The Interplay between Perceived Business Uncertainty and Organizational Capabilities in Firms' Response to Climate Change

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Abstract

With climate change emerging as one of the most important issues increasing uncertainty to the business circle, firms have shown different reactions. Why do firms differ in adopting and implementing carbon management practices (CMPs) in response to the global warming issue? This paper attempts to explore this question with particular attention to two factors: external business uncertainty and internal organizational capabilities. In this paper, we investigated whether business uncertainty, organizational learning and lean production capabilities influenced the adoption and implementation of CMPs as well as examined how organizational capabilities' moderate the relationships between business uncertainty and the level of CMPs. The results of a cross-sectional survey and hierarchical regression analyses indicate that (a) perceived business uncertainty decreases the adoption of CMPs, in particular those conducted within an organization; (b) organizational learning and lean production capabilities strongly facilitate the adoption and implementation of CMPs; and (c) lean production capability positively moderates the impacts of business uncertainty on the adoption of CMPs. This study provides guidance for managers and academics considering how to identify, design, and manage the dimensions of a firm's practices in response to the global warming issue within organization as well as with other organizations.

Keywords: climate change, business uncertainty, carbon management, organizational

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learning capability, lean production

1. Introduction

As climate change has emerged as one of the most important business concerns in the past decade, firms have begun to consider the global warming issue in their strategic management (Lash & Wellington, 2007; Kolk & Pinkse, 2005). The Kyoto Protocol, adopted in 1997 and entering into force in 2005, has served as a main driver behind changes in corporate responses to global warming; however, this inter-governmental treaty has always provoked controversies, and thus increased uncertainty for many industries (Pinkse & Kolk, 2010). For instance, China and Korea, the world's biggest and seventh biggest greenhouse gas (GHG) emitters as of 2010, respectively, refused to join the post-Kyoto agreement as a member of obligatory reduction countries; but at the same time, these countries announced their own voluntary medium-term mitigation goals in order to reduce carbon intensity by 40% to 45% below the 2005 levels and GHG emissions by 30% below the business-as-usual level by 2020, respectively (Lee, 2013). In contrast, Canada, which used to be a passionate advocator for the Kyoto Protocol, has recently announced to withdraw from this treatment.

Given these uncertain and complicated situations regarding climate change public policy, firms have shown different reactions. For instance, the initial response of some major U.S. emitters, such as Exxon-Mobile, focused primarily on political strategies that opposed the adoption of unfavorable regulations, which can be described as 'wait-and-see' or 'avoidant,' (Levy & Kolk, 2002; Lee, 2012). However, other U.S. firms, such as BP and DuPont, took a proactive stance by setting voluntary GHG emissions reduction goals and investing less carbon technologies as well as supporting newly proposed climate policies including the cap-and-trade scheme (Jones & Levy, 2007). In essence, this latter group was willing to take measures in advance, and could be labeled as ‘proactive’ or ‘all-round’ (Levy & Kolk, 2002).

Why do firms differ in adopting and implementing carbon management activities in response to the global warming issue? This paper attempts to explore this question with particular attention to two factors: external business environment and internal organizational capabilities. We examine a firm’s carbon management practices (hereafter, CMPs) as they relate to perceived business uncertainty and organizational capabilities. In addition, we explore how such organizational capabilities moderate the impacts of business uncertainty on the adoption/implementation of CMPs. Thus, this paper makes three contributions. First, this study defines and empirically operationalizes CMPs using a survey instrument. Because management research on climate change and its management from a business perspective is a new endeavor (Lash & Wellington, 2007), little consensus has emerged on the description and terms used with respect to a firm’s response to climate change. By synthesizing and extending the literature, this study characterizes two types of CMPs: CMPs conducted within an organization and between organizations.

Second, we identify the theoretical basis for the antecedents of the CMPs and empirically test the relationships. In contrast, previous studies attempting to gain a better understanding of firms’ responses to climate change have mainly focused on characterizing CMPs and identifying firms’ strategic types (e.g., Jeswani et al., 2008; Kolk & Pinkse, 2005; Levy & Kolk, 2002). Such typology-oriented research is usually conducted in the beginning stage of research.

Finally, this study analyzes a firm’s response to climate change from an organizational capabilities perspective. We explore the linkages between lean production and organizational learning as organizational capabilities, business uncertainty as an external influence, and CMPs. Collectively, this research lays the groundwork for organizational learning and lean practices that respond to the global warming issue, which in turn, can contribute to stronger environmental and financial performance.

The rest of this paper is organized as follows. In the section 2, we review the literature relevant to the study and suggest the definition and CMPs. Section 3 presents the research framework and hypotheses about the relationships between business uncertainty, organizational learning capability, lean production capability, and CMPs. Section 4 describes the research method, and Section 5 presents the results of the empirical analysis and findings. Section 6 discusses this study's academic and managerial implications as well as the limitations and some interesting avenues for future research. Finally, conclusions are summarized in Section 7.

2. Literature reviews and hypotheses development

2.1 Carbon management practices

In a very general sense, carbon management practices (CMPs) can be understood as systems and procedures that firms employ to respond to climate change, with a specific focus on greenhouse gas (GHG) emissions, including carbon dioxide, methane and similar compounds. There are some similarities, but also important differences, between traditional environmental management practices (EMPs) (Lee & Klassen, 2008) and CMPs. By way of similarity, both encompass a diverse range of activities related to products, processes, and supply chains. However, CMPs are very narrowly focused on a few specific performance measures, yet have multiple levels of interactions that integrate energy efficiency, public policy, supply chains, NGOs, and customers (such as adjusting product use). Such differences demand that firms cope with the global warming issue by translating carbon practices into many forms, such as labeling (e.g., carbon footprint), reporting (e.g., carbon disclosure), new technologies (e.g., carbon capture and storage technologies), and financial trade-offs (e.g., emission trading scheme). To begin, the practices and activities that collectively define carbon management are categorized along two different areas: intra-organizational and inter-organizational CMPs, labeled intra- and inter-CMPs, respectively.

