian industries (Cainelli

and Mazzanti 2013); in particular, negative effects are observed when services and manufacturing linkages are taken into account.

Interestingly, Wagner (2007) investigates how environmental management system (EMS) influences both self-reported environmental innovation and patents of German firms; in particular, a positive association is found for process innovation, while a negative sign is obtained for patent counts. He points out that these results might suggest that EMS crowds out more profitable innovation, although the specific measure used by the author (i.e. EMS certification, rather than EMS implementation) might account for the lack of a robust link between ER and environmental innovation. Further confirmation of the Porter hypothesis for German firms is provided in Horbach (2008), in which ER, environmental management tools and general organizational changes and improvements are important drivers of environmental innovation. Horbach et al. (2012) observe a strong influence of regulation on process and product eco-innovation in different fields, but not all policy instruments affect environmental innovation equally.

Table 1 lists the papers reviewed in this section.

Table 1 Studies on the empirical evidence of the weak version of the Porter hypothesis

References	Dependent variable	ER	Effect
Country			
Lanjouw and Mody (1996)	Environmental patents	Pollution abatement expenditure	+
Popp (2006)	Patents	Air pollution control regulation	+
Johnstone et al. (2010)	Environmental patents	Kyoto protocol	+
		Public R&D expenditure	+
Johnstone et al. (2012)	Environmental patents	Perceived stringency	+
Industry			
Jaffe and Palmer (1997)	R&D	Pollution control expenditure	+
	Patents		NS
Hamamoto (2006)	R&D	Pollution control expenditure	+
Yang et al. (2012)	R&D	Pollution abatement fees	+
		Pollution abatement capital expenditure	
Kneller and Manderson (2012)	Environmental R&D	Environmental operating expenditure	+
	Environmental capital investments	End-of-pipe pollution control expenditure	+
Popp and Newell (2012)	Patents	Energy patents	−[a]
Brunnermeier and Cohen (2003)	Environmental patents	Pollution abatement costs	+
		Government inspections and monitoring activities	NS
Corradini et al. (2014)	R&D	CO_2 emission abatement	+
		NMVOC emission abatement	+

Table 1 continued

References	Dependent variable	ER	Effect
Costantini et al. (2013)	Environmental performance (emission)	Technological spillovers	+
		Environmental spillovers	+
Ghisetti and Quatraro (2014)	Environmental productivity	Patents in green technologies per worker (same sector)	+
		Patents in green technologies per worker (vertically-integrated sector)	+
Firm			
Johnstone and Labonne (2006)	Environmental R&D	Perceived stringency	+
Lanoie et al. (2011)	Environmental R&D	Perceived stringency	+
	Environmental performance		
	Business performance		
Frondel et al. (2007)	Eco-innovation	Perceived stringency	+
Horbach et al. (2013)	Eco-innovation	Existing ERs	+
Horbach (2014)	Eco-innovation	Existing ERs	+
Lee et al. (2011)	Environmental patents	Technology-forcing US automobile emission control regulations	+
Demirel and Kesidou (2011)	Environmental R&D	Reaction to ER	General +
	Investments in end-of-pipeline pollution control technologies	Reaction to environmental tax	
	Investments in integrated cleaner production technologies		
Antonioli et al. (2013)	Organization change	Firms operating in polluting sectors	+
Cainelli et al. (2012)	Eco-innovation	Air investments (sector)	+
		Waste investments (sector)	+
		Total investments (sector)	+
		Greenhouse gases/value added (sector)	−
Cainelli and Mazzanti (2013)	Eco-innovation	Eco-innovation in related-manufacturing sectors	−
Wagner (2007)	Eco-innovation	EMS certification	+
	Patents		−
Horbach (2008)	Eco-innovation	Introduction of environmental management tools	+
		Fulfilment of regulations and standards as motive of the innovation	+
Horbach et al. (2012)	Eco-innovation	Fulfilment regulation (present and future) and standards, subsidies, public support for eco-innovation	General +

Source: author's elaboration

[a] This paper shows that energy patents replace other patents, but that a crowd-out effect is not present

3.2 Strong version of the Porter hypothesis: competitiveness effects of ER

Studies on the competitiveness effects of ER are less conclusive on the validity of the strong version of the Porter hypothesis. These studies use a variety of measures of competitiveness (e.g. trade, productivity, financial performance) and different proxies of ER, some of which more direct (such as pollution abatement investments and environmental-related tax) and others mediated by innovation (such as ER-induced innovation or R&D).

