

# ECOLOGICAL UNCERTAINTY, ADAPTATION, AND MITIGATION IN THE U.S. SKI RESORT INDUSTRY: MANAGING RESOURCE DEPENDENCE AND INSTITUTIONAL PRESSURES

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*We draw on resource dependence and institutional theories to study how firms manage uncertainty in nature (ecological uncertainty) in the U.S. ski resort industry. Through resource dependence theory, we develop the concept of ecological uncertainty and explain its effects on firms' access to and management of natural resources. We then predict that firms adapt to ecological uncertainty with natural-resource-intensive practices, as well as practices that attempt to mitigate its underlying causes. Using institutional theory, we also predict that environmental expectations moderate these responses. Our results indicate that firms did manage ecological uncertainty by adopting natural-resource-intensive practices, but not mitigation practices. They also show that stronger environmental expectations constrained firms from adopting natural-resource-intensive practices and promoted their adoption of mitigation practices in response to ecological uncertainty. Copyright © 2015 John Wiley & Sons, Ltd.*

## INTRODUCTION

Research on how economic, political, social, and organizational forces shape firms' relationship with the natural environment is becoming fairly well developed (e.g., Bansal and Roth, 2000; Jennings and Zandbergen, 1995; King and Lenox, 2000; Reid and Toffel, 2009; Sharma and Henriques, 2005). Still, there has been limited attention given to how nature directly influences firm behavior. In this paper, we address this gap by studying how firms manage ecological uncertainty, which we define as uncertainty caused by firms' dependence on

natural resources and changing natural environmental conditions that can disrupt firms' access to those resources (Pindyck, 2000).<sup>1</sup> Examples of ecological uncertainty include ski resorts with unreliable snowfall because of warming winters, farms with unreliable rainfall, and forestry firms' uncertainty over timber harvests due to forest fires and pests that damage standing timber.

We focus on two corporate responses to this form of uncertainty: natural-resource-intensive adaptation and ecological mitigation. We define natural-resource-intensive adaptation as the

**Keywords:** resource dependence theory; institutional theory; uncertainty; adaptation; mitigation

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<sup>1</sup> The term ecological uncertainty has been used in the field of environmental economics to refer to "uncertainty over the evolution of the relevant ecosystems" resulting from policies designed to protect them (Pindyck, 2000: 235). We adapt the term to make it applicable to organizations and to account for the ecosystem dynamics that have ecological or social drivers.

adoption of practices that draw on resources directly from nature in response to natural stimuli that affect those or other natural resources. The aim of such practices is to establish reliable access to critical resources that are sensitive to natural stimuli, or other resources that can act as substitutes. Examples include ski resorts that use water-intensive snowmaking capabilities to compensate for unreliable snowfall, farms that use water-intensive irrigation capabilities to compensate for rainfall uncertainty, and forestry firms that accelerate their harvesting schedules to ensure that fires or pests do not destroy timber before it can be extracted (McCarthy *et al.*, 2001). Ecological mitigation refers to practices that address the underlying causes of natural environmental change and ecological uncertainty (Shrivastava, 1995). The aim of such practices is to protect the health of natural systems in order to improve their capacity to continue generating renewable resources (Costanza and Daly, 1992). Examples of ecological mitigation include firm attempts to address climate-change-related uncertainty by reducing greenhouse gas emissions (GHG) or advocating for political or grassroots action to constrain GHG reductions broadly across society (Hoffman, 2007).

To make sense of ecological uncertainty and firm responses to it, we draw on resource dependence and institutional theories. We adopt a resource dependence perspective to explain how natural-resource-intensive adaptation may help firms cope with ecological uncertainty. We also use this perspective to explain why firms may attempt to mitigate sources of environmental change that cause ecological uncertainty. We use institutional theory to explain how societal pressures shape firm responses to ecological uncertainty. In particular, we argue that environmental institutional pressures may constrain firms' ability to adapt to ecological uncertainty with natural-resource-intensive practices because natural resource consumption is a sensitive environmental issue (Kassinis and Vafeas, 2006). We also argue that these pressures may strengthen the relationship between ecological uncertainty and mitigation by shaping managers' perceptions of the effectiveness of mitigation practices.

We conducted our study in the U.S. ski resort industry, which has been contending with climate change and natural snowfall uncertainty since the 1980s (Barnett, Adam, and Lettenmaier, 2005; Burakowski and Magnusson, 2012; Koenig and

Abegg, 1997; Pederson *et al.*, 2011). Our sample consists of 83 western U.S. ski resorts and 861 resort-year observations during the 2003–2013 time period. Results indicate that ski resorts adapted to snowfall uncertainty by increasing their use of the natural-resource-intensive practices of snowmaking and terrain expansion. Contrary to expectations, they did not increase their use of climate change mitigation practices. Finally, results show that environmental institutional pressures constrained ski resorts' adoption of natural-resource-intensive practices and increased their mitigation efforts as responses to natural snowfall uncertainty.

This study contributes to research on resource dependence theory (RDT) and on the relationship between firms and the natural environment. First, it extends RDT into the natural realm by showing how corporate responses to ecological uncertainty differ from their responses to organizational interdependence. Prior research has shown how resource dependence on other organizations constrains firms' consumption of natural resources (Frooman, 1999; Henriques and Sadosky, 1999). Our study shows, however, that ecological uncertainty can induce firms to increase their use of these resources. Further, the study answers calls to assess how institutional pressures shape how firms manage resource-dependence-related uncertainty (Hillman, Withers, and Collins, 2009; Wry, Cobb, and Aldrich, 2013). Finally, it adds to the limited attention given to nature's direct influence on firm behavior (Hart and Dowell, 2011; Winn *et al.*, 2011).

## THEORY AND HYPOTHESES

Strategic management scholars have generated a rich body of research on corporate environmental management, with contributions to a number of organizational theories, including the resource-based and dynamic capabilities views (e.g., Hart and Dowell, 2011), neoinstitutional theory (e.g., Hoffman, 1999), RDT and stakeholder theory (e.g., Frooman, 1999), and transaction cost economics (e.g., King, 2007). The primary topics of interest in this area have been "win-win" strategies that generate economic and environmental benefits simultaneously, social and political pressures on organizations to limit their negative environmental impacts, economic incentives to create positive environmental impacts, and collective action

problems facing firms and industries that are managing widespread environmental problems (Berchicci and King, 2007).

Still, very little research attention has been given to how the natural environment can directly influence firms. Nonetheless, firms have been managing the physical challenges created by nature throughout history, including desertification, drought, extreme weather, flooding, the spread of invasive species and diseases, and collapsing ecosystems (Hart, 1995). Often, these challenges can affect firms' access to natural resources that may be critical to day-to-day operations (Starik and Rand, 1995). They may also involve "profound uncertainties" (Winn *et al.*, 2011: 158) due to the inherent complexity, size, and multilevel/multisystem configuration of the natural systems that generate them (Starik and Rand, 1995). Further, in some cases the impacts of these challenges are becoming "severe, pervasive, and irreversible" (Howard-Grenville *et al.*, 2014: 617), suggesting that they warrant closer scientific examination.

For these reasons, the goal of this study is to better understand how ecological uncertainty affects firms and how firms manage it. We rely on RDT since this perspective focuses on external uncertainty and its effects on critical resources that are generally outside of the firm's control (Pfeffer and Salancik, 1978). To date, the theory has focused on external resources controlled by other organizations in firms' institutional and industry environments, and uncertainty caused by firms' interdependence with these organizations (Wry *et al.*, 2013). We complement this focus by extending the theory into the natural environment, to explain uncertainty caused by firms' direct dependence on nature. Below, we propose how ecological uncertainty might lead to natural-resource-intensive adaptation and ecological mitigation, and how environmental institutional pressures shape these relationships. Figure 1 illustrates our model.

