

## **A Global Political Economy Conceptualization of the Porter Hypothesis**

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*Abstract: The Porter Hypothesis theorizes that competitive firms attuned to environmental policies should respond in innovative ways, thereby increasing their competitiveness and resulting in a “win-win” scenario for businesses and the environment. While initially empirical support for the Porter Hypothesis (PH) was scant, more recently a large body of literature finds evidence in its favor. Yet most of these are either case studies or empirical investigations confined to only one or several countries. This paper first identifies some of the difficulties induced technological innovation theorists face by taking a purely economic, and sometimes by definition a static, approach to the Porter Hypothesis. Then, it proposes a new dynamic Porter Hypothesis to encompass cross-border spillovers, of both policies and technologies.*

**Keywords:** Porter Hypothesis; Induced Technological Innovation; Green/Environmental Technology; Clean Energy Technology; Innovation; R&D

## 1. Overview: The Porter Hypothesis

Environmental regulations are sometimes able to spur firms to find innovative solutions (Porter and van der Linde 1995; Ashford and Heaton 1983). Following this conceptualization, the Porter Hypothesis understands pollution essentially as “wasted resources” (Porter and van der Linde 1995), and wasted resources are seen as harming firm profits in some economics schools of thought. In this paper, we present a novel conceptualization of the Porter Hypothesis in an international, global political economy context (Newell 2008). This *dynamic* model implies that international environmental policies impact innovations in climate change mitigation technologies *and that this inducement effect occurs across borders*. In a hyper-globalized world where policy-spillovers, knowledge-spillovers, and innovation-spillovers are commonplace, we believe environmental policy-spillovers across borders is also quite likely. Accordingly, it is expected that products and technologies frequently cross over into other industries, while simultaneously investors look abroad for ideas to develop new products (Fagerberg 2004). Our general contention is that this flow of technologies, ideas, and innovations naturally permeates to include policy spillovers as well.

### *Three Divisions of the Porter Hypothesis*

How might properly designed environmental regulations “induce” innovative responses in firms? Porter and van der Linde specify five different ways regulation might enhance firm innovation, and thus result in positive policy spillovers: (1) regulation alerts firms to resource inefficiencies; (2) information gathering becomes more precise and raises awareness of the issue; (3) regulation reduces uncertainty; (4) regulation creates pressure motivating innovation and progress; (5) environmental regulations ensure a level playing field, for example all firms within the same industry must adhere to the same rules. It is important to note that not all of these elements need to present, simply that any of the five represent catalysts towards this win-win (Reinhardt 2000) scenario for policy-makers and firms. However, some of the first researchers to empirically test the hypothesis such as Lanjouw and Mody (1996), even though they found evidence it was correct in certain circumstances, still found it difficult to describe with precision the innovative outputs. The nomenclature did not yet allow for the division of several archetypes of the Porter Hypothesis. That division came in 1997.

Jaffe and Palmer (1997) divide the PH into three different versions: *weak*, *strong*, and *narrow*. This allows for a more adequate investigation into the PH because researchers are then able to isolate specific technological, price, or other measurable firm effects from variegated environmental policies (Ambec et al., 2013). Although the empirical strength of such a delineation of PH into three different vectors should be evident, the literature largely fails to properly account for this division. The weak PH implies regulation induced innovation in firms, yet whether the innovation is positive or negative remains unknown. In other words, environmental regulation causes some kind of innovative response. This is also most closely associated with the idea of induced technological innovation first formulated by Hicks (1932) because it imposes a price change-inducement effect causing firms to spend on R&D in hopes of innovating. ITC is a demand-pull theory implying certain policies induce innovation in certain firms, and thus ITC is considered part of the weak version of the PH. Demand pull, in contrast to technology push, refers to a market demanding a certain innovation leading firms to initiate search and development for that market need. But demand pull is known to rely

“too heavily on a neoclassical economic framework” (Rosenberg 1976, 96), while the Porter Hypothesis is embedded more naturally in a systems of innovation approach embodying both demand pull and technology-push approach.

