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Do perceived operational impacts affect the portfolio of carbon-abatement technologies?

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Abstract

Firms face a variety of stakeholder pressures to improve their environmental performance. A firm's perceptions of these pressures can radically affect its strategic reactions and subsequent resource allocation decisions. Previous studies do not explain how perceived operational impacts may influence a firm's investment in environmental technologies. This study examines the relationship between perceived impacts on process and product and carbon preventive projects within firms' environmental technology portfolio. Using carbon emissions and carbon disclosure data, we find that higher perceived process-related impacts is associated with a higher proportion of carbon preventive projects, while perceived product-related impacts have the opposite effect.

Keywords: Perceived operational impacts; voluntary program; Greenhouse gas emission; environmental technology portfolio

1. Introduction

Over the past decades, governments in developed countries have pledged and committed to reducing Greenhouse gas (GHG) emissions. To achieve the reduction target, various carbon-related regulations and voluntary programs have been put in place to influence firms' investment in emissions reduction projects and technologies. The literature has provided a wealth of analyses of factors that explain firms' participation in voluntary programs and beyond-compliance behavior (e.g. Khanna and Damon, 1999; King and Lenox, 2000; Potoski and Prakash, 2005). Prior studies also examined the implementation and effects of environmental management practices on performance (e.g. Feng et al, 2016; Lucas and Noordewier, 2016) and carbon management issues (Lee, 2012; Doda et al, 2015; Lee and Klassen, 2015). However, the literature has paid little attention to what influence firms' investment decisions on long vs. short-term projects of environmental technologies. The choice of carbon-abatement technologies is a critical question for companies and regulators, because long-term projects are more likely to lead to technological innovations and breakthroughs. Statistics suggest that U.S. firms are considerably less willing to invest in pollution prevention than in pollution control, as the former is presumably more expensive and disruptive to existing processes. The U.S. Census Bureau estimated that total expenditures on pollution prevention in the U.S. manufacturing sector in 2005 reached only 30.5% of expenditures dedicated to pollution treatment and disposal (US Census Bureau 2005). In this study, we found that a firm's perceived likely impacts on its operations play an important role within its investment decision on environmental technologies.

The investment in environmental technologies represents a firm's overall strategy on the natural environment. Environmental strategies and their performance implications have inspired a large body of literature. For example, growing scholarly attention has been drawn to understanding proactive versus reactive environmental strategies (Sharma, 2000; Valentine, 2010), stakeholder and regulatory impacts on firms (Hoffmann et al., 2009; Marcus et al., 2011; Engau and Hoffmann, 2011), and creation of competitive advantages (Russo and Fouts, 1997). However, few studies examine how perceptions of regulatory and stakeholder forces influence a firm's environmental strategy and technology portfolio (Klassen and Whyback, 1999; Li et al, 2010; Nath and Ramanathan, 2016). To our knowledge, no study has addressed this issue empirically in the carbon management context.

This paper contributes to the literature in several ways. First, this study is the first to examine the allocation of the resources within the firms' environmental technology portfolio in carbon management. Second, we also touch upon how stakeholder demands for improved environmental performance and environmental strategies are related to decisions to invest in environmental technologies through how and where these impacts are perceived. Finally, existing studies ignores the organization segments in a firm and assume that firms will respond to stakeholder demands as a unified entity (e.g., Murillo-Luna et al, 2008). This paper extends this framework by exploring how the perceived operational impacts within the firm may affect carbon investment decisions and the configuration of the technologies portfolio.

2. Literature review

The lifecycle of corporate environmental strategies consists of multiple interrelated steps and straddles multiple bodies of literature. Figure 1 shows the scope of literature and the representative papers under each topic areas. The strategizing process begins with the inception of stakeholder pressures (e.g., government agencies and NGOs), which prompt firms to formulate an environmental strategy and to deliberate on environmental technology choices and actions. Subsequently, investments in environmental technologies and processes improvement influence both environmental and financial performances.

The lifecycle of an environmental strategy in Figure 1 seemingly unfolds as a unidirectional and linear process. However, the real strategizing process is often dynamic and interactive. For example, proactive environmental strategies can preempt stakeholder pressures for further regulation (Maxwell et al., 2000). A firm’s environmental performance can also alter the level of attention that it receives from NGOs and regulatory agencies (Baron and Diremeier, 2007), as well as change the course of a firm’s environmental strategies and tactical decisions (Delmas and Montes-Sancho, 2010). The current paper builds on stakeholder theories to examine a firm’s environmental technology portfolio as a function of perceived operational impacts from external environmental pressures. In the following sections, we look into the stakeholder theory arguments and describe the elements of environmental technology portfolio.