2.1.1 Intra-organizational CMPs

Intra-organizational CMPs are systems and procedures that primarily target internal activities related to climate change, such as product improvement, process improvement and employee engagement. First, product improvement practices develop less carbon-intensive and/or more energy-efficient offerings (Weinhofer & Hoffmann, 2010). Firms can commercialize low-carbon technologies through incremental changes in existing products as well identifying carbon-free technologies through radical innovation (Pinkse & Kolk, 2010). Similarly to the 'design for the environment' (Allenby, 1991), the carbon intensity of products is formally assessed, monitored and reduced during the new product design and development process, possibly replacing petroleum-derived raw materials with plant-based ones. To make defensible decisions for product design, carbon footprinting can be used to assess the total amount of CO_2 emissions directly and indirectly embedded in a product over all the life stages (Widemann & Minx, 2007). As this methodology is becoming increasingly standardized, firms have begun measuring and reporting the carbon footprint of their products.

To be fair, carbon footprinting also must include process-related emissions, and process improvement is reflected through improved energy-efficiency and reduced emissions of GHGs. Examples include enhancing energy efficiency through better housekeeping and refurbishment (e.g., insulation) (Jesewani et al., 2008; Schultz & Williamson, 2005), overhauling the entire production process (Weinhofer & Hoffmann, 2010) and adopting the state-of-the art new process technologies (Lee, 2013). Firms also need to reduce indirect GHG emissions that are generated primarily from the use of electricity. To do this, many firms have considered substituting existing energy sources with cleaner or less carbon-intensive fuels, such as liquid natural gas or renewable energy sources (e.g., electricity derived from photovoltaic solar cells and wind turbines). Taking an inventory of greenhouse gas sources is a specific CMP that accounts for GHGs emitted to or removed from the atmosphere over a period of time. Firms use inventories to set a baseline for tracking emission trends in order to develop emissions reduction plans as well as to assess the progresses.

Third, employee engagement emphasizes integrating carbon management issues into daily business routines by encouraging the workforce to increase their awareness and actively participate in activities with respect to the firm's response to global warming (Jeswani et al., 2008). To do so, employees can be educated about environmental and/or climate-change-issues related to the firm's operations, and given incentives to pursue lower targets for GHG emissions (Lee, 2012). Such a practice frequently serves as a catalyst for driving organizational change, which in turn facilitates product and process improvement CMPs.

2.1.2 Inter-organizational CMPs

Inter-organizational CMPs (inter-CMPs) are those practices that focus on developing and exploiting relationships with stakeholders in order to address the global warming issue. Stakeholders include customers, suppliers, regulatory agencies, financial institutions and other business partners.

First, collaboration with supply chain partners, including both suppliers and customers, is crucial for reducing CO_2 emissions because raw material and use phases of a product's life cycle usually account for the largest portion of the carbon footprint. As a result, policy makers, as well as managers, are paying much more attention to supply chain measures as they attempt to reduce GHG emissions (Kolk & Pinkse, 2005). Firms have begun sharing carbon information regarding their products and manufacturing processes with buying firms as well as suppliers in order to present accurate carbon inventories. Collaborative research and development between buyers and suppliers are also required in order to develop less carbon-intensive and/or carbon-free products (Lee, 2012). To conduct such a collaboration-based supply chain measure successfully, a mutual willingness to learn about each other's operations as well as a good understanding of each other's responsibilities and capabilities are strongly demanded (Vachon & Klassen, 2008).

Second, inter-CMPs also include diverse practices that reach external stakeholders beyond a traditional supply chain. Government-sponsored voluntary programs, carbon information disclosure to financial institutions, carbon offset projects (e.g., emission trading schemes and clean development mechanisms) with other business partners are examples (Jeswani et al., 2008; Boiral, 2006; Kolk & Pinkse, 2005). Such practices can enable firms to address global warming in a more effective way. For example, a firm can achieve a GHG emissions reduction target at lower cost by participating in and utilizing an emission trading scheme or the clean development mechanism (Lee, 2013).

Collectively, intra- and extra-organizational CMPs might be influenced by both external forces and internal factors, as well as their interaction. As detailed in the following sections, this paper focuses on two sets of factors that have proven important to strategic and operational competitiveness: perceived business uncertainty, as an external factor; and lean production and organizational learning, as a set of critical internal organizational capabilities. Thus, in the following sections, we examine the theoretical basis for these hypothesized relationships, as illustrated in Fig. 1.

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2.2 Linkages between business uncertainty and CMPs

Business uncertainty, one of the most important business context faced within an industry (ie., competitive setting), can be translated into either managerial perceptions or more objective metrics (Aragon-Correa & Sharma, 2003). While both approaches have value, some have argued that the perceived business context is particularly critical, as management's perceptions drive decision-making for investment and implementation of competitive practice (e.g., Sitkin & Weingart, 1995; Child, 1972).

Initially, Milliken (1987) defined three related facets of business uncertainty that firms can face: state, effect and response uncertainty. State uncertainty occurs when managers perceive their general business setting to be unpredictable; effect uncertainty occurs when managers have difficulty predicting the impact of any changes; and response uncertainty occurs when managers perceive an inability to predict the consequences of individual decisions. In addition, complexity can be understood as a fourth characteristic of uncertainty, and is defined as the diversity of factors and issues influencing that business context (Miler & Friesen, 1983). The greater the number of factors in the business environment that managers perceive they must consider, the more complex and uncertain the business environment becomes.

Previous studies have provided conflicting suggestions on the relationship between business uncertainty and innovation or the adoption of new practices. Some researchers have addressed that managers perceiving more uncertainty associated with a decision are less likely to make that decision (e.g., Forlani et al., 2002; Sitkin & Weingart, 1995). Firms that face greater business uncertainties find it more difficult on how to allocate sufficient resources in order to respond to such a turbulent environment. A proactive response to an emerging issue such as global warming potentially requires significant firm-level resource commitment; however, a return from such investments is uncertain, thereby justifying a 'wait-and-see' approach.

On the contrary, other research has argued that managers in a less certain business setting can be more proactive. For example, Miller and Sharmsie (1999) revealed that as the uncertainty in the business environment increases, so does the variety of products offered by a firm, and therefore, its innovation. For uncertain environmental issues, such as carbon management, managers could attempt preventive actions instead of merely responding to events that have already occurred (Aragon-Correa & Sharma, 2003). Being proactive can also help to shape the nature of future discourse with stakeholders and competitors.

