

WHERE DO WE GO FROM HERE? MUDDLING THROUGH BUSINESS ADAPTATION TO CLIMATE CHANGE

KERRIGAN MARIE MACHADO UNTER

Institute for Economy and the Environment, University of St. Gallen

JORGE RIVERA

George Washington University School of Business

INTRODUCTION

The intensity and frequency of weather-related disasters exacerbated by climate change (CC) are setting new historic records annually. While the media often refers to this dynamic as the new normal, it is more accurately described as “*the new abnormal*.” For over ten thousand years, human civilization has thrived due to unusually stable weather conditions. However, CC-related adversity conditions are worsening. Previously, these trends were seen as problems affecting primarily poor and highly exposed countries. However, given the unprecedented increase in extreme weather events, firms are increasingly facing calamities that not only disrupt their operations but also impact their ability to enhance their products and services.

Global efforts to mitigate CC have fallen significantly short of the levels needed to limit the expected ravages from a world experiencing average warming above 2°C from preindustrial levels. Even if humanity could reduce GHG emissions to zero immediately, some long-term negative effects of CC, such as sea level rising, will continue for centuries or even millennia (IPCC, 2014; 2022). *Climate change adaptation* consists of “the process of adjustment to actual or expected climate and its effects, in order to moderate or avoid harm or exploit beneficial opportunities” (IPCC, 2022: 43). While some exemplary firms are developing incipient plans and strategies for adaptation, most businesses seem to be muddling through adaptation with little understanding of the coping limits and performance implications of these strategies (Oetzel & Oh, 2021; Clement & Rivera, 2017). This is partly because their emerging adaptation strategies do not yet account for the uncertainty in the frequency and severity of different types of extreme events exacerbated by CC (Oetzel & Oh, 2021). Business managers also lack a clear sense of acceptable vulnerability levels to CC-related extreme events.

Surprisingly, the strategic management literature has paid limited attention to the impact of extreme weather events on firms' adaptation strategies and performance (Unter et al., 2023). We aim to address this gap by investigating two critical research questions: 1) How do extreme events exacerbated by CC affect firm adaptation strategies and performance? 2) Can CC adaptation strategies lead to price premiums for firms?

THE CALIFORNIA WINE INDUSTRY

CC is a major concern to wine producers all over the world (MacNeil, 2015). As human activity is driving shifts in climate conditions, CC has unavoidable and significant impacts on wineries (Ashenfelter, 2017; Jones et al., 2005; van Leeuwen et al., 2024). While not the cause of wildfires, CC exacerbates underlying natural conditions, such as drought, which can lead in more intense, frequent, and longer lasting wildfires (IPCC, 2014). Wildfires are of increasing concern to natural resource intensive businesses and can have important consequences for how businesses

respond (Lalonde et al., 2023). Compounding extreme conditions have led to megafires that smother the entirety of California with smoke for weeks on end. Critically, in recent years, wildfires and smoke damage from wildfires have also caused unprecedented amounts of damage to California vineyards (McIntyre, 2021). While wildfires can certainly burn down entire vineyards (Newman & Morrison, 2020), smoke damage is the main concern for wineries. Smoke damage from wildfires within the same region, especially prior to harvest, can damage grapes and negatively impact subsequent wine quality (Krstic et al., 2015). In some cases, seasonal wildfires occur well into or after the harvesting season (Thach, 2018), however, increasingly state-wide wildfires are occurring earlier in the grape growing season (Newman & Morrison, 2020). These conditions have led to increasing concerns around smoke taint in California wines.

THEORY AND HYPOTHESES

The growing trend toward more frequent and severe record-breaking natural disturbances suggests that firms facing these events may be more likely to adopt adaptation strategies (Linnenluecke et al., 2012; McKnight & Linnenluecke, 2019; Pinkse & Gasbarro, 2019; Rivera et al., 2022). This is because these extreme natural events can have multiple detrimental effects on resources availability, business infrastructure, and continuity of operations, among others (Oetzel & Oh, 2015). Natural calamities of higher severity and frequency gradually pose a more imminent threat to core business strategies and operations, making them harder to disregard (Berkhout et al., 2006; McKnight & Linnenluecke, 2019; Pinkse & Gasbarro, 2019).