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2.1 Stakeholder theory and environmental management

Stakeholder theorists argue that a firm’s survival and financial returns hinge on its ability to serve and interact with its stakeholders (Freeman, 1984). The theory was later extended to the realm of corporate environmental and social responsibility (Hart, 1995; Hillman and Keim, 2001), in which stakeholder management is regarded as a key organizational capability necessary to achieve environmental and business sustainability (Hart, 1995; Klassen and Whybark, 1999). Stakeholders can include shareholders, governments, customers, competitors, environmental activists, and industry groups. Stakeholders can exert pressure to influence firms' behaviors and strategies toward the natural environment (Henriques and Sadorsky, 1999).

Among different stakeholder groups, regulatory stakeholders and customers serve as two key driving forces behind the movement toward corporate environmentalism (Henriques and Sadorsky, 1999). Regulators can restrict firm behaviors through legislation, forcing firms to internalize pollution costs, adopt cleaner technologies and comply with specific standards in their operations. Regulators can also initiate voluntary public programs, through which they signal regulatory threats and disseminate industry best practices to encourage firms to take voluntary environmental action (Lyon and Maxwell, 2008). Participating firms receive public recognition and free technical assistance in the reduction planning (e.g. EPA's Climate Wise Program). Similarly, prior studies have found that customers and their demands for corporate environmental performance have motivated firms to adopt pro-environmental practices and management systems (Darnall, 2006; Delmas and Montiel, 2009). Customers in developed countries, for example, can coerce suppliers based in developing countries to obtain ISO14001 certifications (Christmann and Taylor, 2001; Lyon and Maxwell, 2008). Suppliers may be pressured by customers to improve the transparency of their environmental records (Jira and Toffel, 2013; Lee et al. 2015). Murillo-Luna et al. (2008) found that managers view different stakeholder groups as a single pressure source and that the higher the stakeholder pressure level is, the more environmentally proactive a firm's response becomes.

While studies in the stakeholder literature have examined differentiate effects of stakeholder pressure from different stakeholder groups on a firm's environmental strategy and performance, the process in which stakeholder pressure is perceived and understood by a firm has been long overlooked. For example, the same stakeholder pressure (e.g., carbon tax program) can have very different implications for marketing and manufacturing departments in a firm, and the differences in perceptions may influence a firm's final decision about environmental investment. This is a critical theoretical gap, as strategic actions and technological investment decisions often reflect individual organizational constituents' perceptions of external pressures (Delmas and Toffel, 2008). Moreover, most hazardous wastes and pollution are direct by-products of production and operation activities. Therefore, it is important to consider operational contexts in analyses of organizational responses that are driven by external forces. In this regard, Delmas and Toffel (2008) proposed a model whereby firms channel external pressures to different functional departments, which in turn generate an idiosyncratic influence on facility managers' perceptions of environmental affairs. We draw on their model and examine how the perceived impacts on the operational contexts affect the composition of carbon projects within firms' environmental technology portfolios.

Following the findings from the literature, we posit that firms may differentiate their configurations of environmental technology portfolio according to their perceptions of where and how much the external stakeholder pressure may affect them. Next, we elaborate on the literature of environmental technologies.

2.3 Environmental strategies and environmental technologies

Management scholars have developed the conceptual framework for environmental strategies, which grows in parallel with the development of environmental technology framework. Several studies contend that environmental strategies can range from noncomplying, prescriptive, reactive to preventive and anticipatory (Sethi, 1979; Roome, 1992; Harts, 1995; Aragón-Correa, 1998); these two polar strategy sets differ in the degree of top-management involvement and organizational change (Henriques and Sadorsky, 1999). According to Hart (1995), firms that adopt a proactive strategy will go beyond existing standards and regulations, whereas firms that adopt a reactive strategy will minimize efforts as long as the ongoing standard is met. Proactive strategies encourage spontaneous initiatives in strategy formulation that reduces environmental impacts. In contrast, reactive strategies involve the adoption of a passive stance whereby firms only act in response to regulatory mandates.