On the other hand, the strong PH implies that such innovations indeed increase firm competitiveness while environmental policy directly leads to “positive innovations” (Ambec et al. 2013). In other words, the policy in question causes all regulated firms to innovate and make a handsome profit from doing so, thus leading to increases to productivity. Needless to say, evidence for the strong PH is scant (Rubashkina et al. 2015; De Vries and Withagen 2005), although as more dynamic approaches are incorporated, the strong PH is gaining ground. After all, as Schumpeter states, there will be creative destruction in innovative industries and thus we should not expect all firms to innovate and survive. Likewise, it becomes inherently difficult to identify exactly which firms are regulated by the new policy because of global value chains and globalized production methods.

Finally the narrow PH postulates that market policies should induce adequate innovation and overall competitiveness in firms (Lanoie et al., 2011). More clearly stated, carefully calibrated environmental policies will have the effect of inducing innovation in firms able to carry out such innovation in environmental technologies. Therefore, some firms will innovate in response to environmental policy and flourish, while other firms will succumb to creative destruction *a la Schumpeter* (see Aghion and Howitt 1990). It is worth reiterating here an additional caveat: both weak and narrow PH are not expected to induce positive innovation in all firms, only those firms most attuned to environmental policies (Porter and van der Linde 1995). Similarly, our *dynamic* conception of the Porter Hypothesis does not mean all multinational firms respond to all other country environmental policies, only firms expected to work with or export to the countries where policies are instituted. Below we discuss our new conceptualization of the PH.

We add to the three Porter Hypothesis definitions offered by Jaffe and Palmer (1997) (*weak, narrow, strong*) to include a *dynamic* international Porter Hypothesis: *dynamic* international PH refers to *innovative domestic response to environmental policies from abroad*, and such a feature is suggested, but not explicitly defined in previous literature (Sijm et al. 2004; Glachant and Dechezleprêtre 2014; Peters et al. 2012; Kneller and Manderson 2012). We adapt the concept of dynamic innovations across borderers from business innovation theorists who find empirical evidence for a link between technological competitiveness and trade performance in a variety of different sectors: “from such a *dynamic* perspective, it is not surprising that the relationship between technology, trade, and growth is at the center of analysis” (Van Hultst et al. 1991, 251). Further, and also stemming from business innovation literature, is the idea that if competition from abroad, or “learning-by-exporting” (Grossman and Helpman 1991); increasing domestic expertise in the production of environmental technologies should be expected to lead to increased export of these very same technologies, therefore eventually increasing rates of innovations due in large part to foreign environmental and climate policies. These ideas are at the heart of our reconceptualization of the Porter Hypothesis as a dynamic, cross-border theory. A dynamic model is apparently needed to deal explicitly with dynamic, and increasingly global, environmental policies (Grubler 2010; Geels 2006; Etzkowitz and Leydesdorff 2000). Interestingly, our conceptualization of a dynamic Porter Hypothesis seems to be

what Porter and van der Linde (1995) originally had in mind. We will expand on this below.

## **2. Technological Change and Policy-Induced Innovation in Environmental Technologies: Literature Review**

In terms of pollution caused by energy production and use, environmental policies aim to decrease harmful emissions from conventional energy. Simultaneously these policies encourage a shift towards more efficient and non-emitting clean energy technologies. Thus, environmental policies related to climate change specifically target *rates and directions* of innovations in production, storage, and consumption of energy technologies of firms. If the PH is correct by any measurable degree, a “win-win” (Jaffe et al. 2002) situation emerges whereby both society and firms gain by a cleaner climate and greater competitiveness (Kanerva et al. 2009, 12).

As discussed above, Porter (1991) proposes environmental regulations, if properly designed, need not always hinder firms but in fact might spur them to innovate. In contrast, it is typically assumed by most economists (and still is) that all environmental regulations damage firm profits (Ambec and Barla 2006). What is perhaps overlooked, especially from a macroeconomic point of view, is that the Porter Hypothesis (PH) is sometimes misconceived to imply that all environmental policies induce positive innovations in firms. However, this is not what Porter had in mind:

[We are not] asserting that *any strict* environmental regulation will inevitably lead to innovation [...] Instead, we believe that if regulations are properly crafted and companies *are attuned to the possibilities*, then innovation to minimize and even offset the cost of compliance is likely in many circumstances (Porter and van der Linde 1995, 110; italics added).