## Ecological uncertainty and natural-resource-intensive adaptation

Through RDT, Pfeffer and Salancik (1978) argued that firms can cope with uncertainty by adapting to their interdependence with other organizations. Such efforts are taken to maintain access to critical resources that are outside of firms' control (Hillman *et al.*, 2009; Wry *et al.*, 2013). In research on corporate environmental management, a number of papers have used RDT to study how interdependence with other organizations can influence firms' environmental performance (e.g., Frooman, 1999; Henriques and Sadosky, 1999; Kassinis and Vafeas, 2006; Sharma and Henriques, 2005). Generally, they examined how environmentally concerned stakeholders create uncertainty for firms by threatening to withhold critical resources because of poor corporate environmental performance. In response, firms tended to improve their environmental performance by reducing their use of natural resources.

We contend that ecological uncertainty may have the opposite effect on firms' consumption of natural resources. Specifically, we believe it may induce firms to engage in adaptation that increases, rather than decreases, their use of these resources for three reasons. First, natural-resource-intensive adaptation can help firms establish different sources of critical natural resources that are subject to less uncertainty. For example, farming operations facing uncertainty due to unreliable rainfall may be able to use more stable supplies of groundwater to irrigate their farmland (Wall and Smit, 2005). Second, because the direct firm–natural environment relationship does not involve organizational interdependence, firms may be less constrained by other organizations in their use of resources that come directly from nature (Ostrom, 1999). Third, firms may be able to externalize costs of consuming resources directly from nature since natural resources are often not

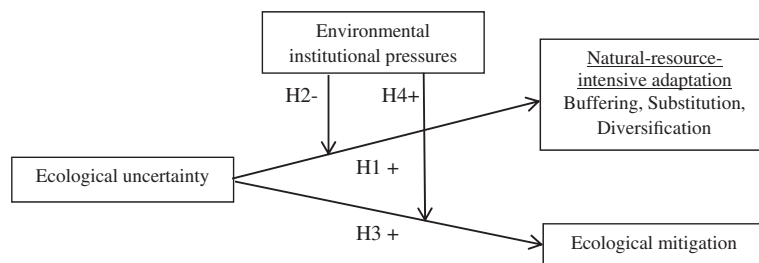


Figure 1. Conceptual model

regulated in a way that reflects their value to ecological and social systems (Costanza and Daly, 1992).

We consider three types of natural-resource-intensive adaptation that can help firms adjust to ecological uncertainty. First, firms may be able to buffer themselves from ecological uncertainty by increasing their inventories of the critical natural resources in question. These efforts can reduce firms' sensitivity to near-term ecological uncertainty by ensuring that they have stocks of critical resources on hand. Buffering may be achieved when firms use new natural resources from an existing site, or develop new supply channels for those resources at different sites. For example, in response to bark beetle infestations in commercial forests, many forestry firms have hastened harvesting schedules on existing sites to extract as much timber as possible before it is damaged by the beetles (Spittlehouse and Stewart, 2003). Second, firms may be able to develop substitutes for uncertain natural resources by expanding capabilities that draw on different or more stable supplies of those resources. For example, as ocean fisheries have become increasingly scarce, the commercial fishing industry has shifted toward the use of aquaculture, which is typically situated in coastal lowlands and mangroves and relies on aquatic and biotic resources from those systems (Piedrahita, 2003). Third, firms may be able to diversify their revenue streams by using natural-resource-intensive practices to develop new lines of business that are less sensitive to ecological uncertainty. For example, many ski resorts have developed real estate businesses in their mountain environments as snowfall uncertainty has made skiing operations less valuable (Scott and McBoyle, 2007). For these reasons, we predict that:

*Hypothesis 1: Ecological uncertainty is positively related to natural-resource-intensive adaptation.*

### **Ecological uncertainty, natural-resource-intensive adaptation, and environmental institutional pressures**

Firms' ability to adapt to ecological uncertainty with natural-resource-intensive practices may depend on the strength of environmental institutional pressures, which refer to the regulatory, normative, and cultural pressures that shape how

firms interpret and manage environmental issues (Bansal and Clelland, 2004). As environmental institutional pressures become stronger, firms may feel stronger pressures to protect the natural environment, in order to maintain their environmental legitimacy (Bansal, 2005; Hoffman, 1999). Environmental legitimacy refers to "the generalized perception or assumption that a firm's corporate environmental performance is desirable, proper, or appropriate. Stakeholders—which include managers, customers, investors, and community members—assess the firm's legitimacy according to their own distinct and diverse norms, "cognitive maps," and pragmatic preferences" (Bansal and Clelland, 2004: 94). We contend that stronger environmental institutional pressures may constrain natural-resource-intensive adaptation by creating legitimacy challenges for firms (Kotler, 2011).

In particular, more stringent regulatory pressures may involve coercive monitoring and sanctioning mechanisms that deter firms from responding to ecological uncertainty with natural-resource-intensive practices (Kassinis and Vafeas, 2006). Regulatory bodies charged with establishing environmental conservation policies with robust oversight and sanctioning mechanisms have shown themselves effective in this regard (Darnall and Sides, 2008). In addition, normative expectations may pressure firms to resist managing ecological uncertainty with natural-resource-intensive practices, in order to avoid scrutiny from activist stakeholders who question the moral validity of such practices (Henriques and Sadosky, 1999). For example, activist stakeholders have proven adept at deterring firms from natural resource consumption by engaging in publicity campaigns that use moral arguments to appeal to other powerful stakeholders, such as customers and investors (Frooman, 1999; Reid and Toffel, 2009). Finally, cultural expectations can generate mimetic pressures on firms to limit their use of natural-resource-intensive practices as a response to ecological uncertainty. Firms tend to be geographically embedded in social communities that share ideologies, identities, and traditions, and, by implication, expectations around corporate environmental responsibility. Further, they often internalize and conform to these expectations in order to "appear legitimate to key stakeholders" (Marquis, Glynn, and Davis, 2007: 932). Thus, we expect cultural expectations for conserving natural resources to translate into reduced use of natural-resource-intensive practices by firms



embedded in those communities. Based on these considerations, we predict that

*Hypothesis 2: Environmental institutional pressures negatively moderate the relationship between ecological uncertainty and natural-resource-intensive adaptation.*

### **Ecological uncertainty and ecological mitigation**

Above, we argue that natural-resource-intensive adaptation may help firms manage ecological uncertainty in the near term; however, this form of uncertainty may intensify and persist over time, and ultimately overtake firms' adaptive capacity (Winn *et al.*, 2011). Thus, we believe that firms may also adopt ecological mitigation practices to address long-term concerns about ecological uncertainty (Shrivastava, 1995). As mentioned above, such efforts aim to improve the health of natural systems that generate ecological uncertainty, in order to enable them to continue to reliably generate those resources (Costanza and Daly, 1992). For example, some forestry firms are adopting sustainable harvesting practices to improve forest health and decrease the sensitivity of timber to wildfire and bark beetle infestations. In addition, some of these firms are working with non-governmental organizations (NGOs) such as the Forest Stewardship Council and Rainforest Alliance to establish standards that can be promoted to the industry at large (Bartley, 2007; Sharma and Henriques, 2005). More broadly, in industries that are concerned about the issue of climate change, many firms are reducing their GHG emissions and investing in GHG sinking projects in support of broader efforts to stabilize the atmosphere and mitigate potential climate-change-related uncertainty (PricewaterhouseCoopers, 2010). Such efforts include improvements in energy efficiency, using renewable energy and GHG emission offsets, promoting ecological mitigation behaviors among firms' stakeholders, and advocating for regulations that reduce GHG emissions in public policy process (Hoffman, 2007).

If ecological uncertainty is localized, firms may be able to mitigate it effectively on their own. For example, some commercial fishing operations have been able to manage uncertainty associated with collapsing fisheries by developing health-monitoring systems for affected fisheries and reducing catch volumes when needed to help

fish stocks recover (Gulbrandsen, 2009). When the source of the uncertainty is geopolitically dispersed, such as climatic uncertainty driven by changing atmospheric conditions, individual organizations may be unable to mitigate ecological uncertainty in a substantive way on their own (Ostrom, 1990; Schendler and Toffel, 2013). In such cases, firms' best option may be promoting collective political and social mitigation action throughout the geographically dispersed systems in question. Such efforts would aim to build support for institutions to incentivize cooperation on mitigation (Ostrom, 1990).