Regardless of the orientation of environmental strategies, however, a firm may invest in a portfolio of environmental technologies according to its strategic orientations and competitive environments (Aragon-Correa, 1998; Klassen and Whybark, 1999). Environmental technologies are those that are designed to reduce negative impacts on the natural environment through process, equipment, and infrastructural innovations and it includes prevention technologies, control technologies, and management systems (Klassen and Vachon, 2003). Prevention technologies are those technologies that bring about fundamental changes in products and production processes as well as organizational changes that prevent the generation of pollution. Control technologies, in contrast, are add-ons that are installed in existing production processes to remove pollution that has already been generated. Finally, management systems are organizational infrastructures that improve the management of environment-related issues and they are often embedded in prevention and control technologies. Following similar studies (e.g. Nath and Ramanathan, 2016), we only consider control and prevention as independent constructors of environmental technology portfolio.

When comparing the two types of technologies, preventive technologies tend to be more disruptive of existing production processes (Klassen and Whybarks, 1999), require long-term capital investment (Cordano and Frieze, 2000; Klassen, 2000), and are endowed with higher levels of abatement potential. Moreover, compared with control technology, prevention technologies often induce more proactive and drastic technological changes that can involve process redesign, new asset acquisition, and new technology development. In contrast, control and end-of-pipe technologies typically rely on incremental innovations and minor alternations of legacy production processes (Hart, 1995; Russo and Fouts, 1997; Barney, 1991; Klassen and Vachon, 2003). When adopting control technologies, firms ameliorate existing process infrastructure and harvest "low-hanging fruit," such as low-budget energy efficiency projects. Although control technologies typically demand fewer resources and require fewer radical process changes than their preventive counterparts, they are less capable of generating long-term environmental improvements and benefits (Klassen and Vachon, 2003). Indeed, prior research has found evidence that preventive technologies are associated with better business performance and can lead to competitive advantage. For instance, Klassen and Whybark (1999) found that the proportion of prevention technologies in an environmental technology portfolio is positively correlated with superior manufacturing and environmental performance. Christmann (2000) found that innovative preventive technologies are associated with a direct cost advantage, though the extent of this cost advantage depends on the firm's internal capability for process innovations and external contextual contingencies such as industrial and market factors. This occurs because preventive technologies require disruptive process innovations, which are difficult to imitate and therefore will enhance competitive advantage according to the resource-based view (RBV) (Christmann, 2000). Moreover, when the business environment involves high levels of regulatory and market development opportunities, investments in preventive technologies may generate sustainable performance improvement (Russo and Fouts, 1997).

Despite the potential performance gains associated with preventive technology, there are also several barriers for adoptions. These barriers include high costs of deploying, the belittling of environmental issues within management teams, rigid organizational structures, limited knowledge transfer between competing firms, and skepticism surrounding new technologies (Cordano and Frieze, 2000). Given these trade-offs, firms will allocate resources to different types of environmental technologies, reflecting firms' strategic response to the perceived environmental impacts.

3. Research hypotheses

In this section, we apply the developed framework to the firm-level decision to reduce GHG emissions. It is constructed based on prevailing stakeholder theories and on the theory on organizational responses to environmental pressures (Delmas and Toffel, 2008).

Figure 2 displays the hypothesized model. In our setting, stakeholder groups first signal pressures for carbon reduction (stakeholder pressure is assumed to be exogenous). Subsequently, firms evaluate how these pressures may affect their business outcomes through the internal organizational contexts related to carbon abatement activities. Finally, firms deliberate over a response strategy and technology investment decision in anticipation of their perceived impacts and opportunities. In this paper, we consider the regulatory threat of carbon emissions (e.g., emission tax, carbon quantity control). We refer to impacts from this factor as "process-related impacts" as carbon regulations, once in place, would have a direct implication for production processes. We also consider the effect from voluntary over-compliance strategies, such as eco-labeling programs, and how a firm's perception about how its participation in the program may influence its investment decision to reduce its carbon emissions. We refer to these impacts as "product-related impacts."

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3.1 Investment in environmental technology and perceived process-related impacts

Process-related carbon policies concern firm-level emissions emitted through production processes. Heavy emitters and carbon-intensive firms are, thus, more likely to be affected by process-related carbon policies than firms that adopt cleaner technologies. Also, they are subject to higher levels of control and scrutiny by public and private agents. For example, regulatory agencies focus on large emission sources since it helps to maximize regulatory outcomes giving the constraints on resources to continuously enforce and monitor rule compliance. Similarly, environmental activist groups tend to target the major emitters with the hope to secure maximized environmental improvement and continuous public support. Because private and public politics are two influential factors that promote proactive environmental behaviors (Henriques and Sadorky, 1996; Reid and Toffel, 2009), firms affected by higher perceived process-related impacts should be more likely to devote substantive resources to process-related environmental technologies.