3.2.1 Country level

Costantini and Mazzanti (2012) obtain that energy tax positively affects export dynamics of high tech and medium–low tech sectors of 14 EU exporting countries, finding support that environmental policies triggers the innovation-performance mechanism. In addition, they restrict the analysis to export of environmental goods (i.e. the narrow version of the Porter hypothesis); they found that public policies (i.e. energy tax and environmental tax) positively influence export performance, as well as certain private actions, especially pollution abatement expenditure. In Costantini and Crespi (2008) and Groba (2014), the export dynamics are investigated with reference to renewable and energy-saving technologies; both studies indicate that ER can reinforce the comparative advantage of nations in export. In particular, Costantini and Crespi (2008) find statistically significant coefficients for CO_2 emissions and environmental protection expenditures as proxies of regulation stringency, while Groba (2014) uses an array of output-related and input-related variables.

3.2.2 Industry level

At the industry-level, Hamamoto (2006) finds positive effects of stringency (measured by pollution control expenditures) on productivity growth in Japan. Yang et al. (2012) finds that induced R&D by ERs in terms of pollution abatement fees has a positive impact on industrial productivity in Taiwan, which the authors attribute to the tax credit instruments favouring the purchase of pollution control capital equipment in Taiwan; conversely, no effects is detected for pollution abatement expenditures. On two-country comparison of productivity growth of food industry, Alpay et al. (2002) find that while US pollution regulations (measured by pollution abatement expenditures) do not have an impact on the profitability or productivity of US food manufacturing, in Mexico the increase of environmental standards (measured by the number of annual inspections) has enhanced productivity growth. Interestingly, Lanoie et al. (2008) find a simultaneous negative impact of ER (measured as investment in pollution-control equipment) on productivity in Quebec manufacturing industries, while the effect turns positive when a time lag in the environmental variable is introduced. In addition, Lanoie et al. (2008) test the Porter hypothesis distinguishing between more and less polluting industries, finding support only for the latter group; moreover, sectors more exposed to international competition tend to confirm the Porter hypothesis.

A recent trend in the empirical literature has considered the effects of stringent regulation of related sectors, both downstream and upstream the value chain, since suppliers and customers can be important sources of knowledge and innovation. Franco and Marin (2014) estimate the productivity effects of energy tax on manufacturing sectors in 7 European countries, accounting for spillovers for both within-sector, and upstream and downstream sectors. They find that the strongest effects on productivity come from taxes on downstream sectors, as they stimulate suppliers of heavy-regulated sectors to innovate more and increase energy efficiency.

3.2.3 Firm level

At the level of firm, Becker (2011) studies the impact of ER (measured as pollution abatement operating costs) on the productivity of manufacturing plants in the US and finds no effect on productivity of being in a county with higher environmental compliance costs.

From survey data on OECD facilities, Lanoie et al. (2011) find that a stringent environmental regime (as perceived by the firm) negatively affects business performance; their control variable for foreign ownership is not statistically significant. In a Swedish sample of manufacturing industries, Broberg et al. (2013) observe a weak negative relation between investments in pollution prevention and technical efficiency of firms; this relation is stronger for the pulp and paper industry.

Conversely, positive effects of ER on productivity are found in van der Vlist et al. (2007) for firms in the Dutch horticulture; in particular, different regulatory regimes that aimed at reducing the use of energy, pesticides and nutrients are found to decrease technical inefficiency. For German facilities, Rennings et al. (2006) detect that the European environmental management system triggers learning processes that eventually positively affect measures of economic performance (i.e. the number of employees, turnover, and exports). Focusing on a specific sector affected by carbon prices, Jaraitė and Di Maria (2012) find positive effects of EU emission trading system on environmental efficiency and productivity change of fossil fuel public power plants across EU countries; their control variable on foreign ownership is positive and significant.