Although we recognize these conflicting arguments, we would anticipate that management's risk aversion to an issue that is not viewed as central to competitiveness will favor a 'wait and see' approach (Forlani et al., 2002). While climate change has emerged as one of the most complicated issues in the past decade, efforts to hammer out international treaties, such as the Kyoto Protocol, first adopted in 1997, remain fraught with challenges. Regulations have continued to be unpredictable, vacillating between public policy statements favoring lower carbon emissions and little or no regulatory action in many countries. For instance, many of the firms have strongly lobbied regulators to delay or avoid carbon taxes or emissions trading schemes due to concerns over their inability to forecast the costs and competitive impacts of such measures (Jones & Levy, 2007). Thus, we expect managers to hesitate in taking precautionary actions when responding to the global warming issue; instead, firms can be expected to implement small token adjustments because of the difficulty in determining key factors that are important for success (Smart & Vertinsky, 1984; Amit & Schoemaker, 1993).

H1. *As perceived business uncertainty increases, the adoption of CMPs decreases.*

2.3 Linkages between organizational learning capability and CMPs

Organizational learning is understood as a dynamic and systemic process by which organizations learn. This process stems from the knowledge acquisition of the individuals and progresses with the exchange and integration of this knowledge until a bundle of collective knowledge is created (Hedberg, 1981), embedded in the organizational processes (Jerez-Gomez et al., 2005). Organizational learning is usually conceptualized as the capability of an organization to create, acquire, transfer, and integrate knowledge (Zander & Kogut, 1995; Teece et al., 1997), and organizational learning capability can be defined as a bundle of tangible and intangible resources or skills the firm uses to create new forms of knowledge providing competitive advantage (Alegre & Chiva, 2008). A number of studies have explored the effective development of organizational learning capability, and arguably emphasized some of essential factors ensuring learning capability: experimentation, continuous improvement, teamwork, group problem solving, interaction with the external environment, dialogue and participative decision making (e.g., Alegre & Chiva, 2008; Chiva et al., 2007).

To effectively tackle climate change, it appears necessary that companies need to develop and deploy proper technologies, commercialize them, and cooperate with a diverse of external stakeholders. First, firms should engage in activities involving development of carbon-free technologies through radical innovation as well as low-carbon ones through incremental changes in existing product/process. Doing this requires further exploring new technological possibilities as well as fully exploiting existing ones (Pinkse & Kolk, 2010), which implies organizational learning (cf. March, 1991). Often, technological innovation required in responding to climate change is much more novel and thus asks for competitive reconfiguration of existing industries to move towards a carbon-free economy (Holdren, 2006). Organizational learning capability should foster innovation regarding to low-carbon and/or carbon-free technologies because product innovation itself is one type of organizational learning processes (McKee, 1992). Learning has been considered to play a determinant role in innovations, because it allows new products/processes to be adapted to changing environmental factors, such as customer demand uncertainty, technological developments or competitive turbulence (e.g., Wheelwright & Clark, 1992). In general, innovation consists of successfully implementing creative ideas, within an organization, and is therefore closely related to organizational learning (Alegre & Chiva, 2008). Changes in a firm’s response to climate change seems to rely on its organizational learning capability as innovation heavily depends on the firm’s capability to learn through which new knowledge is created, distributed, shared and used.

Second, responding to climate change demands firms to cooperate with external stakeholders including supply chain partners, regulatory bodies and business partners. For instance, Hyundai Motor Company has reported that approximately 85% and 12% of CO_2 emissions of its Sonata YF model came from the use phase and the upstream supply chain, respectively (Lee & Cheong, 2012). To develop low-carbon and/or carbon-free products, firms should share carbon information and actively collaborate with customers as well as suppliers. In this regards, organizational learning capability can facilitate such collaboration work with value chain partners because it emphasizes openness to external ideas and knowledge and utilization them through the sequential processes of exploratory, transformative, and exploiting learning (Lane et al, 2006; Jerez-Gomez et al., 2005).

H2. *As organizational learning capability increases, the adoption of CMPs decreases.*

2.4 Linkages between lean production capability and CMPs

The linkages between operations and environmental management have often drawn heavily from the perspective of lean manufacturing, with common objectives such as prevention at the source, reduction of wastes, efficient and effect use of inputs, and control of internal processes (Curkovic et al., 2008; Corbett & Klassen, 2006). Such a synergistic effect between lean production and environmental improvement has been known as "lean and green" (Berchicci & King, 2007; Rothenberg et al., 2001).

The core thrust of lean production is that specific practices can create a streamlined, high-quality system that produces finished products at the pace of customer demand with little or no waste (Womack & Jones, 1996). Lean production is a multi-dimensional approach that encompasses a wide variety of interrelated practices in an integrated system (e.g., Shah & Ward, 2003; McLachlin, 1997). Just-in-time (JIT) pacing, 'pull' triggered production, and quick changeover methods are most frequently included as lean practices, along with lot size reductions, continuous improvement programs and preventive maintenance. Lean also typically encompasses quality programs, such as total quality and process capability management. Collectively, practices can be viewed as forming bundles of related and internally consistent lean practices, such as just-in-time (JIT), total quality management (TQM), total preventive maintenance (TPM) and human resource management (HRM) (Shah and Ward, 2007).

Pollution and process inefficiency are very much related, as emissions can be viewed as a signal of inefficiency of operations (King & Lenox, 2002). Thus, plants with a strong emphasis on lean principles might recognize the potential value of reducing carbon emissions reductions through product and process change, thereby decreasing their need to "buffer" their process with excessive abatement technology (Rothenberg et al., 2001). Moreover, with lean systems, the involvement of employees at all levels of the organization is strongly encouraged. Such organizational involvement has been identified as a driver of environmental efficiency (Florida, 1996), and lean plants emphasize increased interaction between environmental and other plant staff (Rothenberg et al., 2001).

Lean production focusing on collaborative activities with suppliers and customers (Lorenzoni & Lipparani, 1999) helps a firm adopt and implement inter-organizational CMPs with less effort. To reduce CO_2 emission across the entire supply chain, the focal firm needs, first, to calculate the accurate carbon emissions from each phase of a product's life-cycle, and second, to leverage this data to design and develop less carbon-intensive product and process technologies. Such inter-CMPs require close collaboration and interaction with both suppliers and customers, including information and knowledge sharing.