Process-based abatement activities, such as renovating existing processes, purchasing new capital assets and developing new technologies, often require major capital investments and may cause disruptions to production processes and routines. Therefore, process improvement strategies require more resources and longer payback periods for the investment, both of which contribute to risks associated with engaging in such strategies. Research on organizational decision-making suggests that firms will try to avoid risky strategies and long-term commitments in a highly uncertain environment, and those firms will turn to strategies leading to more predictable outcomes (Birnbaum, 1984). As we noted earlier, government agency actions and the financial outcomes of carbon projects can be highly unpredictable due to regulatory uncertainties. Therefore, according to organization decision theory, firms should prefer short-term projects in anticipation of carbon regulations, as short-term projects present less uncertainty than long-term projects.

However, recent environmental management studies suggest a contrary view on environmental uncertainty and find that uncertainty amplifies the positive effect of proactive environmental strategies. Several studies point out that firms that adopt proactive pollution-prevention strategies can secure more competitive benefits during periods of higher uncertainty (Porter and Van der Linde 1995; Klassen and Whybark, 1999). Researchers have found that firms adopting proactive environmental strategies are more risk-seeking. Empirical evidence shows that these firms are more risk-seeking in their technological choices and make more rapid and advanced technological improvement (Aragon, 1998). Aragon-Correa and Sharma (2003) also found that managers tend to be more risk-taking in their resource investments and environmental management capabilities before environmental regulations are established. The authors explained that uncertainty provides opportunities for innovative firms to develop unique resources and competencies, and this positive effect of uncertainty is more pronounced when regulations or industry standards are still evolving. Moreover, when regulatory threats are imminent, an investment in proactive strategies can function as a first-mover advantage when stricter legislation is passed in the future (Lyon and Maxwell, 2007, 2008). Therefore, under higher uncertainty, risk-taking decision can lead to develop unique organizational features which can turn into a first-mover advantage.

Based on the above discussion, we predict that manufacturers will invest more in carbon projects with long-term paybacks when anticipating higher potential process-related impacts.

Hypothesis 1: The higher process-related impacts a firm perceives, the more it will invest in carbon preventive technologies in the environmental technology portfolio.

3.2 Investment in environmental technologies and perceived product-related impacts

Currently, product-related GHG programs typically take the form of voluntary environmental programs (VEPs). For example, carbon and product efficiency labeling represent two important categories in the case of VEPs. Through VEP, firms can lower potential customer's information search costs involved in identifying a product's environmental quality attributes (Cohen and Vandenbergh, 2012). Joining a VEP usually does not require significant upfront investment. Participating firms can gain exclusive access to technical assistance, member information and financial subsidies (Lyon and Maxwell, 2007). Therefore, VEPs may suffer from free-rider problems, whereby certain participating firms devote symbolic rather than genuine efforts to reduce their environmental impact (Delmas and Montes-Sancho, 2010).

Numerous VEPs targeting GHGs have emerged over the years. These programs include those that measure GHGs generated (or reduced) during a product's manufacturing processes (e.g., Carbon Footprint Labels from Carbon Trust) or that certify that a product has met certain GHG standards (e.g., carbon neutrality). However, these programs have proliferated significantly over the years, and competition between labels has started to intensify. According to *ecolabelindex.com*, for example, there are currently more than 400 eco-labels, approximately 10% of which address carbon emissions. Furthermore, different standards can apply different methodologies for evaluating life-cycle carbon footprints, making comparing different labels difficult. Calculating a product's carbon footprint also requires product-specific production information across the supply chain, which is often costly to obtain. Given their voluntary nature, eco-labeling schemes can face competition from standards initiated by other industry organizations, government programs, and competitors (Fisher and Lyon, 2014). These standards often vary in terms of stringency, methodologies, and objectives. Therefore, managers may find it difficult to compare different standards and to arrive at a normative conclusion. Standards can also change or can become outdated due to competition between labels. However, it is difficult for the focal firm to hedge risks by investing in a diversified portfolio of multiple standards. Making long-term investments in one or a number of limited standards would prove risky under these conditions of uncertainty. These limitations may increase risks involved in investing in one specific label, discouraging firms from making long-term resource commitments to respond to the quest for carbon labels.