A related group of studies at the firm-level focuses on the conditions under which regulation-induced innovations improve firm-level advantages. Rennings and Rammer (2011) find that process innovation tend to show a negative impact on financial performance, especially in the field of sustainable mobility regulations; for product innovation, instead, positive impacts emerge for regulation on increasing resource efficiency. Interestingly, Rexhäuser and Rammer (2014) are among the first to distinguish between the environmental innovation introduced to cope with regulation and not regulation-induced. Based on the German part of the Community Innovation Survey, they find a positive effect on financial performance of those firms stating that their environmental innovation was a response to regulation; in particular, the effect is stronger for environmental innovation introduced to improve resource efficiency, irrespectively of whether the firm was responding to regulation or not. Instead, for any other environmental innovation (namely, those reducing

pollution and waste), a weak negative effect on financial performance emerges when the firms have not reacted to regulation. Further confirmation of this mechanism is found in Ghisetti and Rennings (2014), based on the German firms of the Mannheim Innovation Panel; ER-induced innovation in resource efficiency positively affects financial performance, while the gains from ER-induced innovation in reducing pollution and waste do not overcome the cost burden of its adoption.

Another stream of studies have focused on the possible crowding-out of more profitable innovation; in this sense, the lack of evidence on the strong version of the Porter hypothesis might come from a diversion of resources from research projects which are more strategic-coherent to the core competences of firms. An example of this is provided in Marin (2014), in which, by estimating productivity growth of Italian firms, it is found that environmental innovation leads to lower returns than non-environmental innovation.

Table 2 lists the papers reviewed in this section.

Table 2 Studies on the empirical evidence of the strong version of the Porter hypothesis

References	Dependent variable	ER	Effect
Country			
Costantini and Mazzanti (2012)	Trade	Energy tax	General +
		Environmental tax	
Costantini and Crespi (2008)	Trade	CO_2 emissions	−
		Environmental protection expenditures	+
		Environmental tax	NS
		Public investments on environmental protection	NS
Groba (2014)	Trade	Input-oriented measures of environmental stringency	General +
		Output-oriented measures of environmental stringency	
		ER in general and RE supportiveness	
Industry			
Hamamoto (2006)	Productivity	Pollution control expenditure	+
Yang et al. (2012)	Productivity	Induced-R&D by ER	+
Alpay et al. (2002)	Productivity	Pollution abatement expenditure in the USA	NS
		Annual inspections in Mexico	+
Lanoie et al. (2008)	Productivity	Investment in pollution-control equipment (simultaneous)	−
		Investment in pollution-control equipment (time lagged)	+
Franco and Marin (2014)	Productivity	Energy tax	+
Firm			
Becker (2011)	Productivity	Pollution abatement operating costs	NS

Table 2 continued

References	Dependent variable	ER	Effect
Lanoie et al. (2011)	Performance (as perceived by respondents)	Perceived stringency	–
Broberg et al. (2013)	Efficiency Productivity	Investments in pollution prevention	–
van der Vlist et al. (2007)	Efficiency	Regulation to reduce the use of energy, pesticides and nutrients	+
Rennings et al. (2006)	Performance (employment, sales, and export)	EMAS	+
Jaraitė and Di Maria (2012)	Efficiency Productivity	EU ETS	+
Rennings and Rammer (2011)	Financial performance (ROS)	Process innovation in sustainability mobility Product innovation in increasing resource-efficiency	– +
Rexhäuser and Rammer (2014)	Financial performance (ROS)	ER-induced innovation in resource efficiency ER-induced innovation in reducing pollution and waste	+ –
Ghisetti and Rennings (2014)	Financial performance (ROS)	ER-induced innovation in resource efficiency ER-induced innovation in reducing pollution and waste	+ NS
Marin (2014)	Productivity	Indicator based air emission intensity	General + –

Source: author's elaboration

3.3 ER and MNE location choice: the pollution haven hypothesis

Studies on the pollution haven hypotheses reviewed in this paper can take a single-*home*-country perspective or a single-*host*-country perspective, while more rare is the case of large sample of both home and host countries. Overall, these studies seldom show a systematic negative relation between host ER stringency and incoming FDI. The most common proxies of ER are pollution abatement costs and perceived ER stringency.