H3. *As the use of lean practices increases, the adoption of CMPs increases.*

2.5 Moderating influence of organizational capabilities with business context

As mentioned above, previous studies have provided conflicting results on the relationships between business uncertainty and implementation of new practices. Although managers perceive the same degree of business uncertainty, their decision-making might differ based on their firm's readiness and capabilities. For instance, managers facing uncertain business environment may use more proactive strategies and implement preventive actions (Milliken, 1987) if they recognize their organization is sufficiently capable to undertake these conditions; however, in the same business context, managers may prefer a wait-and-see option to the proactive one (Forlani et al., 2002) when they are not confident with their organizational capabilities. We anticipate that lean production and organizational learning, as forms of organizational capabilities, complements business uncertainty and its effect on the adoption/implementation of CMPs.

The development of a firm's strategy for managing the business-natural environmental interface has been shown to be significantly influenced by managerial interpretations and attitudes (Andersson & Bateman, 2000; Sharma, 2000). Organizational capabilities should affect the process of managerial interpretations of external business context. When firms' organizational capabilities are low, we expect that business uncertainty leads managers to avoid taking risks and thus, they prefer a reactive response to proactive CMPs because they find it more difficult to allocate existing resources in developing a proactive environmental strategy because they are not sure about the consequences of such a response. In contrast, when firms' capabilities are high, business uncertainty facilitates managers to take greater risks and attempt to undertake preventive actions regarding climate change. This is not only because managers of capable plants are more confident with the consequences of precautionary responses but also because they perceive that such proactive strategies can help them achieve differentiation in uncertain business climates (Miller & Shamsie, 1999).

Sophisticated organizational capabilities are the most suitable for complex and uncertain situations because they confuse competitors, thus providing the potential for differentiation and competitive advantage (Black & Boal, 1984). Organizational learning and lean production enable firms to be more adaptive and thus timely respond to the quick changes in market and customer preference without compromising existing quality and cost performance (Spear & Bowen, 1999; Lichtenthaler, 2009). In the end, business uncertainty regarding global warming leads to aggressive invest in a proactive environmental approach only in which firms are confident to be able to differ themselves from competitors with such investments.

H4. *Organizational capabilities (lean production and organizational learning capabilities) positively moderates the relationship between business uncertainty and the adoption CMPs.*

3. Research methodology

3.1 The survey

Whenever possible, the survey instrument employed previously validated the scales. However, new scales were needed for the CMPs. We conducted a series of intensive interviews with managers at the energy, utility, environmental or production departments of six plants in the petrochemical and steel industries in Korea. These managers were well acquainted with GHG emissions reduction activities that their plant has undertaken. After these interviews, the questionnaires were further revised and modified.

Carbon management practices (CMPs). Two scales were designed to measure the levels of carbon management practices: intra-organizational (intra) CMPs and inter-organizational (inter) CMPs. We developed nine items for intra-CMPs by modifying the relevant items from the previous literature (e.g., Lee, 2012; Weinhofer and Hoffmann, 2010; Jeswani et al., 2008; Kolk & Pinkse, 2005). These include items related to product/technology improvement, process improvement and organizational involvement for reducing GHG emissions. The scale for inter-CMPs was combined with both new items and modified items from the green supply chain literature (e.g., Vachon & Klassen, 2008) and carbon management literature (e.g., Lee, 2012; Kolk & Pinkse, 2005). The seven-item scale also reflected collaborative emissions reduction activities, such as carbon information and knowledge sharing with customer and supplier, collaborative product development with customer and supplier, participation in the carbon disclosure project (CDP), an emission trading scheme, and the clean development mechanism.

Business uncertainty. We developed five items for business *uncertainty* based on the discussion of Milliken (1987) and Ward et al. (1995). These reflect state, effect, response, uncertainty as well as complexity.

Organizational learning capability. By synthesizing measurements suggested in the previous studies (e.g, Alegre & Chiva, 2008; Jerez-Gomez et al., 2005; Lichtenthaler, 2009), we developed seven items for organizational learning capability. The scale includes experimentation, interaction with the external environment, openness and communication, and participative decision making.

Lean production capability. We identified ten items for lean production based on previous literature (e.g., Shah & Ward, 2003; 2007; McLachlin, 1997). The scale for lean production in this study includes just-in-time flow, quality management and facility preventive maintenance.

3.2 The sample

Our unit of analysis was the individual plant for two reasons. First, many of the decisions regarding environmental management are dealt with at the plant level, based on site-specific conditions (Kocabasoglu et al., 2007; Vachon & Klassen, 2006). Furthermore, the present paper suggested the very site-specific factor – lean production capability – that would influence CMPs. Second, the new directive on GHG management of South Korea (the GHG directive), which entered into force in 2010, demanded 1570 heavy polluting sites to report the current levels of their GHG emissions, goals of emissions reduction and plans on how to achieve the goals in the near future. Each individual site was allowed to participate in and utilize the Korean emission trading scheme in order to accomplish its own emissions reduction target.

A Korean sample was compiled from an exclusive source, the *Greenhouse Gases Management Sites Directory*. The GHG directive designated a total of 1570 sites to be under monitoring of the Korean government, which consist of the agro-livestock (68 sites), general industry (784 sites), utility (140 sites), waste management (331 sites) and building and transportation (247 sites) sectors. Consistent with the purpose of this study, we selected the general industry sector. After excluding 114 sites from the industry sector, because these were just a retail store, a total of 670 plants were finally complied. As of August 2010, these sites emitted about 214-million tons of CO_{2e}, which accounted for almost 30.0% of total GHG emissions of South Korea.

Ideally, information should be gathered from multiple respondents at each site to minimize the potential of single-informant bias. However, this study, like many other studies in operations and supply chain management, targeted a single well-informed respondent, such as managers of production, environmental or energy/utility departments, who were well acquainted with their activities in reducing carbon emissions in product, process and supply chain sides as well as collaborative activities with customer, suppliers or other related organizations. The first phone-call to each plant had been made in order to ask whether the firm would participate in this survey and who would be a proper respondent. Following the answers to the first phone-call, the questionnaires were mailed, faxed or emailed to the willing-to-participate respondents. An initial mailing of surveys was followed one week later by reminder phone-calls to the contact persons at the companies that did not answer the survey.