Toward this end, firms can advocate for policies that attempt to mitigate ecological uncertainty. They can also engage stakeholders at the grass-roots level to promote bottom-up collective social action on mitigation, which may subsequently generate additional pressure on governments to adopt mitigation policies (Reid and Toffel, 2009). Finally, even though firms' private efforts at mitigating geopolitically dispersed ecological uncertainty may not be substantively effective on their own, they help demonstrate leadership on solving environmental issues, which legitimates firms' own calls for collective mitigation action (Schendler and Toffel, 2013). For example, although U.S. ski resorts do not generate significant GHG emissions, many are actively attempting to "to raise awareness of the potential impacts of climate change on our weather-dependent business and the winter recreation experience, reduce our own greenhouse gas emissions, and encourage others to take action as well."<sup>2</sup> A number of these resorts have also joined industry lobbying efforts for instituting U.S. regulations to curb GHG emissions. In light of these considerations, we predict that

*Hypothesis 3: Ecological uncertainty is positively related to ecological mitigation.*

### **Ecological uncertainty, ecological mitigation, and environmental institutional pressures**

The strength of environmental institutional pressures may also affect the relationship between ecological uncertainty and mitigation. Above, we argued that such pressures may constrain firms

<sup>2</sup> Quote from the National Ski Area Association "Ski Industry Climate Change Policy." Source: <http://www.nsaa.org/environment/climate-change> (accessed 21 August 2013).

from adapting to ecological uncertainty with natural-resource-intensive practices by creating legitimacy challenges for them. Here, we argue that robust environmental institutional pressures may help condition managers to more seriously consider the strategic value of adopting ecological mitigation practices in response to their firms' ecological uncertainty (Reid and Toffel, 2009). In particular, we note that ecological uncertainty overlaps with other issues that are important for environmentalists and policymakers who exert institutional pressures on firms, including climate change, collapsing ocean fisheries, and declining biodiversity (Winn and Pogutz, 2013). Thus, pressures exerted by these actors might also promote expectations for firms to adopt practices that mitigate ecological uncertainty. (Pinkse and Kolck, 2009).

As institutional expectations associated with specific practices increase, managers may become more likely to consider those practices as viable responses to related strategic issues (Dutton and Dukerich, 1991). Thus, stronger environmental expectations may lead managers to believe that their efforts to promote collective mitigation action will be influential with stakeholders in their institutional environments, both at political and grassroots levels. At the political level, existing or impending regulations on ecological mitigation complement firm attempts to advocate for related policies (Marquis *et al.*, 2007). Further, at the grassroots level, shared values and beliefs about the importance of ecological mitigation for society provide a normative foundation for firms to promote similar values and beliefs to their stakeholders (Reid and Toffel, 2009). Finally, cultural expectations, which are based in shared cognitive structures, influence how stakeholders pre-consciously interpret and evaluate corporate actions addressing specific issues (Kostova and Roth, 2002). Thus, stronger cultural expectations for ecological mitigation should make stakeholders more cognitively predisposed to interpret firms' promotional efforts on that issue as a call to action.

We contend that the positive effect of these pressures on stakeholders' willingness to join firm efforts at ecological mitigation should help create a strategic rationale for firms to adopt mitigation practices. Conversely, if institutional support for collective mitigation action is low, managers may be less likely to believe that such efforts will be influential or have strategic importance. More formally, we predict that

*Hypothesis 4: Environmental institutional pressures positively moderate the relationship between ecological uncertainty and ecological mitigation.*

## METHODOLOGY

### Data and sample

The study combines data from multiple sources to build the sample of U.S. ski resorts. Our initial sample was drawn from the Ski Area Citizens Coalition (SACC) database. The SACC is an alliance of nonprofit organizations that rates U.S. ski resorts on their environmental management practices. Previous studies have used the SACC ratings to examine the effects of voluntary certification programs and green marketing efforts on ski resorts' environmental performance (Rivera and de Leon, 2004; Rivera, de Leon, and Koerber, 2006). We use them to measure ski resorts' use of natural-resource-intensive adaptation, including their use of new terrain expansion, snowmaking, and real estate development in their mountain environments, as well as their efforts at ecological mitigation, including their energy efficiency, use of renewable energy, promotion of these practices to their stakeholders, and efforts to advocate for public policy on constraining GHG emissions. The SACC began rating resorts in 2001 with an initial sample of 57 firms; however, they only began comprehensively rating ecological mitigation practices in 2003. As a result, we began our sampling history in that year. Over time, the SACC expanded their coverage of resorts. In 2003, coverage was expanded to 70 firms; in 2005, to 76 firms; in 2006, to 77 firms; in 2009 to 83 firms; and, in 2011, coverage was expanded to 85 firms. Thus, our initial sample from the SACC was an unbalanced panel of 85 resorts and 868 resort-year observations from 2003 to 2013 [(70 resorts  $\times$  2 years) + (76 resorts  $\times$  1 year) + (77 resorts  $\times$  3 years) + (83 resorts  $\times$  2 years) + (85 resorts  $\times$  3 years)].

The SACC develops its ratings from different sources and methods of data collection. Archival sources include U.S. Forest Service documentation, such as ski resort environmental impact statement (EIS) files, forest district master development plans and management plan revisions, and ski resort expansion proposals (Rivera *et al.*, 2006). In addition, it reviews U.S. Fish and Wildlife Service field-work analysis, ski resort websites, and corporate

reports, media reports, business press, and trade journals. The SACC also administers an annual survey to resort managers to measure their efforts to reduce GHG emissions.<sup>3</sup> Although the SACC collects different types of data and uses different data collection methods, we acknowledge the possibility of common methods bias, since we use the data in more than one measure. To test for common methods bias, we relied on Harmon's (1967) one-factor test and factor analyzed the SACC ratings used in the study. Two distinct factors with eigenvalues of greater than one emerged from the analysis, which accounted for 39 percent of the variance in the data. As a result, we concluded that the ratings we used did measure different constructs.

Our final sample was determined by merging data from the SACC with ecological uncertainty data, which were generated using the United States Geological Survey (USGS) Precipitation-Runoff Modeling System (PRMS).<sup>4</sup> The PRMS is a "deterministic, distributed-parameter, physical process watershed model" (Markstrom *et al.*, 2008: 4) developed by the USGS to simulate climatic data, because of the limited amount of physical instrumentation available for collecting this type of data (Leavesley *et al.*, 1983). It has been widely used by climatologists, geographers, ecologists, and hydrologists for this reason (e.g., Hay *et al.*, 2006; Jeton, Dettinger, and Smith, 1996; McCabe and Hay, 1995; Wilby, Hay, and Leavesley, 1999). The Appendix contains a more detailed description of how the PRMS was used in the current study. Ecological uncertainty data could be simulated for 83 of the 85 resorts rated by the SACC, leaving us with a final unbalanced panel of 83 resorts and 861 resort-year observations from 2003 to 2013.

## Measures

### *Natural-resource-intensive adaptation: buffering, substitution, and diversification*

We develop three individual measures of natural-resource-intensive adaptation using SACC ratings. We measured resorts' use of *buffering* adaptation practices with a rating of new terrain developed over the previous year. Terrain expansion

can buffer ski resorts from snowfall uncertainty by providing access to potentially snowier terrain with more favorable aspects, elevations, and/or ground cover conditions (Hoffmann *et al.*, 2009; Scott and McBoyle, 2007). We measured resorts' use of *substitution* adaptation practices with a rating of new snowmaking adopted over the previous year. Snowmaking, where feasible, is a ground-water-intensive substitute for snowfall. We measured resorts' use of *diversification* adaptation practices with a rating of new real estate development on undisturbed land from the previous year. On-mountain real estate development is used by many resorts to generate alternative revenue streams that are less vulnerable to ecological uncertainty (Scott and McBoyle, 2007). The raw versions of the ratings actually measure how well ski resorts avoided these three practices. For this reason, we reverse-coded the ratings so that they capture the extent to which resorts adopted these practices. We also converted each rating to a ratio score (points awarded ÷ total possible points) since the maximum scores for the ratings sometimes changed from year to year.