3.3.1 Country and sub-national level

For single-*home*-country approach, Xing and Kolstad (2002) find that US outward FDI to 22 economies (both industrialized and developing countries) are determined by host lax ER in the chemical and primary metals industries, but not in other polluting industries.

For a sample of OECD source countries, Kalamova and Johnstone (2011) find a general but small effect of ER on FDI; in addition, they found an inverted U-shaped relation for FDI from OECD to non-OECD countries, meaning that below a certain

level of environmental stringency countries become less attractive for investments, as if too lax ER would signal an unfavourable investment location.

About empirical studies taking a single-*host*-country perspective (albeit at the sub-national level), Keller and Levinson (2002) find a robust but moderate effect of abatement costs on FDI in 1977–1994 across US states. Lan et al. (2012) look at Chinese provinces and found that the relation between pollution emissions and FDI depends on the level of human capital, and the pollution haven hypothesis is observed only when human capital level is low.

3.3.2 Industry level

For empirical studies taking a single-*host*-country perspective, Waldkirch and Gopinath (2008) find that industries with lower emission intensity attract larger FDI in Mexico, suggesting that ER enforcing lower emission may not necessarily harm FDI inflows. For single-*home*-country approach, Wagner and Timmins (2009) look at German FDI to 90 countries and find a negative effect of foreign ER in chemical industry, but not in primary metals and paper. Instead, for Japanese outward FDI to Malaysia, Indonesia and the Philippines in 1986–1998, Elliott and Shimamoto (2008) fail to find evidence of pollution haven; they also found that regulations in Japan seem to be a deterrent of FDI to the Philippines.

Few studies take a wide coverage of countries both as home and as host. Eskeland and Harrison (2003) test their formal model on a panel data of FDI from the US and France to Mexico, Morocco, Côte d'Ivoire and Venezuela. They do not find systematic evidence of an effect of pollution abatement costs on FDI, even by considering different measures of pollution emissions.

3.3.3 Firm-level

For a single-*host*-country perspective, List and Co (2000) look at new foreign manufacturing plants in 1986–1993 in the US and obtain a statistically significant negative effect of all measures of stringent ER, both for dirty and clean firms. By looking at equity joint ventures in China, Dean et al. (2009) find that investments in highly-polluting industries coming from Hong Kong, Macao, and Taiwan are attracted by weak environmental standards, but not joint ventures funded by MNEs of high-income countries (regardless of the pollution intensity of the industry).

Taking a single-*home*-country perspective, Smarzynska and Wei (2001) use US MNEs investments in 24 Central/Eastern and former Soviet Republics and, after accounting for measure of host corruption, find moderate support to the pollution haven hypothesis, although not robust to different specifications. Instead, by looking at outward FDI by UK firms, Manderson and Kneller (2012) do not find evidence of a pollution haven hypothesis; in addition, MNEs with high environmental costs do not tend to locate in countries with lax ER with respect to MNEs with lower environmental costs.

Table 3 lists the papers reviewed in this section.