Data collection was completed in August 2011. A total of 204 surveys were collected, representing a response rate of 30.1%, which was generally considered acceptable in OM and SCM research (e.g., Prahinski & Benton, 2004). Table 1 provides a summary of the respondents. By excluding twenty nine responses due to extensive missing data, 175 surveys were used for further analysis. Non-respondent bias was tested by comparing the responses that were returned before the reminder-call with those that were returned after the reminder-call. Twenty items were randomly selected from the survey, and *t*-tests were performed on the responses of the early and late responding groups. The results were not statistically significant at the 95% confident interval, suggesting no difference between our sample and the population.

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3.3 Validity of the measurement model

The measurement instrument used in this paper was tested for reliability, construct validity and unidimensionality. First, we used three ways to support the content validity of this survey: an extensive literature review; in-depth interviews with managers at plants; and a pre-test of the survey by the interviewees after designing the survey.

Second, an exploratory factor analysis (EFA) was utilized in order to evaluate the construct validity of CMPs because this construct was new to literature. After eliminating the three items (CMP07, CMP08 and CMP09) that violated the prior specific criteria and caused low reliability of Cronbach's-alpha, the EFA for the CMPs resulted in the identification of two distinctive dimensions as we anticipated: intra-CMPs and inter-CMPs (Table 2). The three items eliminated here were all about practices regarding organizational involvement. This may imply that activities related to organization or human resource management are a necessary condition for CMPs rather than an element of CMPs.

Third, we conducted a confirmatory factor analysis (CFA) to evaluate the unidimensionality and convergent validity of three variables: uncertainty, organizational learning, and lean production. After modification, LEAN07 and LEAN09 were removed. The final model fit indices (e.g., GFI, CFI, NFI, RMSEA and normed χ^2/d.f.) meet the recommended criteria, supporting unidimensionality. Thus, the three variables exhibit good convergent validity. All the results of the AVE, composite reliability, and Cronbach's alpha are greater than the critical values of .50, .70 and .70, respectively, demonstrating good reliability for each variable (Hair et al., 2006).

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Lastly, we assessed the discriminant validity by examining if the AVE, by the items of a construct, is greater than the average shared variance (square of the correlations in the off diagonals) between two constructs (Fornell & Larcker, 1981). All constructs satisfy this criterion (see Table 4), supporting discriminant validity. Table 4 also shows the correlations between control variables and latent variables.

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4. Results

4.1 Direct impacts of business uncertainty and organizational capabilities on CMPs

Hierarchical linear regression was used to test the hypothesized framework. Our model examines whether the levels of (perceived) business uncertainty and organizational capabilities influence the adoption/implementation of CMPs. In step one, the control variables (industry dummies and firm size) were regressed against intra- and inter-CMPs. Step two examined the predictor variables (uncertainty, organizational learning capability, and lean production capability) against each dependent variable. The results for Hypothesis 1 and 2 are presented in Table 5.

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Mixed results were found with regards to the relationships between business uncertainty and CMPs. For example, the levels of perceived business uncertainty are shown to be negatively related to intra-CMPs (β=-.16) at a cut-ff *p*-value of .05, whereas business uncertainty does not seem to significantly influence inter-CMPs. Those results provide partial support for Hypothesis 1.

The results of the analysis indicate support for Hypothesis 2, with organizational learning capability positively and significantly related to the levels of adoption/implementation of both intra-CMPs (β =.30, p < .001) and inter-CMPs (β=.23, p < .01). Hypothesis 3 is also supported that lean production capability is positively and significantly associated with intra-CMPs (β=.36, p <.01) as well as inter-CMPs (β=.30, p <.01).

Finally, we note that firm size had a significant and positive association with the adoption of both intra- and inter-CMPs. This finding may reflect that relatively larger firms have greater motivation to take proactive responses toward global warming issues.

4.2 Tests of moderation of organizational capabilities

Hypothesis 3 postulated that organizational capabilities, organizational learning capability and lean production capability positively affect the relationship between perceived business uncertainty and CMPs. The data were examined using moderated hierarchical OLS regression techniques, with the results also presented in Tables 5 (step 3). In the analyses, the independent variables (uncertainty, organizational learning and lean production) were standardized to the multiplication of the interaction term, which was entered in step 3.

Mixed results were found with regards to the interaction between business uncertainty and organizational capabilities on CMPs. For example, significant and positive interaction terms were found for business uncertainty and lean production capability (β=.23, p=.01 and β=.21, p < .01 for intra-CMPs and inter-CMPs models, respectively). However, the interaction terms of business uncertainty and organizational learning capability were not found.

To further probe these moderation effects, we calculated regression equations for the relationships between business uncertainty and intra- and inter-CMPs at high and low levels of lean production capability. We define high and low values as plus and minus one standard deviation from the mean (Cohen & Cohen, 1983). Fig. 2 illustrates these effects.

In Fig. 2, high levels of lean production capability are shown to positively reinforce the relationship between business uncertainty and intra- and inter-CMPs, supported by a significant simple slope calculation (*b*=.07 and *b*=.18 for intra-CMPs and inter-CMPs, respectively). Conversely, low levels of lean production have significant and negative effects on the relationships between uncertainty and intra- and inter-CMPs (*b*=-.37 and *b*=-.24, respectively).

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5. Discussion

5.1 Managerial implications

The results of the statistical analysis presented in Section 4 are discussed in this section. There are a number of strategic options that firms can choose to take in order to reduce and manage their GHG emissions as well as to cope with the related external pressures placed onto them. Such a response may encompass various but often complicated activities that require cooperation with other external organizations as well as those that are usually conducted within an organization. Practitioners can benefit from our results by noting the importance of operational and organizational factors in adopting and implementing CMPs in order to address the global warming issue.