The growth of eco-labels signifies a growing demand for environmental information such as carbon footprints of products. For environmentally conscious customers, eco-labels offer a way to identify products with superior environmental attributes. However, research has shown that most consumers do not fully understand the meaning of eco-labels (D'Souza et al., 2006; Lyon and Maxwell, 2008). Customer ambivalence about environmental standards may increase in the presence of multiple competing labels. Harbaugh et al. (2011) show that customers' perceived uncertainties about meanings of eco-labels, coupled with the proliferation of labels, can undermine the value of eco-labeling and eliminate producers' potential gains from participating in eco-labeling programs. In the presence of extreme uncertainty, some customers may even view eco-labeling schemes as forms of greenwashing. Customer-side uncertainties may thus render long-term investment riskier, making short-term investment the firms' preferred option.

For these reasons, we predict that firms will tend to invest less in carbon projects with long-term paybacks when experiencing higher potential product-related impacts.

Hypothesis 2: The higher products-related impacts the firm perceives, the less it will invest in carbon preventive technologies in the environmental technology portfolio

4. Empirical analysis

4.1 Sample

We tested our hypotheses using data from the Climate Change Program under the Carbon Disclosure Project (CDP). The CDP is an international UK-based NGO that serves as a platform for companies to measure, disclose, and manage risks and strategies related to climate change. Every year, the CDP questionnaire is sent and firms are requested to submit online information about the business strategies on climate change, organizational risks and opportunities arising from climate change, reduction activities and plans, and GHG emissions.

Our sample includes manufacturing companies in S&P 500 that responded within at least one year of the CDP climate change program's initiation. We focus on manufacturing firms because such firms are carbon intensive and are subject to direct pressures from regulatory and market stakeholders. We restrict our analysis to 2011 and 2012, as the CDP questionnaire has undergone major changes in some of the most relevant sections and thus not permitting the inclusion of earliest years in the analysis. To control for firm-level carbon performance, we used firm-level carbon emissions data from Trucost. Trucost is a data provider that collects carbon emissions data disclosed through different programs and company reports. Through Trucost, we obtained the emission figures for those sample firms that did not report their emissions in CDP but through other information channels. Finally, we drew on Compustat data to obtain the financial variables used as control variables in our analysis.

The final sample includes 144 manufacturing firms that belong to NAICS manufacturing industries 311 to 339. Table 1 presents the distribution of these companies in each manufacturing sector (i.e., three-digit level code). As Table 1 shows, the computer and electronics, chemical, food and machinery manufacturing sectors form the majority of our sample.

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Insert Table 1 about here

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4.2 Variable Measures

According to Böttcher and Müller (2015), the relevant carbon practices are those associated with production, product and logistics areas. Following this study, we first identify the carbon abatement projects linked to these three areas and, then, we compute the percentage of firm's carbon abatement projects with a long payback period. Our dependent variable is, therefore, the proportion of investment in carbon preventive technology within firm's environmental technology portfolio. In the CDP questionnaire, a project can assume one of the three payback periods (i.e., less than one year, one to three years, or more than three years). We set the cut-off point for long versus short payback to one year. For example, project costs such as those related to lighting upgrades can be recouped in a matter of months, whereas the payback period for most energy efficiency projects is less than two years (McKinsey, 2009). These data were drawn from CDP Climate Change Program responses.

We construct the independent variables on perceived impacts based on firm responses to the CDP survey. In the CDP questionnaire, firms are required to describe their risk perceptions of GHG regulations and other climate-related developments. In particular, for each risk driver that firms are exposed to, they must specify the potential magnitude of its impact and its likelihood of occurring. The potential impact magnitude (mag_i) can take five different values: High, Medium-high, Medium, Low-medium, and Low. The likelihood of occurrence

($prob_i$) can take seven different values: Virtually certain; Very likely; Likely; More likely than not; Unlikely; Very unlikely; and Exceptionally unlikely.

We use the following scheme to classify the risk drivers into process-related, and product-related categories (see Table 2).