Table 3 Studies on the empirical evidence of the pollution haven hypothesis

References	Dependent variable	ER	Effect
Country			
Xing and Kolstad (2002)	FDI	Index based on sulphur dioxide emissions	− and NS depending on industry
Kalamova and Johnstone (2011)	FDI	Environmental policy stringency index	Inverted U-shaped
Keller and Levinson (2002)	FDI	Industry-adjusted index of environmental abatement costs	+
Lan et al. (2012)	Emission intensity	Investments in pollution treatment	+ for low human capital levels
Industry			
Waldkirch and Gopinath (2008)	FDI	Pollution intensity	–
Wagner and Timmins (2009)	FDI	Perceived regulation stringency	− in chemical industry NS in primary metals and paper
Elliott and Shimamoto (2008)	FDI	Pollution abatement capital expenditure cost	− for FDI to Philippines NS for FDI to other countries
Eskeland and Harrison (2003)	FDI	Pollution abatement cost	NS
Firm			
List and Co (2000)	FDI	State expenditure to control air, water and waste	+
		Pollution abatement operating expenditures	
		Environmental protection index	
Dean et al. (2009)	Joint Venture	Water levy	NS
		Effluent intensity	− for polluting industries
			NS for MNEs from high-income countries
Smarzynska and Wei (2001)	FDI	Participation to international environmental treaties	General +, but not robust to different specification
		Emission standards	
		Number of NGOs	
		Reduction in emission (lead, water pollutants, and CO_2)	
Manderson and Kneller (2012)	FDI	Pollution abatement operating costs	General NS
		Perceived ER stringency	
		Perceived ER enforcement	

Source: author's elaboration

4 The linkage between ER and MNE location choice: a conceptual framework

4.1 Integrating the Porter hypothesis and the pollution haven hypothesis

Since the pollution haven hypothesis relies on the premise that ER bears costs of compliance, so far empirical analyses have been mainly devoted to assess whether these compliance costs are important location determinants for MNEs (e.g. Eskeland and Harrison 2003). However, the Porter hypothesis contends that, although ER certainly raises costs, firms' competitive advantage is driven by their capacity to innovate; in this context, the ER can provide opportunities to introduce new resource-efficiency products or processes that lead to additional innovation and—eventually—to reinforce the competitive advantage towards foreign competitors. Therefore, the "escape" to pollution havens through FDI is only one possible answer that MNEs can give to a more stringent ER in developed countries.

The matrix in Fig. 1 summarizes the three possible outcomes of a more stringent ER in the home country. On the vertical dimension, MNEs in home countries (i.e. industrialized economies) face two choices to respond to a more stringent ER: either (a) generate ER-induced innovation, or (b) do not come up with innovation stimulated by ER.[2] On the horizontal dimension, subsidiaries of advanced countries' MNEs in developing host countries face the same two options, but I assume that the innovation in host countries is the result of environmental-related knowledge and technologies transferred from home country (Mansfield and Romeo 1980). Indeed, IB studies have acknowledged that the subsidiaries may assume a knowledge-creating role within the R&D network of the MNE (Cantwell and Mudambi 2005). The subsidiaries bring external benefits to the foreign locations and at the same time they may benefit from local technological context; accordingly, knowledge and technologies developed in the subsidiaries may be transferred from subsidiaries to the parent company (Ambos et al. 2006). However, MNEs carry out the bulk of their R&D at home (Laurens et al. 2014) and, especially in developing countries, the subsidiaries are more likely to exploit existent knowledge base rather than being actively promoter of new knowledge, since developing countries are lagging behind in terms of technological competences (Athreye et al. 2014).

The home innovation can be either simply innovation offsets, or general innovation; anyhow, it is innovation resulting from more stringent ER. No innovation might be due either to not-proper-designed ER which induces only incremental innovation that does not cover the costs of compliance (Porter and van der Linde 1995) or to firms which have not had the capabilities to offset the cost of compliance with an innovation output, even if ER is well-designed.

As a final note, quadrant 3 illustrates a rather unlikely situation, namely when parent company at home fails to innovate but overseas subsidiaries introduce an eco-innovation; accordingly, quadrant 3 is not discussed.

[2] For simplicity, I focus on developed countries as home because they are still the major source of outward FDI (UNCTAD 2014) and they are at the forefront of environmental regulation.