Notice, in particular, the PH does not rest entirely on price-inducement effects on firm innovation. This salient point is of critical importance. Companies *attuned to the possibilities*, rather than implying all companies benefit from innovation, implies instead that only companies cognizant of their innovative responses to policies will partake in this “win-win” scenario (Reinhardt 2000). Therefore the PH does not, as many mistakenly claim, mean all environmentally stringent policies induce innovative efforts in firms. Importantly, we should not expect a price inducement effect to represent an acceptable approach if the PH is used as a lens for analysis.

In short, firms can actually benefit from properly crafted environmental regulations that are more stringent (or imposed earlier) than those faced by their competitors in other countries. “By stimulating innovation, strict environmental regulations can actually enhance competitiveness” (Porter and van der Linde 1995, 98). Indeed, this would be a win-win situation (Reinhardt 2000), especially if those innovative firms were successful exporters of innovative environmental technologies. How might researchers go about exploring these important questions on competitiveness and innovation in environmental technologies? And why haven’t researchers fully uncovered a dynamic, cross-border PH?

### *A review of the literature employing the Porter Hypothesis*

The Porter Hypothesis has gathered enormous empirical evidence over the past 20 years. Earlier empirical research mostly cautioned against Porter’s predictions (Jaffe et al. 1995; Walley and Whitehead 1995) but more recent research suggests otherwise (Nemet et al. 2017). A variety of studies are able to demonstrate the positive innovation

outputs in reaction to properly constructed environmental policies (narrow PH). Finding a positive innovation effect from environmental policies is critical to climate policy, because technologies for the environment will play a salient role in combating climate change (Verdolini and Galeotti 2011; Johnstone et al. 2010). The importance lies in the implication that climate policies might be able to offer a “double dividend” (Hoffman 2000), or “win-win” (Reinhardt 2000), by catalyzing one or all of Schumpeter’s innovation vectors into action to produce and diffuse new climate change mitigation technologies. In sum, climate technologies will be critical for stabilizing greenhouse gases in the atmosphere (Hoffert et al. 2002), and therefore Schumpeter’s innovation vectors are increasingly important for examining the role climate policy has on effectuating firm innovation for these technologies.

Table 1: Brief Summary of literature on Porter Hypothesis, which shows various empirical and theoretical approaches developed by researchers since 1994.

Author(s)	Data	Porter strong	Porter narrow	Porter weak
Walley & Whitehead (1994)	Large Companies, always a cost	No	No	No
Jaffe & Stavins (1995)	find scant evidence for strong PH (looking at productivity increases from EPS).	No	No	Yes/No
Lanjouw and Modi (1996)	Patents Germany, Japan and the US	No	Yes	Yes
Jaffe and Palmer (1997)	Patents and R&D US Manufacturers	No	No	Yes (for patenting only)
Brunnermeier & Cohen (1998)	Environmental regulation positively impacts environmental patents at sector level	No	Yes	No (patents)
Xepapadeas, A., & de Zeeuw (1999)	Productivity in capital stock and machines	No	No	Yes
Berman and Bui (2001)	Productivity Los Angeles Refineries	Yes	No	No

Jaffe & Lerner (2001)	environmental policy stringency leads to specific energy innovation	No	Yes	No
Alpay et al. (2002)	Productivity Mexico and the US Manufacturers	No	Yes Mexico/ No US	No
Brunnermeier and Cohen (2003)	Green Patents US Manufacturers PACE/No Regulations	No	Yes	No
Murty (2003)	Productivity Indian Enterprises	Yes	No	No
Popp (2003)	186 plants in the U.S. from 1972 to 1997	Yes	Yes	No
Filbeck & Gorman (2004)	24 U.S. electrical Impact of environmental regulation	No	No	No
De Vries & Withagen (2005)	Green Patents 14 OECD countries	No	Yes	Yes
Gupta & Goldar (2005)	17 Indian Pulp and Paper	No	No	No
Popp (2006)	Green Patents Germany, Japan and the US	No	Yes	No
Lanoie et al. (2008)	Productivity Quebec	No	*Yes (international)	No
Rutquist (2009)	Productivity 48 US manufacturers (but sub-sectors variability)	No	No	No
Carrión-Flores and Innes (2010)	Green Patents 127 US Manufacturers Support	No	Yes	No
*Johnstone et al. (2010)	Green Patents 25 countries Support	(Dynamic)	Yes	Yes