### *Ecological mitigation*

We measure *ecological mitigation* as a summative index of four SACC ratings of resorts' practices to reduce and promote reductions in GHG emissions: (1) using wind and solar power; (2) promoting commuter buses, shuttle buses, and trains for guests and employees; (3) using low emission machinery and/or alternative fuel vehicles within the resort; and (4) advocating for climate change policy.<sup>5</sup> We consider this set of practices consistent

<sup>3</sup> Source: [http://www.skiareacitizens.com/index.php?nav=how\\_we\\_grade](http://www.skiareacitizens.com/index.php?nav=how_we_grade) (accessed 28 February 2012).

<sup>4</sup> The USGS provides PRMS instructions and source code at [http://www.wr.crs.usgs.gov/projects/SW\\_MoWS/PRMS.html](http://www.wr.crs.usgs.gov/projects/SW_MoWS/PRMS.html)

<sup>5</sup> We considered ecological mitigation as formative construct and developed the measure as a summative index, in order to capture a resort's total efforts at adopting practices related to ecological mitigation. Formative constructs differ from reflective constructs in that they are caused by a set of observed indicators, whereas reflective constructs are latent variables that are theorized to cause a set of observed indicators. Formative constructs also differ in their rules of validation from reflective constructs. Unlike reflective construct indicators, formative construct indicators need not be interchangeable, covary strongly, or have the same antecedents and consequences. Rather, they should capture a broad scope of phenomena related to the construct, avoid strong collinearity to limit the redundant influence of any one indicator in the measure, and have face and external validity (Diamantopoulos and Winklhofer, 2001; Podsakoff, Shen, and Podsakoff, 2006). To meet these conditions, we followed the method used by Strike, Gao, and Bansal (2006) to measure a firm's "corporate social responsibility practices" using Kinder, Lydenberg, Domini ratings. First, to address validity and scope requirements, we selected SACC ratings when there was a theoretical basis for doing so in prior

Table 1. Formative construct collinearity tests of the ecological mitigation indicators

Condition index SACC rating	3.80 Mean	S.D.	Range	VIF
1. Using wind and solar power	0.13	0.27	0–1	1.19
2. Promoting commuter buses, shuttle buses, and trains	0.46	0.38	0–1	1.15
3. Using low emission machinery and/or alternative fuels in the resort	0.14	0.28	0–1	1.14
4. Advocating for climate change policy	0.46	0.49	0–1	1.10

See Footnote 5 for a discussion of this table.

with substantive attempts by ski resorts to mitigate climate-change-related uncertainty because they capture efforts to promote collective climate change mitigation action, as well as resort-specific GHG emissions reductions to make their calls for action on the issue credible (Schendler and Toffel, 2013). Before summing the ratings into the index, we converted each rating to a ratio score (points awarded ÷ total possible points), because the maximum SACC scores were different for each rating and we wanted to ensure that practices received equal emphasis in the index.

### Ecological uncertainty

We measure *ecological uncertainty* as the coefficient of variation (standard deviation divided by the mean) of the average winter snowpack depth (in feet) at each resort year over the previous 10 years. The average winter snowpack depths for each year were calculated using monthly mean winter snowpack depth data from November to April, which were simulated with the PRMS program.<sup>6</sup> We rely on the coefficient of variation, which normalized

research. Second, we calculated variance inflation factors among the indicators, which yielded scores well below the rule of thumb of 10. We also assessed multicollinearity at the construct level with a condition index, which was acceptably low at 3.80 (Belsley, Kuh, and Welsch, 1980). Table 1 presents these tests.

<sup>6</sup> PRMS estimates were spot checked with average monthly snowpack depths measured by nearby National Weather Service weather gauges, where available, to ensure that the estimates were reasonable.

snowpack depth variability by average snowpack depth, because ski resorts with deeper snowpacks on the average are less sensitive to year-over-year variability. Our use of snowpack depth data follows previous research that identifies it as critical to ski resorts, because it determines both the quality and quantity of skiing terrain that can be opened (Hamilton, Brown, and Keim, 2007; Koenig and Abegg, 1997; Mote *et al.*, 2005; Scott and McBoyle, 2007). As Lazar and Williams (2010: 1) explain: “Research on the potential climate change impacts at ski areas is necessarily concerned with snowpack characteristics during the snow accumulation and early melt seasons, and needs to be able to evaluate issues important to managing ski areas, such as snow coverage and depth. Ski area managers are interested in knowing how early they might be able to open, how deep will the snowpack be in the fall and during critical holiday periods, and when snowmelt might force premature area closings. To answer these questions, an approach to modeling snowpack properties during the operational season (November through early April) is required.” We lagged the measure by one year, because ski resorts may be more likely to respond to past trends. As an example, in 2003, ecological uncertainty is measured as the coefficient of variation of average winter snowpack depth from 1993 to 2002.

### Environmental institutional pressures

We measured *environmental institutional pressures* using data from the League of Conservation Voters (LCV) that rates congressional support for environmental policies at the U.S. state level. The LCV is a nonprofit organization that measures the percentage frequency of each state’s congressional delegation legislative votes in favor of issues on the “environmental agenda” in each year (Delmas, Russo, and Montes-Sancho, 2007). We use a state-level measure, because states are largely responsible for developing and implementing environmental policy in the United States, and their policy stances on environmental issues tend to be consistent with locally prevailing norms and attitudes (Kassinis and Vafeas, 2002; Mazur and Welch, 1999). Following previous studies, we measure these pressures by averaging the LCV scores for each state’s House of Representatives and Senate congressional delegation in each year (e.g., Delmas *et al.*, 2007; Kassinis and Vafeas, 2002; Kim, 2013). We lagged the



measure by one year since institutional pressures may not immediately influence firm behavior.

### Control variables

We include several control variables that were lagged one year. We controlled for whether ski resorts were members of the NSAA Sustainable Slopes Program (SSP) with a dummy variable. Rivera and de Leon (2004) and Rivera *et al.* (2006) found that ski resorts participating in the SSP were more likely to adopt both natural-resource-intensive and energy conservation practices. We obtained data from the NSAA website to determine whether or not a resort was a member of the SSP in a given year.<sup>7</sup> We controlled for a ski resort's size in thousands of acres of operating terrain. Size can affect a ski resort's propensity to adopt natural-resource-intensive practices, such as snow-making and real estate development (Clifford, 2003). We measured this variable in 2013 by recording the number of acres of skiing terrain reported on each ski resort's website, and then in previous years by subtracting expansions occurring in those years as reported in news media and U.S. Forest Service EIS (16USC§497c, 1986). We controlled for whether ski resorts operated on *public land* with a dummy variable. Firms operating on public land might be subject to stricter environmental oversight from government agencies responsible for those lands (Briggs, 2000; Clifford, 2003). We controlled for *public ownership* with a dummy variable, since publicly traded firms can have greater access to financial capital for adaptation and mitigation efforts (Darnall and Edwards, 2006; Hoffmann *et al.*, 2009). Finally, we controlled for whether resorts were subunits of ski resort management companies with the dummy variable *group*. Horizontally integrated resorts might have more resources to deal effectively with the ecological uncertainty of any one subunit (Scott and McBoyle, 2007). We measured these final three variables with data from resort websites and websites from resort parent companies.

### Analysis

We tested our hypotheses using regression analysis with fixed effects at the resort level. Fixed-effects

regression is commonly used with time-series cross-sectional data because it controls for unobserved time-invariant cross-sectional effects. As a result, our use of the procedure estimates within-resort changes (Hsiao, 1986). We chose fixed-effects over random-effects regression because significant Hausman tests indicated that random-effects estimates were inconsistent. For the moderation tests in Hypotheses 2 and 4, we followed the recommendations of Aiken and West (1991) and mean-centered variables used in interaction terms.