		Eco-innovation in host country	
		yes	**no**
ER-induced innovation at home	**yes**	*(2) strong Porter hypothesis*	*(1) weak Porter hypothesis*
	no	*(3)*	*(4) pollution haven hypothesis*

Fig. 1 The responses of MNEs to stringent ER at home. Source: author's elaboration

4.1.1 Quadrant 1: the weak version of the Porter hypothesis

If the ER causes only innovation that offsets the cost of compliance (i.e. the weak version of the Porter hypothesis), it is very likely that these improvements are introduced only in the locations where firms are obliged by law to be more resource-efficiency and reduce emissions. These types of innovation, being strictly connected to the need to deal with regulation, hardly become part of that fundamental body of knowledge and technologies that constitute the firm-specific advantage that the MNE is willing to spread to its network of subsidiaries. In fact, not all the environmental management activities reinforce MNE's capabilities (Kolk and Van Tulder 2010). In the case of innovation offsets, MNEs do not have the incentive to transfer new resource-efficient technologies and best practices to countries with lax ER, as older technologies and practices are compatible with local conditions, especially when technology transfer to developing countries entails risks and difficulties (Kaufmann and Roessing 2005). Therefore, the ER-induced innovation at home would not be introduced in host countries with lax ER (quadrant 1).

Although the empirical evidence on the weak version of the Porter hypothesis is wide (e.g. Johnstone and Labonne 2006), an exclusive focus on MNEs is lacking; however, firm-level studies controlling for foreign ownership find mixed results on whether MNEs are more innovative than domestic firms (Lanoie et al. 2011; Lee et al. 2011; Cainelli et al. 2012; Antonioli et al. 2013). In particular, it is reasonable to assume that eco-innovation would be mostly used in countries where MNEs are forced to use less-polluting technologies, processes and materials. It is only when these environmental innovations trigger more general innovation that the MNEs would be incentivized to disseminate such improvements in foreign countries (which is the case in quadrant 2).

4.1.2 Quadrant 2: the strong version of the Porter hypothesis

Quadrant 2 in Fig. 1 illustrates the case of additional innovation at home and abroad. If the additional innovation does not simply offset the cost of compliance, but it spurs firm innovation in general, then the MNEs might reinforce their exiting unique capabilities or create new ones, which enhance their competitive advantage (i.e. the strong Porter hypothesis); accordingly, the new capabilities developed at home would contribute to the unique intangible assets that constitute the MNE

competitive advantage towards rivals. Because MNEs base their competitiveness on their ability to manage geographically distant assets, new capabilities developed at home are spread within the internal network of subsidiaries located in different countries in order to be exploited in conjunction with host-country specific advantages (Cantwell 1989; Rugman and Verbeke 1992; Dunning 1993). Therefore, if ER spurs overall innovation and competiveness of MNEs, the new knowledge and best practices would be transferred and introduced also abroad (Kogut and Zander 1993). This might be the case of a technology or an organization practice developed at home that significantly reduce production cost (e.g. processes requiring less energy) or increase profits (e.g. in the case of new products); therefore, the MNE are willing to use the better processes or products also in developing countries, regardless of the stringency level of the host ER.

The recent empirical literature provide ambiguous results on the linkage between ER and overall firm competitiveness (Broberg et al. 2013). No one of the reviewed studies on the Porter hypothesis explicitly focus on MNEs. Some firm-level studies insert a control variable for foreign ownership, finding not-significant positive and significant negative effects (Lanoie et al. 2011) and statistically positive coefficient (Jaraitė and Di Maria 2012). How MNEs respond in general to ER has been objected of research. For example, Levy and Kolk (2002) discuss how different is the response of four MNEs in oil industries in terms of emission monitoring, setting of emission targets, or investment in alternative energy sources. Nevertheless, there is evidence that MNEs might be more environmentally responsible than domestic or uni-national firms; Eskeland and Harrison (2003) find that US plants are more energy efficient and use cleaner type of energy than local firms in four developing countries, while Christmann and Taylor (2001) find that foreign firms in China are more likely to comply to environmental standards that go beyond local requirements in order to respond to high social pressure from worldwide customers or because they get efficiency gains from self-regulation.