Rexhäuser & Ramer (2010)	Productivity German enterprises	No	No	No
Greenstone (2010)	Productivity USA Manufacturers	No	No	No, Ozone and particles/Yes CO
Rübbelke & Weiss (2011)	Rübbelke, D. T., & Weiss,	No	No	Yes
Lee et al. (2011)	Green Patents US enterprises	No	Yes	Yes
*Lanoie et al. (2011)	Patents 7 OECD countries	(Dynamic)	Yes	Yes
Kneller & Manderson (2012)	R&D UK Manufacturers R&D	No	No	Yes
*Costantini & Mazzanti (2012)	Exports EU-15 countries	(Dynamic)	No	No/Yes
*De Santis (2012)	Exports EU-15 countries treatments: Kyoto, Montreal, cause change	(Dynamic)	No	No ER/Yes
*Johnstone et al. (2012)	77 countries, patents, WEF survey data as proxy for EPS.	(Dynamic)	Yes	Yes
Aguirre and Ibikunle (2014)	found no significant positive influence of policies on RE growth.	No	No	Yes/No
Nesta et al. (2014)	Renewables policies in competitive markets	No	No	Yes
*Sauvage (2014)	Exports OECD countries Support in Env. goods	(Dynamic)	Yes	No
*Groba (2014)	Exports 21 OECD countries	(Dynamic)	Support in Env. sector	No
*Rubashkina et al. (2015)	Patents and R&D in 17 EU countries	Yes Support in	No	No

		patents/No support in R&D (Dynamic)		
Lindman & Soderholm (2016)	wind industry in the EU	No	Yes	No

Literature surveys of empirical PH approaches are given by several researchers (Lanoie et al. 2011; Ambec et al. 2011; Ambec and Barla 2006). We do not intend to offer an extensive literature review of the PH here, only enough evidence to support our contention that price-inducement methods, and consequently the bulk of economic ITC models for climate technology, encounter some difficulties in capturing interindustry, and likewise cross-country, Porter Effects. The Porter Hypothesis evidently causes a renewed interest in induced innovation from environmental technologies. In general, a key finding is that environmental policies can and do induce firms to innovate in a variety of environmental innovations. Evidence for weak (Lanoie et al. 2011; Rubashkina et al. 2015; Lanoie et al. 2011), narrow (De Vries and Withagen 2005) and even strong PH (Ambec and Barla 2002) are found in the empirical literature.

### **3. On the different conceptual approaches to Climate Technology and Inducements Across Borders**

#### *Some Dynamic Approaches*

De Vries and Withagen (2005) are among the first to mention a *dynamic Porter Hypothesis* using an empirical approach. They find it very important to understand how domestic and foreign innovations, proxied by domestic and foreign patents, are diffused and integrated if indeed a foreign innovator is quicker to deliver an important environmental technology. They find that, even though domestic firms typically do not rely on foreign environmental technology for “off the shelf” technologies (end products), domestic firms do indeed rely on “foreign patents in developing their new equipment” (De Vries and Withagen 2005, 8). What this signifies is that foreign firms are probably responding to other countries’ environmental policies, but not to the extent we may think; foreign innovators might be supplying technologies which jump to other technological fields and therefore the foreign inducement effect is more spurious than by design. That is, foreign environmental technologies are integrated into new, end product environmental technologies needed at home.

The seminal paper by Johnstone, Hascic and Popp (2010) follows this approach to examine 25 OECD countries in all renewable energies (dynamic and semi-complex because renewable energies can sometimes be considered one industry and other times not). This highly cited article finds strong evidence of policy induced innovation in renewable energies, and that certain renewable energy technologies respond in variegated ways to different policies. For example, tradable energy certificates induce innovation in technologies that are already mostly competitive with fossil fuels while feed-in-tariffs (subsidies to distinct renewable energy technologies such as wind or

solar), are found to induce innovation in relatively new or novel (i.e. less competitive) environmental technologies.