## RESULTS

Tables 2 and 3 report descriptive statistics and correlations, respectively. On average, ski resorts in the sample achieved 30 percent (1.19/4.00) of the possible score for adopting ecological mitigation practices. The means of buffering, substitution, and diversification imply that ski resorts achieved 61, 73, and 71 percent of the possible scores, respectively, for natural-resource-intensive practices. Finally, the mean of ecological uncertainty indicates that ski resorts had an average snowpack depth coefficient of variation over the previous 10 winters of 0.48. Table 3 indicates that ecological uncertainty has correlations of -0.15 with ecological mitigation, 0.02 with buffering, -0.10 with substitution, and 0.13 with diversification.

Hypothesis 1 predicted that ecological uncertainty is positively related to natural-resource-intensive adaptation involving buffering, substitution, and diversification practices. Models 1, 3, and 5 in Table 4 report these results. Since we measure ecological uncertainty as coefficient of variation of a resort's snowpack depth over the previous 10 winters, we hold constant the denominator of the coefficient of variation (the mean snowpack depth over the previous 10 winters) at one foot, in order to facilitate a meaningful interpretation of the effect sizes of ecological uncertainty in terms of feet of variability. Model 1, which assesses the relationship between ecological uncertainty and buffering, provides marginal support for Hypothesis 1 (coefficient on ecological uncertainty:  $b = 0.13$ ,  $p < 0.10$ ). This result suggests that a one-foot increase in the variability of the resort's snowpack depth over the previous 10 winters (holding the mean snowpack depth constant at one foot) leads to a 13 percent increase in resorts' adoption of terrain

<sup>7</sup> Source: <http://www.nsaa.org/environmentsustainable-slopes/> (accessed 21 August 2013).

Table 2. Descriptive statistics

	Variable	Mean	S.D.	Min	Max
1.	Ecological mitigation	1.19	0.95	0.00	4.00
2.	Buffering	-0.61	0.36	-1.00	0.00
3.	Substitution	-0.73	0.31	-1.00	0.00
4.	Diversification	-0.71	0.32	-1.00	0.00
5.	Ecological uncertainty	0.48	0.21	0.13	2.05
6.	Environmental institutional pressures	0.51	0.28	0.00	0.98
7.	SSP	0.87	0.33	0.00	1.00
8.	Size (thousands of acres)	1.70	1.11	0.20	5.29
9.	Public land	0.78	0.42	0.00	1.00
10.	Public company	0.16	0.36	0.00	1.00
11.	Group	0.46	0.50	0.00	1.00

$n = 861$  resort-year observations for 83 resorts.

expansion practices. Model 3, which assesses the relationship between ecological uncertainty and substitution, supports Hypothesis 1 (coefficient on ecological uncertainty:  $b = 0.14$ ,  $p < 0.05$ ). This result suggests that a one-foot increase in the variability of a resort's snowpack depth over the previous 10 winters (holding the mean snowpack depth at one foot) leads to a 14 percent increase in resorts' adoption of snowmaking practices. Finally, model 5, which assesses the relationship between ecological uncertainty and diversification, does not support the hypothesis (coefficient on ecological uncertainty:  $b = 0.04$ , *n.s.*). In sum, we conclude that our results support Hypothesis 1 when natural-resource-intensive adaptation takes

the forms of buffering and substitution, but not when it takes the form of diversification.

Hypothesis 2 predicted that environmental institutional pressures negatively moderate the relationship between ecological uncertainty and adaptation. Models 2, 4, and 6 in Table 4 tested this hypothesis. In model 2, the coefficient of the interaction effect of environmental institutional pressures and ecological uncertainty on buffering is negative and marginally significant ( $b = -0.37$ ,  $p < 0.10$ ), providing marginal support for Hypothesis 2. Figure 2 illustrates this relationship at high and low levels of environmental institutional pressures (one standard deviation above and below the mean of environmental institutional pressures), and shows that resorts' adoption of buffering practices in response to ecological uncertainty declines as those pressures increase. In model 4, the coefficient of the interaction effect of environmental institutional pressures and ecological uncertainty on substitution is negative and significant ( $b = -0.52$ ,  $p < 0.05$ ), providing support for Hypothesis 2. Figure 3 illustrates this relationship at high and low levels of environmental institutional pressures, and shows that resorts' adoption of substitution practices in response to ecological uncertainty declines as those pressures increase. Finally, in model 6, the coefficient on the interaction effect of environmental institutional pressures and ecological uncertainty on diversification is negative and significant again ( $b = -0.37$ ,  $p < 0.05$ ), indicating that environmental institutional pressures also weakened the relationship between ecological uncertainty and diversification. Figure 4 illustrates this relationship at high and low levels of environmental institutional pressures,

Table 3. Correlations

	Variable	1	2	3	4	5	6	7	8	9	10	11
1.	Ecological mitigation	1.00										
2.	Buffering	0.12	1.00									
3.	Substitution	0.12	0.23	1.00								
4.	Diversification	0.02	0.40	0.22	1.00							
5.	Ecological uncertainty	-0.15	0.02	-0.10	0.13	1.00						
6.	Environmental institutional pressures	0.06	-0.15	-0.18	-0.16	0.12	1.00					
7.	SSP	0.26	0.11	0.12	-0.01	-0.21	-0.02	1.00				
8.	Size (thousands of acres)	0.28	0.20	0.30	0.27	-0.13	-0.12	0.17	1.00			
9.	Public land	0.01	-0.15	0.10	-0.25	0.00	0.16	0.15	-0.12	1.00		
10.	Public company	0.16	0.30	0.24	0.14	0.00	0.05	0.16	0.37	0.03	1.00	
11.	Group	0.24	0.11	0.19	0.10	-0.05	0.12	0.08	0.34	0.01	0.40	1.00

$n = 861$  resort-year observations for 83 resorts

Correlations greater than 0.09 are significant to the 95% level or greater.

Table 4. Fixed effects regression results on natural-resource-intensive adaptation and ecological mitigation

Variables	Buffering		Substitution		Diversification		Mitigation	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ecological uncertainty	0.13 <sup>τ</sup> (0.07)	0.15* (0.07)	0.14* (0.06)	0.17** (0.06)	0.04 (0.06)	0.06 (0.06)	-0.32 (0.22)	-0.43* (0.22)
Environmental institutional pressures	-0.05 (0.06)	-0.05 (0.06)	-0.05 (0.05)	-0.05 (0.05)	-0.21*** (0.05)	-0.21*** (0.05)	0.48** (0.17)	0.48** (0.17)
Environmental institutional pressures × ecological uncertainty		-0.37 <sup>τ</sup> (0.20)		-0.52*** (0.18)		-0.37* (0.16)		2.16*** (0.61)
SSP	0.05 (0.06)	0.06 (0.06)	0.02 (0.05)	0.03 (0.05)	0.05 (0.05)	0.06 (0.05)	0.23 (0.18)	0.16 (0.18)
Size (thousands of acres)	-0.02 (0.06)	0.01 (0.06)	-0.25*** (0.05)	-0.27*** (0.12)	0.05 (0.05)	0.04 (0.05)	-0.02 (0.20)	-0.02 (0.19)
Public land	-0.05 (0.06)	-0.06 (0.06)	0.12* (0.05)	0.11* (0.05)	-0.09 <sup>τ</sup> (0.05)	-0.09 <sup>τ</sup> (0.05)	-0.24 (0.19)	-0.20 (0.19)
Public company	0.09* (0.04)	0.09* (0.04)	-0.05 (0.03)	-0.04 (0.03)	-0.03 (0.03)	-0.03 (0.03)	0.14 (0.12)	0.11 (0.12)
Group	0.00 (0.04)	0.00 (0.04)	-0.08* (0.03)	-0.08* (0.03)	-0.01 (0.03)	0.00 (0.03)	0.52*** (0.12)	0.51*** (0.12)
Intercept	-0.66*** (0.12)	-0.65*** (0.12)	-0.36** (0.10)	-0.35*** (0.10)	-0.75*** (0.10)	-0.75*** (0.10)	0.93* (0.38)	0.91* (0.38)
R <sup>2</sup>	0.13	0.13	0.08	0.08	0.11	0.12	0.08	0.12
F	1.81 <sup>τ</sup>	2.00*	7.99***	8.17***	3.81***	3.96***	6.34***	7.15***

n = 861 resort-year observations for 83 resorts  
<sup>τ</sup>p < 0.10; \*p < 0.05; \*\*p < 0.01; \*\*\*p < 0.001  
 Standard errors are in parentheses.