4.1.3 Quadrant 4: the pollution haven hypothesis

MNEs might be reluctant to invest in innovation offsets and can find more profitable to produce polluting-intensive goods in countries with lax ER; this would certainly imply that MNEs reduce production at home and would serve domestic or international market through imports from foreign locations (quadrant 3). Therefore, a pollution haven hypothesis applies *only if* the MNE is unable to offset the cost of compliance to ER in industrialized countries.

Empirical studies on the pollution haven hypothesis attempt to estimate whether the stringency of local ER is an important determinant of FDI (e.g. Smarzynska and Wei 2001; Xing and Kolstad 2002; Elliott and Shimamoto 2008). However, these studies do not take into consideration whether the MNE has been able to respond to home-country ER with innovation offsets or not. In particular, given that ER is only a part of the costs that MNEs take into account in the FDI location decision (Dunning 1998), how the MNEs have responded to such ER at home can shed some light on the unclear evidence of the pollution haven hypothesis.

5 Conclusion

Although there is wide political consensus on the urge to take actions to tackle environmental issues (UNCTAD 2010), it is no clear whether stringent ER bears only costs to the economy (Palmer et al. 1995) or it is rather an opportunity for firms to develop innovation and increase competitiveness (i.e. the Porter hypothesis in its original formulation) (Porter 1991; Porter and van der Linde 1995). The empirical evidence reviewed in this study suggests that it is likely that ER spurs innovation to offset the cost of compliance (i.e. the weak version of the Porter hypothesis) (Jaffe and Palmer 1997), while more uncertain is that ER enhances the competitiveness of firms (i.e. the strong version of Porter hypothesis) (Lanoie et al. 2011).

This issue is particularly relevant for MNEs, as either they can be greater contributors in the creation and dissemination of green technologies or they can transfer activities to pollution havens discouraging developing countries from introducing stringent ER. The empirical evidence is scarce on whether MNEs respond to home-country ERs with additional innovation or they escape to pollution havens. In particular, the empirical literature is not conclusive on whether lax ER is an important determinant of MNEs' location choice (Smarzynska and Wei 2001).

I contribute to this debate firstly by reviewing the empirical evidence on the linkage between ER and innovation/competitiveness; secondly, I provide a conceptual framework that links the Porter hypothesis to the pollution haven hypothesis in what I believe to be a novel way to guide future research on the issue. Indeed, by relying on the IB literature (Cantwell 1989; Rugman and Verbeke 1992; Dunning 1993; Kogut and Zander 1993), I posit that, given a stringent ER in home industrialized countries, three possible outcomes emerge. First, if the weak version of the Porter hypothesis is verified, then the MNEs have developed only innovation that offsets the cost of compliance to home ER, with no incentive to transfer knowledge abroad. Second, if the strong version of the Porter hypothesis applies, the regulation has induced MNEs to enhance their competitive advantage, which would be exploited both at home and abroad. Third, if the Porter hypothesis is not verified at home, then a pollution haven hypothesis applies; this is mostly likely due to firms lacking capabilities to innovate at home which—accordingly—are attracted to location advantages in terms of lower environmental standards.

Further empirical studies should be devoted to provide evidence on the importance of lax ER as location determinant of MNEs (i.e. the pollution haven hypothesis); in doing so, forthcoming analyses shall take into account whether the MNE responds to home strict ER with innovation. Possible future directions are about taking into account the portfolio of patents in environmental technologies retained by parent company (Horbach 2008), or whether the MNEs have implemented environmental management systems (Christmann and Taylor 2001).

The issue has policy relevance from the point of view of both the developed countries and the developing countries. Providing evidence of the innovation-induced role of ER is important for environmental issues in industrialized countries that are more committed to reduce emissions (UNCTAD 2010) and pursue a green growth (OECD 2011). Moreover, failing to identify a pollution haven hypothesis (or

confining it only to technological-backward MNEs) might convince developing countries that more stringent ER is not harming foreign investments, and that—on the contrary—they should promote FDI from advanced countries that are likely to transfer green technologies.

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