The strongest example of a true dynamic-complex PH is conducted by Constantini and Crespi (2008). They look at strong PH in 20 OECD countries and find that firms do indeed react to environmental policies across borders, as well as to global environmental agreements such as the Kyoto Protocol. This approach is unique because it considers the expected future market of clean technologies as a result of international climate agreements. In a separate study, Costantini and Mazzanti (2012) carry out a similar approach, but rely more heavily on PACE (Pollution Abatement Costs) even though environmental taxes are also factored into their model. Although the latter approach is dynamic, the results are weaker, perhaps due to over relying on PACE which is now seen as a poor proxy for environmental policy stringency (Dechezleprêtre and Sato 2017).

Lastly, Albrizio et al. (2014) investigate 17 OECD countries using the strong PH and, indeed, find productivity increases as a result of environmental policy stringency (proxied by pollution intensity and total factor productivity). Taken together, these approaches carve out important avenues in the literature, and although the weaknesses of PACE are now well known (Rubashkina et al. 2015), these aforementioned studies sufficiently opened up the dynamic Porter Hypothesis. Finally, Rubashkina et al. (2015) examine weak and strong PH across European countries, and find evidence in favor of weak while their results are somewhat inconclusive for the strong PH. We would point out that their analysis appears to be very strong evidence of a dynamic PH. One drawback of this study, and indeed several of those discussed above, is in relying on PACE as environmental stringency indicator. PACE serves as a weak environmental policy indicator (Dechezleprêtre and Sato 2017; Galeotti et al. 2017), especially concerning the PH (Ambec et al. 2011). We recommend using environmental policies directly as a measure of stringency (such as the OECD's EPS), rather than a post-hoc measure of estimated costs spent by firms to combat environmentally stringent regulations.

### *Economic Black-Box Thinking*

The benefit to economists of conceptualizing induced innovation as a direct response to increased (energy) prices allows their favored variable "price" and secondarily "expenses" to take center stage. This leads to a more straightforward, or static, interpretation of the theory as a neoclassical economic problem. The neoclassical interpretation assumes prices guide markets, while innovation arises out of firm's response to prices; in short, a market-pull. As we shall see below, the PH is not a static theory (by definition) and as such suffers major setbacks if interpreted through the lens of neoclassical economics. This is in large part due to abstracting away variables such as institutional capacity or government policy changes, which invariably affect rates of innovation (Glass and Saggi 2002; Gross and Helpman 1993) especially in clean technologies which are evidently highly sensitive to government subsidies.

Research on innovations, especially environmental technology innovations, are sometimes guilty of leaving environmental innovations inside the black box. What happens within this "box" has been left to scholars from other disciplines (Fagerberg, 2004, 4). In other words, the puzzle is left unresolved. A related issue develops from this line of reasoning. The insistence on looking at climate innovations as coming from either

one of two schools: the demand-induced (market/policy), or technology-pushed. Meanwhile both systems, if employed independently, continue to keep innovation inside the black box because a dynamic approach is not considered. Whereas the supply school focuses on R&D as a primary variable going into the innovation system, in turn giving rise to innovations coming out of the black box, the demand school begins from the top and works down, i.e. demand changes will produce positive benefits at the bottom (Lundvall et al. 1988). As a result of these shortcomings, neither school is able to formulate a generally adaptable hypothesis for the PH, but only one that functions within very specific parameters (ibid).

Regulation-induced price changes cannot be confined to simply one country if we are looking at innovation in climate change mitigation technologies (CCMTs) (Kemp, Rip and Schot 2001). The latter are indeed globally dispersed throughout the global value chain (Dechezleprêtre et al., 2016), or in other words CCMTs are globally “saturated” (Dechezleprêtre et al., 2008). This means innovations in CCMTs are taking place around the world. Deductive reasoning leads to the finding that if environmental technologies are now unhinged from energy prices, the expansive innovative effects must be in some part due to various environmental policies in different countries. In contrast, price inducement requires the following assumption: innovation in environmental technologies occurs in regulated firms only *after regulation induces a price change*, which gives rise to R&D and only later, to new innovations. This assumption is based on a rather simplified understanding of innovation as a linear process, invariably leading to analysis using static models. These static models are often guilty of following a “deterministic model of technical change” that only weakly resembles the effect of policy on innovation rates (Weyant and Olavson 1999).