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Insert table 2 about here

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Next, we measure each firm's perceived operational impact by computing the expected impact under each impact category (i.e., process and product). For an impact category, its expected impact is calculated as the sum of the magnitude multiplied by the occurrence probability of its associated risk drivers. Then, we standardize the expected impact by dividing it by the maximum score of each category (i.e., the magnitude measure has five levels, and the probability measure has seven levels) to control for differences in perceptions (see Equations 1 and 2).

$$Process\_related\_impacts_i = \frac{\sum_{i=1}^{3} mag_i * prob_i}{5*7*3} \quad (1)$$

$$Product\_related\_impacts_i = \frac{\sum_{i=1}^{3} mag_i * prob_i}{5*7*3} \quad (2)$$

We control for the following firm characteristics that may confound our empirical analysis: Proximity to the market, GHG emissions, inventory turnover, size and profitability. Proximity to the market is a binary variable which takes the value 1 whether the manufacturing sector at 6-digit level NAICS directly sells to whole trade and/or retailers and 0 otherwise. Data come from 2002 Benchmark I-O Account, "Direct Requirements, Make, and Use Tables". The variable for *GHG emissions* is operationalized as the sum of GHG emissions as a direct result of a firm's productive activities (i.e., Scope 1 and 2 emissions) and comes from Trucost. Inventory turnover is measured as cost of the goods sold divided by the total inventory, reflecting the presence of the lean manufacturing practices put in place. We also control for size using the natural logarithm of total assets, and profitability using the natural logarithm of returns on assets. In addition, dummy variables identifying three-digit NAICS sectors are included to account for industry fixed-effects, and a dummy for the year 2012 is used to discount specific events that occurred in that year and their effects on all firms and sectors.

4.3 Estimation method

To test our hypotheses, we use a pooled OLS regression with industry and year fixed-effects. The regression model is given below:

$$\%\, carbon\_preventive\_projects_{it} = \beta_0 + \beta_1 Process\_related\_impacts_{it} + \beta_2 Product\_related\_impacts_{\mathrm{it}} + \beta_3 Proximity\_market_i + \beta_4 GHG_{it} + \beta_5 Inventory\_turnover_{it} + \beta_6 Size_{it} + \beta_7 Profitability_{it} + \beta_8 Industry\_dummies_{it} + \beta_9 year\_dummies_t + \varepsilon_{it} \qquad (3)$$

As our sample includes firms that reported in both 2011 and 2012, we report robust standard errors to control for heteroscedasticity and non-independence of the firms' responses (Greene, 2003).

5. Empirical Results

Table 3 shows descriptive statistics and correlation matrix among the variables. The dependent variable is the percentage of carbon preventive projects within the firm's environmental technology portfolio is positive and significant correlated (p<10%) with perceived process-related impacts, size and profitability and negatively correlated with product-related impacts. Among independent and control variables, we find the variable GHG is positive and significant correlated with size and with inventory turnover (p<1%). A test for multicollinearity was then run, finding values for that variance inflation factors (VIF) less than 5 which it means that multicollinearity is not an issue in our analysis (Hair et al., 1998).

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Insert Table 3 about here

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The regression results are presented in Table 4, which includes five models. Model 1 presents the estimations for the control variables, being the baseline model. In Models 2 to 3, we include each impact category separately (i.e., process-related impacts in model 2 and product-related impacts in model 3). Model 4 displays the full specification model.

The estimation results support our hypotheses regarding process and product perceived impacts. The coefficient of perceived process-related impact is positive and significant in model 2 and 4 (p<0.05 and p<0.01, respectively), indicating that a higher perceived process-related impact is associated with more investment in carbon preventive projects within the firm's environmental technology portfolio. Therefore, Hypothesis 1 is supported. As we expected, product-related impact is negative and significant in model 2 and 4 (both models, $p<0.01$), indicating that a higher perceived product-related impact is associated with a less investment in carbon preventive projects within the firm's environmental technology portfolio. These results confirm Hypothesis 2.

Among the control variables, firm's GHG emissions have a negative and significant effect ($p<0.10$), while profitability and firm size have a positive and significant effect on the percentage of investments in long-term carbon projects ($p<0.05$ and $p<0.01$ respectively). Large GHG emitters tend to resort to short-term solution associated with pollution control technologies. As expected, profitability and firm size positively influence the percentage of carbon preventive projects conducted, as indicated by the positive and significant coefficient found.

6. Discussion and conclusion

Corporate environmental management is usually triggered by stakeholder pressure. As a result, how stakeholder pressure is perceived may significantly alter the course of environmental strategies, investment decisions, and performance results. While researchers have used several theories to explain this strategizing process, most studies view the firm-level decision-making, and few examine how internal contexts of a firm may moderate how pressure is perceived and ultimately influence environmental technology investments. This paper contributes to the literature by presenting a framework that elucidates contingencies between internal contexts and decisions to make long-term investments in carbon abatement projects within the environmental technology portfolio. More generally, we refine the theoretical underpinning of the nuances of perceived pressure that influences the configuration of the carbon technology portfolio.