First, the results suggest that the relationships between organizational capabilities – organizational learning and lean capabilities – and CMPs are very straightforward; yet, the relationship between business uncertainty and CMPs is less clear. These results indicate that organizational learning and lean production capability play a more critical role in adopting and implementing intra- and inter-organizational CMPs than business uncertainty. Consistent with previous literature that addresses proactive environmental management as a learning process as well as recourse and capability (e.g., Hart, 1995; Arragon-Correa & Sharma, 2003), these results imply that cross-functional teamwork, open communication, and employee support and encouragement for idea generation, information searching and sharing enable firms to successfully implement intra-organizational CMPs, including low-carbon product/technology development, energy-efficient initiatives and energy and material source substitutions. The results of this study also provide support for the idea that set-up time reduction, just-in-time, quality at the source and total preventive maintenance of lean production facilitate the adoption/implementation of intra-organizational CMPs. These results are very consistent with previous literature that addresses the fundamental parallels between lean production and environmental management (e.g., Curkovic et al., 2008; Corbett & Klassen, 2006), Similarly, the results for H2 and H3 indicate that organizational learning and lean production capability facilitate collaborative activities with other stakeholders in reducing and managing firms' GHG emissions, such as clean mechanism development (CDM), carbon information disclosure and GHG information sharing with customers and suppliers.

These results suggest that firms, who endeavor to foster organizational learning and lean production capabilities within the organization, may be able to respond to global warming much easily and timely. Managers who intend to increase the levels of their firm's response to global warming need to understand that carbon management does not differ greatly from the approach of an organizational learning and adaptation. Furthermore, intra- and inter-organizational CMPs do not build on an entirely new set of skills since lean production and carbon management are deeply interrelated. Therefore, efforts put in building an organizational learning and lean process should contribute to the extant continuous improvement capabilities of a business, which in turn enhances organizational capability to address global warming.

Second, we found partial support for Hypothesis 1. Business uncertainty negatively influences intra-CMPs, but not inter-CMPs. This indicates that managers facing uncertainty are generally likely to make small adjustments rather than big and radical changes. This result is consistent with our anticipation and that in previous literature (e.g., Smart & Vertinsky, 1984; Amit & Schoemaker, 1993). However, we did not find a direct relationship between uncertainty and inter-CMPs. Managers who face greater business uncertainty may take greater risks and thus take a proactive stance on the environmental issues, or they may not. While some managers may take preventive actions in order to reduce the uncertainty (Aragon-Correa & Sharma, 2003), others prefer a wait-and-see option because they find it difficult as to what and how to allocate resources (Forlani et al., 2002). Such a mixed result of this study may illustrate that additional work is needed in order to understand the factors that lead to CMPs, including stakeholder commitment and policy entrepreneurs, as suggested by previous literature (e.g., Carter & Ellram, 1998; Kocabasoglu et al., 2007).

Third, the results provide the overall support for Hypothesis 3. Lean production capability was found to moderate the impacts of business uncertainty on intra- and inter-CMPs. Support for H3 clearly illustrates that firms perceiving high business uncertainty are willingly to adopt CMPs only if their lean production capability is high. Conversely, firms with less lean production capability are more reluctant to adopt CMPs in high business uncertainty than in low business uncertainty. As mentioned before, the results strongly suggest that a contingent theory, which identifies interacting and moderating variables, can provide a better understanding of effects of business environment on the risk-taking behavior of a firm in environmental issues (Aragon-Correa & Sharma, 2003), including the global warming issue.

This can also explain as to why previous studies of the direct relationship between business uncertainty and environmental management investment have produced mixed results (e.g., Kocabasoglu et al., 2007). Furthermore, lean production intensifies the significance of the impacts of business uncertainty on CMPs. High lean production enhances positive associations between business environment and CMPs whilst low lean production intensifies negative associations between them. Overall, the results of the study clearly imply that lean production capability strongly influences the adoption and implementation of CMPs through both a direct and a moderating way.

5.2 Limitation and future research

By clarifying the limitations of this paper, we suggest the directions for future research. First, the concept of carbon management practices was first introduced in this study. While considerable attention has been paid to ensure the validity and reliability of the measures designed and used in the research, they should be re-tested in the future research. Second, we collected all the data from self-reports that may result in common method variance. We verified that common method variance did not influence the data and the data were reasonable; however, future research should enhance the generalizability of this study's findings by using more bias-free data. For instance, future research needs to utilize multiple respondents from each participating respondent, including production, environmental and supply chain departments. Third, although we control for potential confounding variables in the model, other variables may also impact the constructs of interest. Future work could examine other contributing factors (e.g., stakeholder commitment, technological capabilities and social capitals) that may influence the levels of intra- and inter-organizational CMPs. Fourth, the surveys were only administered to Korean manufacturing plants. However, the extent and strength of particular relationships might vary from country to country since contextual differences may matter. For instance, corporate responses to climate change as well as general environmental management differ depending on the environmental regulations and policies of countries (e.g., Klassen & Angell, 1998; Jeswani et al., 2008). Future research should investigate how institutional differences cause differences in firms' carbon management. Lastly, while the research has had light on research and practice regarding to the intersection of climate change and business, there is a deficit of theoretical background to better understand the relationships between business environment, organizational capabilities and firm performance. CMPs can be conceptualized modeled through a diverse range of organizational theories, including institutional theory, resource-based view, stakeholder theory and social network theory.

6. Conclusion

The growing number of research dealing with environmental issues anticipates that environmental management will have become an established and accepted part of mainstream operations and supply chain management sooner or later (Corbett & Klassen, 2006). Moreover, climate change has recently emerged as one of the most important environmental issues for the business circle. The purpose of this study is to identify a set of management practices in order to address global warming as well as to investigate the factors that may influence those carbon management practices: business uncertainty and organizational capabilities. Specifically, we considered whether business uncertainty influenced the adoption and implementation of CMPs. In addition, we examined organizational capabilities' moderating effect on the relationship between business uncertainty and the levels of CMPs as well as the direct impacts on them.

Broad-scale, empirical research using a survey methodology is relatively novel to this research field of operations management. The study has developed valid and reliable instruments for measuring CMPs. The validity and reliability of the scales were shown to meet the requirements through a series of rigorous tests, and thus can be used in future research. The construct with a better definition and measure can also facilitate empirical research efforts. Our findings present a range of issues for managers seeking to effectively address global warming in order to eventually improve performance. Organizational learning and lean production capabilities were shown to be important enablers for the successful adoption/implementation of CMPs since they are believed to facilitate continuous improvement and innovation inside an organization as well as collaborative activities with external stakeholders. Lean also moderates the impacts of business uncertainty on CMPs, providing managers with confidence, which also enable them to take risks, and thus take a proactive stance on the global warming issue. Overall, the results of this study provide guidance for managers and academics considering how to identify, design and manage the dimensions of CMPs within an organization as well as with other organizations.