#### **4. Evolutionary Economics and the Porter Hypothesis**

Innovation might not be “fully responsive” to economic stimuli and occurs within certain patterns and constraints (Dosi 1988; Malerba 2002). Empirical studies often suffer from incorporating a linear model of innovation which is, by necessity, deterministic, assuming a “one-way flow of information, ideas and solutions from basic science [...] through the market to consumers” (Williams and Edge 1996, 3). Yet the evolutionary model is dynamic. Therefore innovation is an iterative and interactive process, not linear as assumed by price/R&D/innovation models (Freeman, 1982). However, as discussed above, most models for the PH rely on the antiquated premise of price/R&D/innovation as the primary drivers for innovative responses to policies (i.e. linear innovation models). Evidently, remaining fixated on price-induced innovation continues to frame the debate incorrectly, and as such wrongly supports a “static view of environmental regulation [...] where firms have already made their cost-minimizing choices” (Porter and van der Linde 1995, 97).

Clearly, induced technological change models are begging for more input from evolutionary economics. Apparently neoclassical models impose such a strong bias that the idea of induced technological change, which is itself partly extrapolated from evolutionary economics, continues to be embedded in the neoclassical economic frame. It is therefore critical to make a clear distinction between neoclassical and evolutionary approaches to induced innovation because most studies only differ in their choice of assumptions (Rennings, 2000: 324). Whereas neoclassical approaches implies “methodological individualism”, the evolutionary approach assumes serendipity of innovations, knowledge and technology spillovers (ibid).

### *Merging Eco-evolutionary and evolutionary economics for Dynamic Porter*

Both evolutionary economists and the eco-evolutionary school are highly cognizant of the potential for different spillovers, even though order of importance is different. For example, evolutionary economists find technology spillovers to be a primary feature of the global technological innovation system, while eco-evolutionary researchers tend to focus more on knowledge spillovers. We introduce a rather novel conceptualization here: *Environmental Policy Spillovers*. Spillovers are sometimes used to account for the observation of induced innovation from foreign countries (Galeotti & Verdolini 2011). Foreign spillovers come in several forms, all related deeply to the technological paradigm: knowledge spillovers, technological spillovers, and innovation spillovers. Foreign knowledge spillovers of energy technologies are an example of the dynamic forces at work in the global CCMT industry (Buonanno et al., 2003; Galeotti & Verdolini, 2011; Grubler, 2010). Foreign knowledge spillovers means, literally, knowledge of new technologies is “spilled” over, through any number of human ways, into the home country. But knowledge takes many different forms: know what, know why, know-how and know who (Lundvall and Johnson, 1994). Being able to make proper distinctions among these different conceptions in knowledge allow researchers to effectively branch away from classical economic theories. Indeed “devotees” of evolutionary economics would most likely argue innovation in environmental technologies involves dynamic changes in systems which go way beyond simply prices (Grubler 2010). ITC researchers stop short of embodying technical change by insisting on using equilibrium models, or production models based on prices, but technological change in climate innovation is known to be highly contingent on path dependence (Dosi 1984) and existing “capital stocks” rather than purely knowledge stocks (Grubler 2010). Nelson, Richard R., and G. Sidney. "Winter. 1982. An evolutionary theory of economic change." (2005).

### *Summing up the Eco-Evolutionary Approach to a Dynamic PH*

Eco-evolutionary theorists understand climate technology innovation as a longer, more dynamic process. In contrast to ITC economists positioned firmly in neoclassical models, eco-evolutionary theorists align more closely with evolutionary or behavioral economists. Subsequently, the latter might help to improve research related to the Porter Hypothesis, in particular investigations into foreign environmental policy spillovers and innovative effects at home. While evolutionary economists are mostly responsible for formulating modern innovation theory on the heels of Schumpeter, followed by evolutionary economists such as Nelson and Winter (1982), eco-evolutionary theorists are credited with providing support for concepts such as PH, and indeed ITC for CCMTs. The latter are more equipped to “open up the black box” of climate technology innovation. Indeed, eco-evolutionary theorists (Kemp, Rip, Schot, Nill et al.) “approach differs from the more cognitive technology approach of” evolutionary economists as the former examine characteristics of technologies as these technologies related to techno-institutional contexts, and more importantly how these technologies are symbiotically related to institution (Kemp 2000). This is what limits the economic decisions for policy-makers, and informs technological trajectories in the eco-evolutionary view (Kemp 2000).