In our analysis, we examined whether different perceived business impacts differentially affect the composition of carbon abatement projects within a firm's environmental technology portfolio. Specifically, we tested whether perceived process- related impacts increase a firm's investment in carbon preventive projects and whether perceived product-related impacts have the opposite effect. Our empirical results support our hypotheses. Our findings provide several important implications for both managers and policymakers. This study suggests that firms will adjust their investment decisions for environmental technologies according to the level of perceived uncertainty. In this situation, one useful strategy that managers may consider is the real-option approach (McGrath, 1997). In this approach, a firm initially makes gradual and small investments in exchange of the capability to exercise a full-scale adoption at a better future timing. Firms may also cooperate with their competitors to establish a standardized technological and marketing protocols to preclude unnecessary competition and create a win-win solution. For policymakers, our message is that they should take actions to reduce regulatory uncertainty. This would call for a far-sighted, continuous (instead of disruptive), and stepwise scheme for environmental policymaking. Policymakers may also consider organizing platforms on which firms can learn or share their best environmental practices, so as to flatten the learning curve for adoption a new environmental technology.

Interestingly, prior studies do not specifically focus on GHG regulations but instead focus on environmental regulations in general. As such, the main source of uncertainty examined would be that of regulatory stringency rather than regulatory legitimacy. GHG regulation in the U.S. is undergoing a tremendous period of uncertainty, as a coordinated legal framework for GHGs has not yet been established across different nations and constituencies. More importantly, the legitimacy of GHG regulations in the U.S. has been called into considerable question, as opponents posit that the U.S. EPA is not authorized by law to regulate GHGs (Alder, 2001). The benefits associated with process-related technologies for GHGs are therefore expected to vary considerably, lowering firm incentives to invest in long-term carbon abatement projects. Australia’s recent enactment and abolition of carbon tax policies and the Waxman-Markey bill serve as good examples of controversies and uncertainties surrounding domestic GHG legislations. Therefore, our findings suggest that regulators should act prudently and be transparent in the regulatory process.

One factor fueling the regulatory uncertainty is the magnitude of future social and economic impacts from climate change. However, these impacts depend on parameters that are infamously difficult to estimate or determine, such as the discount rate for damage, development for carbon abatement technologies, and human’s ability to adapt to climate change. In a highly cited study, Stern (2007) estimates that 5% of global GDP will be lost if no aggressive GHG abatement action is taken. The loss, according to the report, can increase to 20% by the end of this century if the climate-induced risk and damage are defined more broadly. However, Nordhaus (2007) shows that the damage predicted by Stern (2007) is estimated based on an unrealistically low discount rate and the study may have overestimated the overall impact by a factor of 10.

The electric utility industry is arguably the sector that takes the hardest hit from regulatory uncertainty. The optimal fuel mix and generation and mitigation technologies are contingent on the prevailing carbon price, which is sensitive to regulatory policy (Reinelt and Keith, 2007). Companies also postpone their investment in anticipation of future regulatory certainty (Engau and Hoffmann, 2009). Anecdotal evidence suggests that the perceived regulatory uncertainty of GHG emissions is causing investment in GHG reduction to decline and that the surveyed firms are *"…increasingly focusing on investments with shorter payback periods, which tend to deliver only incremental benefits*" (CDP, 2014; 3).[1]A stable and robust regulatory policy not only increases companies' willingness to invest in proactive and long-term projects, but also helps companies to persuade their supply chain partner to monitor and manage their carbon performance (Chen, 2015). However, we argue that regulatory uncertainties are not very likely to alter the effects from product labeling. This is attributable to the fact that the effect of labeling is created by the growing segment of environmentally aware customers. Therefore, we predict that green customer segment should remain largely unaffected by unstable legislative processes.