7. References

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Appendix: Questionnaire items

Construct	Item code	Items
Carbon management practices		
		To which extent do you agree or disagree to each following statement (*1=not at all, 4=moderately, 7=great extent*) ? *Over the past 2 years, your plant…*
Intra-organizational	CMP01	has continued to develop energy-efficient or less carbon-intensive products
	CMP02	has invested in R&D for less carbon-intensive products/technologies
	CMP03	has continued to undertake projects to increase energy-efficiency in your production processes
	CMP04	has continued to conduct projects to reduce greenhouse gas (GHG) emissions in your production processes
	CMP05	has introduced innovative process technologies to dramatically reduce GHG emissions in your production
	CMP06	has substituted exiting energy sources with cleaner fuels
	CMP07*	has integrated carbon measures into your firm's performance evaluation and compensation system
	CMP08*	has engaged the entire employees and departments in reducing GHG emissions
	CMP09*	has provided employees with environmental and climate-change-related education and training
Inter-organizational	CMP10	has actively participated in emission trading schemes
	CMP11	has transparently disclosed your plant's GHG emissions information (e.g., the carbon disclosure project; CDP)
	CMP12	has acquired emissions permits by utilizing clean development mechanism (CDM)
	CMP13	has shared carbon-related information and knowledge with major customers
	CMP14	has undertaken collaborative work to develop less carbon-intensive products with major customers
	CMP15	has shared carbon-related information and knowledge with major customers
	CMP16	has undertaken collaborative work to develop less carbon-intensive products with major customers
Business uncertainty		
		To which extent do you agree or disagree to each following statement (1=*strongly disagree*, 4=*moderately,* 7=*strongly agree*)? *Over the past 2 years,*
	UNC01	trends in markets have become less predictable
	UNC02	the impacts of market changes on your firm have become less predictable
	UNC03	you have found it difficult on how to respond to market changes
	UNC04	increasing number of factors have influenced competitive environment
	UNC05	competitive environment has become complicated
Organizational learning capability		
		To which extent do you agree or disagree to each following statement (1=*strongly disagree,* 4=*moderately,* 7=*strongly agree*)?
	LEARN01	Employees receive support and encouragement when presenting new ideas
	LEARN02	Innovative ideas that work are regarded in our plant
	LEARN03	This plant promotes experimentation and innovation as a way of improving the work processes
	LEARN04	Employees are encouraged to interact with external knowledge sources (e.g., customers, suppliers, technological institutes, universities, etc.)
	LEARN05	Employees feel a free and open communication within their work group
	LEARN06	Cross-functional team is a common practice in our plant

	LEARN07	Employees are frequently involved in important decision making processes
Lean production		
		Please indicate which of the following lean practices have been implemented in your organization's production processes (1=*hardly implemented,* 4=*moderately,* 7=*fully implemented*)
	LEAN01	Lot size reduction
	LEAN02	Just-in-time (JIT) production
	LEAN03	Pull production
	LEAN04	Kanban system
	LEAN05	Mixed model production
	LEAN06	Set-up time reduction
	LEAN07*	Total quality management
	LEAN08	Quality at the source
	LEAN09*	Quality circles
	LEAN10	Total preventive maintenance

Note: Items denoted with an asterisk (*) were subsequently dropped from the study.

Table 1 Summary of responses

Industry	Oil, Petrochemical, Chemical (D1)	Pulp and paper (D2)	Metal, mineral (D3)	Electric and electrical (D4)	Machinery, automotive (D5)	Cement, construction materials (D6)	Other manufacturing	Total (mean)
Sample size	217	70	123	59	66	83	52	670
Respondents	64	26	42	6	21	17	26	204
No. of employees	415	210	494	146	2992	177	258	659

Table 2 Exploratory factor analysis for carbon management practices (CMPs)

Items	F1 Intra-CMPs	F2 Inter-CMPs
CMP01	**.68**	.39
CMP02	**.75**	.30
CMP03	**.88**	-.04
CMP04	**.87**	.20
CMP05	**.79**	.35
CMP06	**.57**	.18
CMP10	.04	**.85**
CMP11	.28	**.74**
CMP12	.09	**.86**
CMP13	.39	**.68**
CMP14	.26	**.77**
CMP15	.35	**.77**
CMP16	.28	**.83**
Eigenvalue	4.07	4.79
Variance explained (%)	31.3	36.8
Cronbach's alpha	.90	.92

Table 3 Confirmatory factor analysis

	Item	Loadings	AVE	Composite reliability	Cronbach's alpha	Fit statistics
Uncertainty	UNC01	.67	.51	.83	.86	χ^2/d.f. = 2.32, RMSEA = .085, GFI = .98, AGFI = .93, NFI=.98, CFI=.99, SRMR=.028
	UNC02	.67				
	UNC03	.70				
	UNC04	.71				
	UNC05	.79				
Organizational learning	LEARN01	.73	.57	.92	.90	χ^2/d.f. = 2.00, RMSEA = .073, GFI = .97, AGFI = .92 NFI=.98, CFI=.99, SRMR=.027
	LEARN02	.63				
	LEARN03	.80				
	LEARN04	.75				
	LEARN05	.84				
	LEARN06	.77				
	LEARN07	.74				
Lean production	LEAN01	.80	.56	.91	.91	χ^2/d.f. = 2.02, RMSEA = .081, GFI = .96, AGFI = .90, NFI=.97, CFI=.98, SRMR=.033
	LEAN02	.76				
	LEAN03	.64				
	LEAN04	.87				
	LEAN05	.91				
	LEAN06	.72				
	LEAN08	.54				
	LEAN10	.51				

Table 4 Correlation matrix

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1. D1	.31	.46												
2. D2	.13	.34	-.26**											
3. D3	.20	.40	-.33**	-.18*										
4. D4	.04	.19	-.13^{+}	-.08	-.10									
5. D5	.10	.30	-.23**	-.13	-.16*	-.07								
6. D6	.09	.29	-.21**	-.12	-.16*	-.06	-.10							
7. Firm size	5.34	1.27	.01	-.07	-.01	.13^{+}	.38**	-.16*						
8. Uncertainty	5.19	1.16	.17*	.02	-.06	-.03	-.04	-.01	.10	(.56)				
9. Intra-CMPs	4.63	1.27	.09	-.09*	-.05	.02	-.01	.14^{+}	.18*	-.18*	(.61)			
10. Inter-CMPs	3.27	1.54	.13	-.16*	-.06	.07	-.02	-.11	.17*	-.06	.56**	(.62)		
11. Learning	5.02	1.08	.27**	-.12	-.12	.01	.06	.02	.24**	.07	.47**	.36**	(.57)	
12. Lean	4.05	1.44	.01	-.06	-.02	-.03	.14^{+}	-.14^{+}	.10	-.18*	.47**	.41**	.36**	(.56)

$^{+}$: p <.1, *: p <.05, **: p<.01

Notes: The lower half of the matrix shows the estimated correlations between the latent variables; the diagonal in brackets shows the values for the averaged variance extracts (AVE).