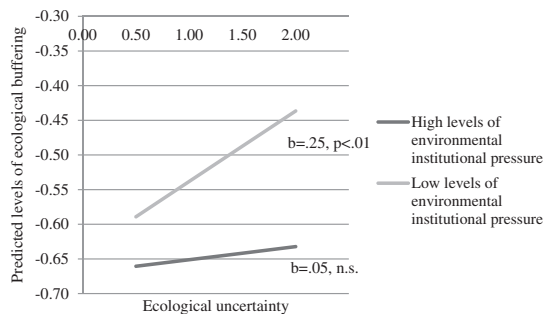


Figure 2. Effect of ecological uncertainty on buffering at high and low levels of environmental institutional pressures

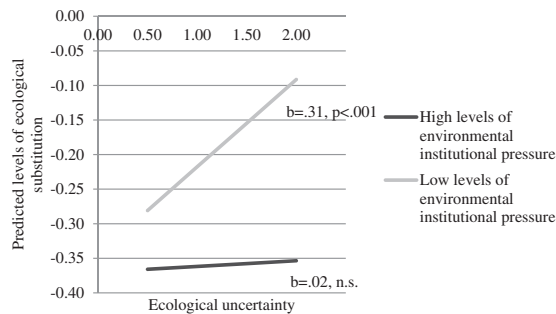


Figure 3. Effect of ecological uncertainty on substitution at high and low levels of environmental institutional pressures

and shows that resorts' adoption of diversification practices in response to ecological uncertainty declines. Overall, results support Hypothesis 2.

Hypothesis 3 predicted that ecological uncertainty and ecological mitigation are positively related. Model 7 in Table 4 reports the results for tests of this hypothesis, which is not supported (coefficient on ecological uncertainty:  $b = -0.32$ ,  $n.s.$ ). Interestingly, it appears that environmental institutional pressures drive resort's adoption of mitigation practices instead (coefficient on

ecological uncertainty:  $b = 0.48$ ,  $p < 0.01$ ). Finally, Hypotheses 4 predicted that environmental institutional pressures positively moderate the relationship between ecological uncertainty and mitigation. In model 8, the coefficient on the interaction effect of environmental institutional pressures and ecological uncertainty ( $b = 2.16$ ,  $p < 0.001$ ) provides support for Hypothesis 4. Figure 5 illustrates this relationship at high and low levels of environmental institutional pressures, which suggests that resorts become more likely to adopt mitigation practices

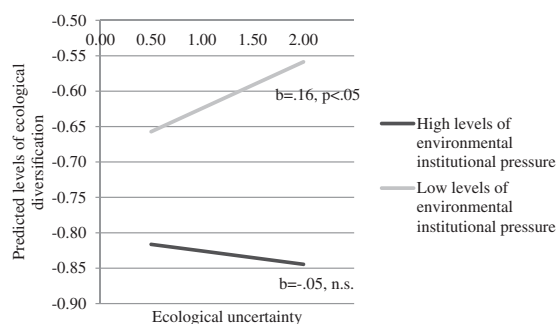


Figure 4. Effect of ecological uncertainty on diversification at high and low levels of environmental institutional pressures

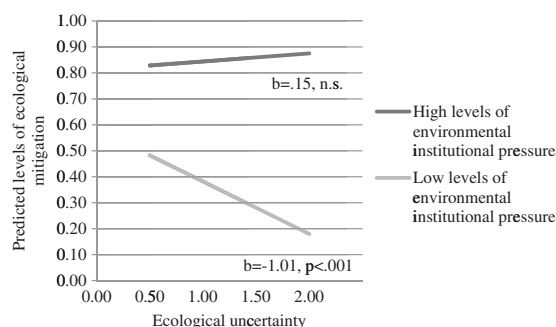


Figure 5. Effect of ecological uncertainty on ecological mitigation at high and low levels of environmental institutional pressures

in response to ecological uncertainty as those pressures become higher. Interestingly, the figure shows that ecological uncertainty does not seem to affect the adoption of mitigation practices when environmental institutional pressures are high ( $b = 0.15$ ,  $n.s.$ ). However, when those pressures are low, uncertainty is associated with a decrease in mitigation effort ( $b = -1.01$ ,  $p < 0.001$ ). Thus, strong environmental expectations may be necessary to pressure resorts to maintain their use of mitigation practices as their ecological uncertainty increases.

### Robustness checks

First, we reestimated each model with the inclusion of a variable that measures resorts' 10-year moving average winter snowpack depths (lagged one year), in order to control for a resort's sensitivity to ecological uncertainty. It is possible that managers of resorts with shallower snowpacks, on the average, consider snowpack depth variability a more urgent issue than managers of resorts with deeper snowpacks. Although our measure of ecological

uncertainty normalizes snowpack depth variability by average snowpack depth, and fixed effects in the analyses control for omitted time-invariant factors, average winter snowpack depths over set time periods in the past can change from year to year. Models including this control corroborate the primary results and are available from the authors upon request. Second, we reestimated each of our models using a Heckman correction on the SSP variable. This correction is commonly used for addressing endogeneity concerns related to self-selection bias with independent dummy variables (Greene, 2011; Heckman, 1978, 1979).<sup>8</sup> We implemented this test because ski resorts may self-select into the SSP based on their prior use of natural-resource-intensive and ecological mitigation practices.<sup>9</sup> Models using this correction also corroborate the primary results and are available from the authors upon request.

## DISCUSSION AND CONCLUSIONS

We studied how firms adapt to uncertainty in their natural environments, as well as how they may attempt to mitigate this form of uncertainty. We found that ecological uncertainty was positively related to natural-resource-intensive adaptation (Hypothesis 1), and that this relationship became weaker as environmental institutional pressures become stronger (Hypothesis 2). We did not find a significant positive relationship between ecological uncertainty and mitigation (Hypothesis 3). Still, we found that stronger environmental institutional pressures positively moderated the ecological uncertainty and mitigation relationship (Hypothesis 4). In particular, our results suggest that strong environmental institutional expectations pressured resorts to maintain their use of mitigation practices as ecological uncertainty increased, while weak pressures allowed firms to decrease their use of those practices in response to ecological uncertainty.

<sup>8</sup> To implement the Heckman correction, we first estimated a panel logit regression of SSP participation on the remaining set of controls, a new instrumental variable (*population living within a 75-mile radius*), and year fixed effects, in order to calculate the probability of participation in the SSP. Second, we substituted the estimated probabilities of SSP participation for the SSP dummy, and reestimated each of our fixed effects models.

<sup>9</sup> We thank an anonymous reviewer for bringing this to our attention.



## Research implications

Our study makes contributions to research on corporate environmental management and to resource dependence theory. In the former area, it adds to the nascent research attention on how firms respond to direct pressures from the natural environment. Very little research has operationalized independent variables capturing the direct influence of nature on business, even as many firms face challenges associated with phenomena such as climate change, extreme weather, declining biodiversity, and collapsing ecosystems (Hart, 1995; Hart and Dowell, 2011; Winn *et al.*, 2011). Our results provide early evidence that firms manage resource dependence challenges created by ecological uncertainty by engaging in more natural-resource-intensive adaptation. They also suggest that institutional pressures related to the social desirability of natural-resource-intensive adaptation and ecological mitigation shape the magnitude of these responses. Finally, our results complement the natural-resource-based view of the firm (NRBV). This perspective suggests that ultimately “businesses [markets] will be constrained by and dependent upon ecosystems [nature],” and that these constraints will become “a physical [not a legal or regulatory] requirement” (Hart, 1995: 991). Empirical studies of the NRBV show that dynamic capabilities can allow firms to decrease their consumption of natural resources while creating positive spillover effects on the effectiveness of other organizational capabilities (Hart and Dowell, 2011). Our work suggests, however, that firms may also face physical constraints from nature, and that they manage these constraints by increasing their use of natural resources unless environmental institutional pressures are robust.