Investment in carbon abatement projects plays a critical role in solving pressing problems of environmental degradation. The goal of this research is to examine the mechanism through which firms allocate resources within its environmental technology portfolio. Our analysis suggests that a firm's investment in carbon technologies is affected by the perceived impacts of stakeholder pressures, but most importantly, this effect is uneven depending on where the impact is expected to occur. Our findings suggest that policymakers should be wary about the firms' heterogeneous perceptions when designing environmental programs or developing an environmental regulation. For managers, our results suggest the same stakeholder pressure can be perceived very differently by different departments or functions in a firm, and therefore, top managers should base their environmental strategy on a balanced view. Finally, our analysis is based on a sample of the S&P 500 firms. Therefore, the findings are more applicable to larger firms, which also represent the population facing a greater regulatory threat. Further research should be conducted to investigate the impact on smaller firms.

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[1] Supply Chain Report 2013–14; Collaborative Action on Climate Risk. https://www.cdp.net/CDPResults/CDP-Supply-Chain-Report-2014.pdf. Accessed on June 18, 2015.

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NAICS	Manufacturing sectors description	No. of firms
311	Food manufacturing	17
312	Beverage and tobacco products manufacturing	8
314	Textile products mills	1
315	Apparel manufacturing	1
316	Leather and allied product manufacturing	1
321	Wood product manufacturing	1
322	Paper manufacturing	7
324	Petroleum and coal products manufacturing	7
325	Chemical manufacturing	31
326	Plastic and rubber products manufacturing	2
327	Nonmetallic mineral product manufacturing	1
331	Primary metal manufacturing	2
332	Fabricated metal product manufacturing	4
333	Machinery manufacturing	11
334	Computer and electronic product manufacturing	36
335	Electrical equipment, appliance and component manufacturing	2
336	Transportation equipment manufacturing	9
337	Furniture and related product manufacturing	1
339	Miscellaneous manufacturing	2
	Total	144

Table 1. Distribution of the firms by manufacturing sector at the 3-digit NAICS codes

Impact category	Risk drivers reported in CDP
Process	1. Cap and trade schemes 2. Carbon taxes 3. Fuel emissions tax
Product labelling	1. Product efficiency regulations and standards 2. Product labeling regulations and standards 3. Emission reporting obligations

Table 2. CDP's risk drivers and impact categories

		Mean	SD	1	2	3	4	5	6	7	8
1	% Carbon preventive projects (within the firm's environmental technology portfolio)	0.60	0.37	1.00							
2	Process-related impact	0.19	0.14	0.11 *	1.00						
3	Product-related impact	0.14	0.12	-0.13 *	0.36 *	1.00					
4	Proximity to the market	0.27	0.44	-0.03	-0.05	-0.01	1.00				
5	GHG	13.56	1.83	0.01	0.15 *	0.12 *	-0.16 *	1.00			
6	Inventory turnover	1.84	0.60	-0.07	0.06	0.14 *	-0.03	0.32 *	1.00		
7	Size	9.55	1.18	0.13 *	-0.05	0.12 *	0.05	0.63 *	0.11 *	1.00	
8	Profitability	0.07	0.07	0.17 *	-0.10	-0.03	0.01	-0.07	-0.21 *	0.09	1.00

Table 3. Descriptive statistics and correlations matrix (n=266)
* Significance levels at 10% for two-tailed tests.

	% Carbon preventive projects (Firm's environmental technology portfolio)			
	Model 1	Model 2	Model 3	Model 4
Proximity to the market	0.172	0.182	0.160	0.172
	(0.149)	(0.141)	(0.157)	(0.146)
GHG	-0.040*	-0.042*	-0.044*	-0.050**
	(0.023)	(0.024)	(0.023)	(0.024)
Inventory turnover	-0.019	-0.022	-0.004	-0.003
	(0.046)	(0.046)	(0.045)	(0.046)
Size	0.076***	0.081***	0.085***	0.098***
	(0.027)	(0.027)	(0.027)	(0.027)
Profitability	0.645**	0.676**	0.658**	0.720**
	(0.284)	(0.283)	(0.282)	(0.279)
Process-related impact		0.323**		0.580***
		(0.157)		(0.160)
Product-related impact			-0.482***	-0.745***
			(0.176)	(0.196)
Year dummy	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes
No. of observations	266	266	266	266
Adj. R-squared	0.082	0.094	0.1049	0.158

Table 4. Pooled OLS regression with robust standard errors. The dependent variable is the percentage of carbon preventive projects within firm's environmental technology portfolio. Regressions included industry dummies for 3-digit NAICS and year dummy for 2012, but they are not reported.

Robust standard errors are shown in parentheses below the coefficient estimates.

***, **, * Significance levels at 1, 5 and 10%, respectively, for two tailed tests.