Table 5 Results of a hierarchical regression analysis

	Model 1: Intra-CMPs			Model 2: Inter-CMPs		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Controls						
Industry (D1)	.11	.08	.10	-.10	-.14	.12
Industry (D2)	-.03	.03	.08	$-.26^{*}$	$-.23^{*}$	$-.18^{*}$
Industry (D3)	.00	.04	.04	$-.20^{+}$	$-.17^{+}$	$-.18^{*}$
Industry (D4)	.01	.03	.04	-.04	-.02	-.01
Industry (D5)	-.06	-.09	-.10	$-.21^{*}$	$-.24^{*}$	$-.24^{*}$
Industry (D6)	$.19^{+}$	$.22^{**}$	$.23^{**}$	$-.19^{*}$	$-.16^{+}$	$-.16^{+}$
Firm size	$.23^{*}$	$.15^{*}$	$.18^{*}$	$.20^{*}$	.13	$.13^{+}$
Main effects						
Uncertainty		$-.16^{*}$	$-.16^{*}$		-.02	-.03
Organizational learning		$.30^{**}$	$.27^{**}$		$.23^{**}$	$.21^{*}$
Lean production		$.36^{**}$	$.37^{**}$		$.30^{**}$	$.30^{**}$
Moderating effect						
Uncertainty × Learning			.00			.02
Uncertainty × Lean			$.23^{**}$			$.21^{**}$
R^2	.07	.38	.45	.09	.28	.30
$Adj.R^2$	.04	.36	.41	.05	.23	.27
F	1.84^{+}	9.80^{**}	9.86^{**}	2.69^{*}	5.62^{**}	5.73^{**}

$^{+}$: p <.1, *: p <.05, **: p<.01

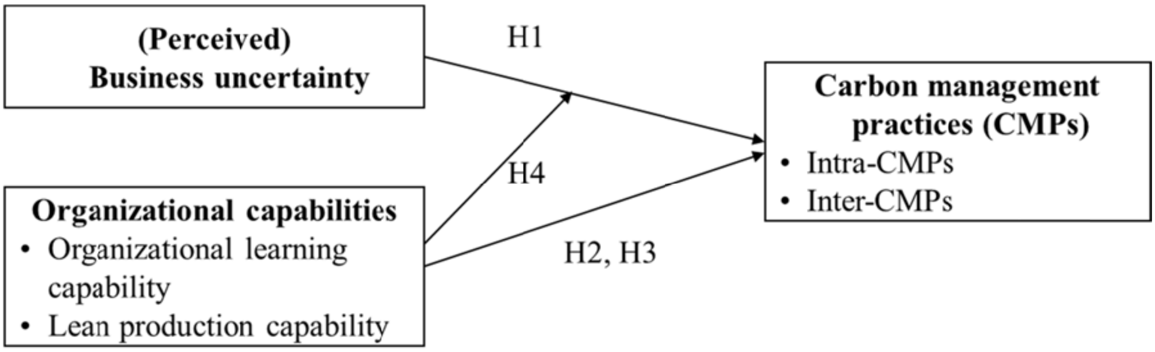

Fig. 1 Theoretical framework

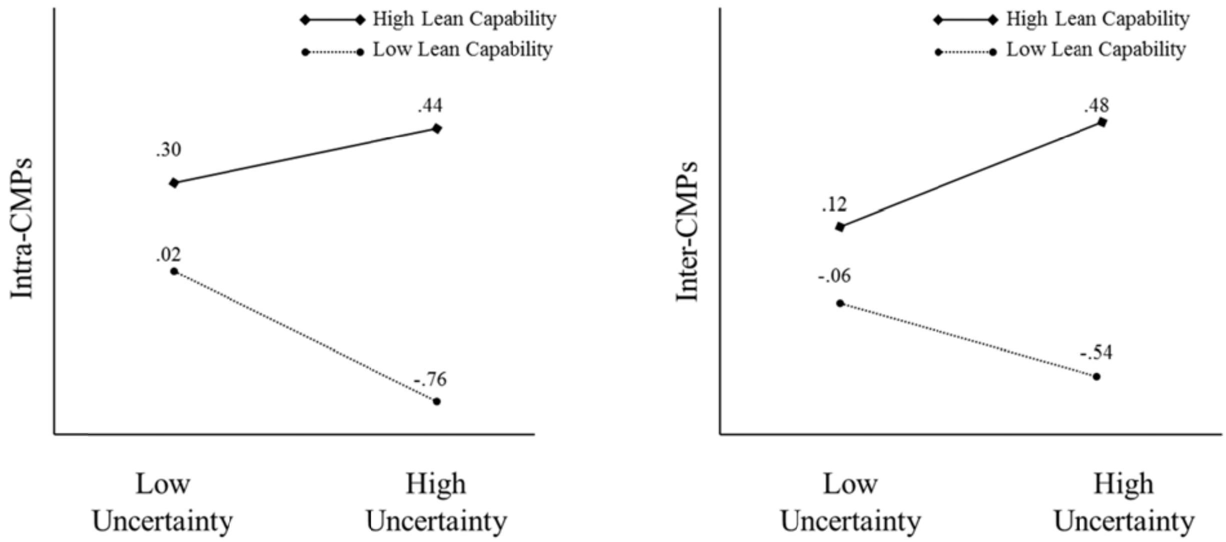

Fig. 2 Business uncertainty and CMPs by lean production capability