In other words, eco-evolutionary theorists follow evolutionary economists but focus more on policy and institutional variables, and are therefore able to open up the black box of climate and environmental innovations induced by policies. This approach more readily allows various spillovers, including policy spillovers, to explain innovation in climate technologies. Consequently, the over-reliance on price models can be dropped. In this eco-evolutionary approach, powerful actors such as lobbyists might also be incorporated but their influence in technological development is muted because of the various other effects incorporated into the model (such as bounded rationality, exogenous influences) (Schot 1998). As such it is a quasi-evolutionary theory (ibid). Hence eco-evolutionary theorists emphasize institutional shaping and structuring of climate technology innovation, development and deployment. They show how government policies clearly alter the decisions of actors within the innovation system (Hekkert, 2011). In a sense, the eco-evolutionary lens draws in all three phases of Schumpeter's innovation system: invention, innovation, and diffusion.

Another advantage of focusing on institutional components is the ability to embody a co-evolution of policies and technologies. This means, more explicitly, a focus on the socioeconomic interactions influencing the rate and direction of technological change for the climate (Kemp 2000; Rip and Kemp 1998). In this manner, eco-evolutionary theorists are able to allow for serendipitous and niche innovations. As the name implies, niche inventions are able to slowly edge out frontier innovations over time. Thus niche inventions are quite related to "serendipity of innovation". New niche technologies often cause bifurcations, different from Dosi's path dependencies, which are unexpected innovations stemming from various industries, indeed sometimes not the industry regulated by environmental policies at all (Kemp, 1997).

In sum, eco-transition approaches attempt to re-establish the fundamental role institutions play in green technology development, much as earlier national innovation systems theorists (Lundvall et al.) sought to bring back the importance of institutions to economics because strong institutions allow innovations to flourish. Institutions are not static, but instead quite dynamic and morphing over time (Roland 2003). In this way, eco-evolutionary approaches closely align with the formal Porter Hypothesis: regulation has the effect of pointing out to firms, quite blatantly, that their pollution is a "wasted resource"; firms capable of responding are expected to innovate and survive, while those incapable of innovating will be destroyed (Schumpeter 1942).

## **5. Conclusion**

The literature on cross-border environmental policy inducement effects on innovation leads to lengthy debate in the literature over the past two decades. Though much of the debate centers around methods, we argue a reconceptualization of the Porter Hypothesis is able to blend seemingly disparate approaches. Still, much work is yet to be undertaken. Central to this debate is the role of carefully designed environmental policy. The question of whether global climate institutions and policies induce such innovation is and will continue to be vaguely understood. What is more clear are the importance of developing policies in the context of the Porter Hypothesis and global innovation. The weak and narrow PH are hypothesized here to be at work in the international realm, meaning stringency of a country's environmental policy may induce foreign technology innovation to satisfy foreign market demand. The latter is itself the result of targeted government environmental policy to create a strong clean energy industry. Consequently, a country that does not itself have the strongest environmental

policies may, as it were, become a clean energy technological leader. This is probably the most likely case for China. On the other side of the coin, a country with very strong environmental policies is able to induce varied innovators to supply increasing demand for these technologies, with the expectation learning-by-using environmental products will inevitably increase innovative offsets to policy leader.

We identify gaps in the literature which, if pursued in future research, might be able to find both qualitative and quantitative evidence of the PH at work. In terms of the latter, the magnitude of such effect should be of utmost importance for global and federal policy-makers. Meanwhile, qualitative research might continue to follow (Rip, Kemp, and Schot) in evolutionary transitions to eco-economy. The PH shifted the debate in a big way, but now it is time to better encompass government and institutional capacities (Norberg-Bohm 2001) into a new, dynamic Porter Hypothesis. Many of the international innovation effects pointed out in this paper (global policy leads to domestic policy changes; multinational companies respond to foreign policies; innovation is strengthened by participation in foreign markets; foreign direct investment in/out encourages more innovation) are already well known in the evolutionary economics literature.

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