In addition, our study and findings have implications for RDT. To date, RDT has focused on explaining how firms manage uncertainty caused by other organizations’ control of critical resources (Carroll, 1993; Davis and Cobb, 2009; Hillman *et al.*, 2009; Pfeffer and Salancik, 1978). The current study extends the theory by accounting for the possibility that firms can depend directly on nature for resources, and can face uncertainty associated with accessing those resources. Our results provide evidence that firms’ adaptation to ecological uncertainty may differ from their efforts to manage uncertainty caused by other organizations’ control critical resources. Existing research has

shown that firms manage organizational resource dependence with tactics that either reduce interorganizational power imbalances and their effects on firm access to critical resources, or secure access to new resources (Hillman *et al.*, 2009; Wry *et al.*, 2013). These tactics include acquiescing to the demands of other organizations, exercising countervailing power against them, growing via mergers and acquisitions, and organizational cooptation via board interlocks (Pfeffer and Salancik, 1978). Our findings suggest that firms adapt to ecological uncertainty, instead, by changing how they manage nature.

Prior research on how resource dependence and related uncertainty shapes the firm–natural environment relationship has shown how organizational interdependence can pressure firms into conserving natural resources. In particular, a number of studies have shown that firms reduce consumption of natural resources when environmentally concerned stakeholders create uncertainty by threatening to withhold critical resources (Frooman, 1999; Kassinis and Vafeas, 2002, 2006; Sharma and Henriques, 2005). As noted, our findings suggest that firms respond to ecological uncertainty by increasing their use of natural-resources-intensive practices. We cite three reasons to explain this result: first, firms may be able to adapt to ecological uncertainty by establishing more stable sources of natural resources; second, nature cannot willfully counter-vail itself against firms that use its resources; and, third, using resources directly from nature is potentially cost effective because firms may be able to externalize some of the costs of those resources. In sum, while prior research has demonstrated how resource dependence on socioeconomic systems constrains firm consumption of natural resources, our research suggests that the opposite may occur when the dependence is on nature.

Third, our results suggest that firms’ mitigation efforts depend on whether uncertainty is a function of relationships with other organizations or with nature. Prior research suggests that firms may attempt to mitigate uncertainty by working to shape the institutional arrangements that stabilize existing distributions of power among organizations (Wry *et al.*, 2013). In particular, research on this topic has found that new market entrants promoted new market logics via strategic alliances through the exercise of “soft” power (e.g., Santos and Eisenhardt, 2009), while incumbents pursued political strategies aimed at reshaping the rules of

competition (e.g., Mizruchi, 1989). However, our results do not suggest that firms act as agents of institutional change when uncertainty is caused by nature and involves natural resources. On the contrary, they indicate that firms decrease their use of mitigation practices as ecological uncertainty increases, unless institutional expectations pressure them into maintaining those practices. We attribute this result to concerns over the effectiveness of climate change mitigation efforts. Indeed, there is no guarantee that one firm's efforts to promote collective action on climate change mitigation will be effective (Schüßler, Rüling, and Wittneben, 2014). Stakeholders may not be receptive to firms' messaging, or climate change mitigation policy may not generate its intended benefits, even if it is instituted. Collective action on climate change has been difficult to institute because of political disagreements and contested views on the causes and effects of climate change. Further, climate change mitigation research acknowledges that the climate may take generations to stabilize even with widespread reductions in GHG emissions. As a result, these resorts may have instead focused on adapting to climate change uncertainty because it has more immediate and certain benefits than mitigation. Further, they may have diverted resources from mitigation to adaptation as climate change uncertainty becomes more acute, unless institutional pressures persuaded them otherwise.

Finally, our study is one of the few that empirically demonstrates how institutional pressures shape firms' management of resource-dependence-related uncertainty. Oliver (1991) theorized that firms may be able to respond strategically to institutional pressures with prescriptions from RDT, and that these responses may depend on the strength and cohesion of those institutional pressures and the urgency of firms' uncertainty. An implication of this work is that institutional pressures may influence firm efforts at managing resource-dependence-related uncertainty. Some work has subsequently studied this subject by examining how different national institutional environments affect firms' approach to managing resource-dependence-related uncertainty (see Wry *et al.*, 2013: 462 for a review). However, we are not aware of studies that explicitly test how institutional pressures specific to a set of practices can influence firms' adoption of those practices for managing uncertainty. Our results suggest that environmental institutional pressures deter firms

from using natural-resource-intensive practices and promote mitigation practices in response to ecological uncertainty.

### Practical implications

Our findings have several managerial implications. First, while natural-resource-intensive adaptation may help firms insulate themselves from natural environmental uncertainty in the near term, the use of natural-resource-intensive practices over the long term may eventually affect the legitimacy of the firm (Bansal, 2005). In the short term, natural-resource-intensive adaptation may not generate negative environmental impacts; however, over the long term these practices may create visible impacts that could stir the ire of environmentally concerned stakeholders. To mitigate this potential issue, managers might consider more holistic approaches to natural-resource-intensive adaptation that incorporate sustainable consumption of those resources and even help mitigate related uncertainty. As an example, some forestry firms are eschewing clear-cutting practices in favor of selective logging, which can protect forest health by thinning stands and creating species and age-class diversity. Further, enhanced forest diversity may help reduce a forest's sensitivity to bark beetles, which are tree-species specific and thrive in forests with high concentrations of those species (Spittlehouse and Stewart, 2003).

Second, we believe that firms facing higher levels of ecological uncertainty may need to reconsider the importance of mitigation efforts since adaptation may only be a near-term solution. Phenomena driving ecological uncertainty, including climate change, collapsing ecosystems, declining biodiversity, and the spread of invasive species and diseases, may continue to intensify in the future, implying that ecological uncertainty may intensify for vulnerable firms moving forward (Winn *et al.*, 2010). Further, natural resources are finite, implying that firms may only be able to adapt to ecological uncertainty with natural-resource-intensive practices for so long before those resources are depleted (Ostrom, 1999). Thus, there may be limits to how well this form of adaptation can help firms maintain their fit with the natural environment over the long term. As explained by Auden Schendler, vice president of sustainability for Aspen Skiing Company, adaptation plans in the ski resort industry may not be effective over the long term: "If

making snow is your response to climate change, then you've got a problem" (Schendler: in Michelson, 2013: 126). Ecological mitigation, instead, focuses on long-term implications of ecological uncertainty.

Our results also suggest that managers can recognize the limitations of their firms' individual ecological mitigation efforts, which may be why we did not find a significant positive relationship between ecological uncertainty and mitigation. Instead, our findings suggest that state-level environmental pressures played a significant role in resorts' decisions to adopt mitigation practices. As a result, those decisions may best be seen as a means of helping firms satisfy societal expectations for corporate engagement in collective mitigation action, as opposed to substantive efforts to mitigate ecological uncertainty. By implication, institutional pressure may be necessary to persuade many firms to adopt these practices. We believe, therefore, that industry leaders and associations that have substantive concerns about geopolitically dispersed ecological uncertainty could consider more aggressive corporate political strategies for instituting mitigation behaviors through policy. Further, firms and associations from different industries that are affected by the same forms of ecological uncertainty (e.g., climate change) may consider partnering on advocacy efforts for such policies. We also believe that industries lobbying for these policies might also consider more aggressively promoting ecological mitigation practices among their members, in order to legitimize their advocacy for such policies. Passing ecological mitigation regulation may be very challenging, because past efforts have been contested by powerful constituencies who would face negative financial impacts from such policies. For example, opponents of GHG emission regulations, including firms in a number of GHG-intensive industries, have successfully fought off national legislation to constrain GHGs in the United States by highlighting potentially disruptive effects of such legislation to their industries and casting doubt on climate change science (Schüßler *et al.*, 2014). Thus, advocates for these policies may need to lead by example if they wish to maximize their influence in the policy process. To do so, industry leaders and associations could promote widespread participation among their members, perhaps via industry self-regulation involving third-party certification programs with robust enforcement mechanisms (King and Lenox, 2000).

### Limitations and future research

This study has several notable limitations. First, our measure of natural-resource-intensive adaptation captures practices that promote such adaptation as opposed to the actual amount of adaptation that occurred. More specifically, our measures of new terrain expansion, snowmaking, and real estate development are point-scaled ratings developed by the SACC, as opposed to the actual amounts of new terrain, snowmaking, and real estate development undertaken by each resort in a given year. Second, our study focuses on a global and complex form of ecological uncertainty (climate change), which transcends geopolitical boundaries and has ambiguous causes and uncertain solutions. Firms may respond to more proximal and less complex forms of ecological uncertainty differently. As a result, we believe it is important for future research on ecological uncertainty to consider the dimension of complexity.

Third, while our study analyzed how firms manage variability in the availability of critical natural resources, it did not directly assess how natural resource scarcity impacts firm behavior. In particular, resource scarcity may be a more urgent issue for managers than resource uncertainty, and may cause them to take more immediate action. Fourth, our study did not account for adaptation to ecological uncertainty involving the adoption of eco-efficient practices and technologies, which can help firms manage ecological uncertainty by reducing their dependence on the natural resources in question. For example, high-efficiency irrigation systems can help agricultural firms manage uncertainty associated with natural rainfall. Future research could explore how firms respond to ecological uncertainty with eco-efficient practices, and whether environmental institutional pressures enable this response, as opposed to acting as a constraint as it does with natural-resource-intensive adaptation.

Fourth, the study did not account for other potential moderating factors in firms' social environment. While U.S. ski resorts are governed under a common federal policy regime and may be subject to state-level environmental institutional pressures, community actions can also affect the ability of firms to deploy strategies that create negative environmental impacts (Gunningham, Kagan, and Thornton, 2004). Indeed, community opposition has slowed many ski area development plans (Clifford, 2003). Future work could study the



influence of community preferences on the firm's ability to pursue natural-resource-intensive adaptation or its propensity to engage in ecological mitigation. In addition, if community stakeholders and firms jointly depend on scarce ecological resources, contests over the property rights to those resources could impede firms' ability to adapt to ecological uncertainty. For example, local communities have prevented ski resorts from using snowmaking in regions with water shortages (Clifford, 2003). Future research could study how firm and nonmarket stakeholder interdependence affects competition for common environmental goods in response to ecological uncertainty.

Finally, the current study focuses on one industry and analyzes a form of uncertainty that may only affect firms that directly depend on natural resources as critical inputs. Further, the study may not generalize to extractive industries, because nonrenewable natural resources are frequently insensitive to ecological dynamics and uncertainty (Costanza and Daly, 1992). Still, firms in other sectors could experience ecological uncertainty indirectly through organizational interdependence. Since raw materials derived from renewable natural resources are critical in most value chains, indirect corporate exposure to ecological uncertainty could be widespread (WBCSD, 2008). Future research could study how ecological uncertainty creates indirect effects on organizations farther downstream in a variety of industry value chains and ecosystems.

## ACKNOWLEDGEMENTS

We owe debts of gratitude to the review team members for their patience and invaluable feedback. We also relied heavily on the advice of many others, including Melissa Appleyard, Tima Bansal, Magali Delmas, Ted Khoury, Andy King, Valentina Marano, Jennifer Oetzel, Desiree Pacheco, Anu Phene, Pamela Tierney, Jim Walsh, and Jorge Walter. Finally, we owe thanks to the Portland State University School of Business Administration for help in funding the study.

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## APPENDIX: PRECIPITATION-RUNOFF MODELING SYSTEM (PRMS) PROCEDURE

The PRMS consists of a system of submodels called the *water budget module*, which simulate values for different potential variables of interest (Markstrom *et al.*, 2008). Each submodel in the water budget module contains a subsystem of calibrated parameters that yield estimates for their respective variables at specific locations and times. The water budget module specifies the snowpack depth submodel (illustrated in Figure A1) as a two-layer system based on water

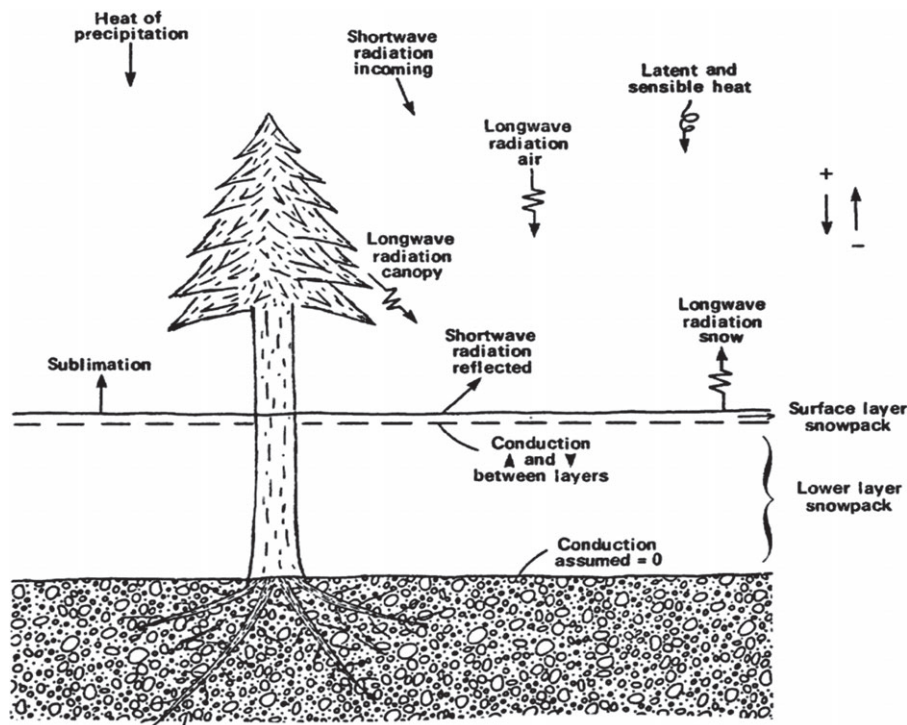


Figure A1. PRMS snowpack submodel schematic (originally in Leavesley *et al.*, 1983: 40)

content and thermodynamics. Snowpack initiation and accumulation depend on estimates of precipitation form (rain/snow), amount, accumulative snow density, and rate of snowmelt. These variables are endogenous to temperature, precipitation, elevation, aspect, and land cover characteristics, such as soil type and vegetation, which affect the timing and amount of accumulating or melting snow.

The latter variables were measured by physical instrumentation, and are archived in publicly available databases. Climatic data (temperature and precipitation) specific to each resort's location and time series were obtained from the National Weather Service (NWS) COOP dataset using the USGS Climate Data DownSizer (Ward-Garrison, Markstrom, and Hay, 2009). This application uses an algorithm to select the spatially appropriate climate gauges based on proximity and elevation. Topographic and land cover data were obtained from three federal government data sources, using the geographical information systems (GIS) application ArcGIS. Following the procedure outlined in Hay *et al.* (2006), the GIS application was used to measure the ski resort's elevation and average aspect by matching their locations with USGS 30-m digital elevation models (DEMs). Predominant soil and

vegetation characteristics at each resort's location were obtained by matching their locations with state soils geographic (STATSGO) 1-km gridded soils data (U.S. Department of Agriculture, 1994) and the U.S. Forest Service 1-km gridded vegetation type and density data (U.S. Department of Agriculture, 1992). After data collection and entry, the PRMS snowpack module parameters were modeled following the methods outlined by Hay *et al.* (2006). The calibration procedure works by inputting starting values for each parameter, assessing model fit, and then updating parameter values until no further increases in model-fit accuracy are seen. The PRMS models were calibrated using the USGS tool LUCA, which performs shuffled-complex evolution on user-defined parameters to optimize the module's objective function. Monthly fit was assessed via the Nash-Sutcliffe efficiency statistic with a threshold of 0.6 set for model performance (Hay *et al.*, 2006). Once model fit was deemed sufficient, the fully calibrated models were used to estimate average monthly snowpack depths for each resort year. Sufficient model fit was achieved in simulations for 83 of the 85 ski resorts that were rated by the SACC.