The heightened severity of CC-related extreme events amplifies the perceived vulnerability and the sense of urgency to act, garnering greater internal support for engaging in adaptation efforts (Kelly & Amburgey, 1991; Kraatz & Zajac, 2001; Pinkse & Gasbarro, 2019). This increased sense of vulnerability enhances the perceived net economic benefits of adaptation and subsequently weakens internal organizational inertia that may have previously hindered a firm's willingness to develop and implement adaptation strategies when facing milder impacts (Clement & Rivera, 2017; Pinkse & Gasbarro, 2019; Rivera & Clement, 2019). Furthermore, the repeated occurrence of extreme events results in reaccumulating damages to resources and infrastructure, necessitating a adaptation by the firm to align with its environment (Camenisch et al., 2020; Weinhofer & Busch, 2013), or in this case, the "new normal". Thus, we hypothesize:

Hypothesis 1 (H1). *Climate change-related extreme events are directly and positively related to the adoption of climate change adaptation strategies.*

Adapting to extreme natural conditions can be essential for the survival of a firm as it can reorient the firm to better respond to environmental changes and ensure that opportunities for the firm are not lost and additional costs are not incurred (Hoffmann et al., 2009; Linnenluecke et al., 2012). Adopting CC adaptation strategies rely on a combination of tangible and intangible resources. First, CC adaptation strategies require a range of tangible assets including capital, land, and physical infrastructure. Second, CC adaptation strategies need several intangible resources including CC knowledge, time, social connections, and networks. Firms that can better synergize, bundle, and use these resources together to adopt a successful adaptation strategy will be able to produce products and services that deliver superior value (Barney et al., 2021; Becerra, 2008; Penrose, 1959). However, the adoption of CC adaptation strategies involves assets and capabilities that, until recently, have not been considered as sources of value within the strategy literature, particularly in resource-based view (RBV) (Kolk & Pinkse, 2008). We draw from RBV (Barney, 1991) to illustrate that the adoption of CC adaptation strategies are valuable, rare,

inimitable, and non substitutable. Due to this, CC adaptation can enable firms to sell their products at a price premium.

First, CC adaptation strategies can be valuable to a firm. Adopting a CC adaptation strategy can allow the firm to respond to threats and opportunities related to CC. CC adaptation strategies that enable firms to ensure business continuity while contending with extreme adverse events may yield price premiums. These advantages stem from reduced operational risks, enhanced access to raw materials, improved efficiency, and consistent product and service availability (Linnenluecke et al., 2012; Tashman & Rivera, 2016). Importantly, CC adaptation strategies enable a firm to produce a quality product or service that can be sold at a price premium. For example, wineries may move their grape growing operations to new locations where weather conditions are more ideal for the maturation of the winegrapes. By selecting the ideal climate for a specific varietal of grape, wineries can produce grapes with better flavor profiles and, subsequently, higher wine quality (Nicholas & Durham, 2012). Finally, adopting a CC adaptation strategy can increase the firm's resilience against future adverse conditions (Clement & Rivera, 2017; Linnenluecke et al., 2012). Hence, going beyond mere coping, businesses that invest more significantly in CC adaptation measures can distinguish themselves by offering products and services that are resilient to CC-related extreme disturbances.

Second, the adoption of CC adaptation strategies are also rare. There are a limited number of strategies available to firms, and it can be difficult to access knowledge about what types of strategies exist and how to implement them (DiBella, 2019). Further, the more effective an adaptation is in developing resilience and buffering the firm against adverse conditions in the long run, the more costly and difficult it is to implement, especially in the case of extreme conditions such as wildfires (Linnenluecke & Griffiths, 2013).

Third, CC adaptation strategies are very difficult to imitate. CC adaptation is not an easy task. There is a high degree of tacit knowledge required for these types of strategies, making them ambiguous resources (Le Breton-Miller & Miller, 2015). To respond to changes in the surrounding natural environment, firms need to not only know what changes they are experiencing, but also when and to what degree those changes are occurring and how they affect the firm's ability to operate and generate profit (Flammer et al., 2021; Galbreath et al., 2016). Further, firms need to have an extensive knowledge around what types of actions they can take in response given their specific climate; what degree the adaptation will address the full extent of their resources affected by CC; any new challenges that may arise from adopting an adaptation strategy, such as unintended, negative consequences that are associated with maladaptation; and much more. Not nearly enough is known about these types of adaptation strategies which make it difficult to both effectively implement these strategies and determine the value of the strategy for the firm (Galbreath, 2014). Due to this, firms often develop their adaptation strategies through extensive research, years of experience, and trial-and-error. Further complicating this, CC adaptation strategies must be adjusted to fit the local climate of a firm, especially in industries that are sensitive to changes in natural conditions, such as agriculture, fishing, and tourism. An adaptation strategy that may work for one firm, may not be easily transferable to another firm in a different location. Finally, synergizing several resources within the firm to adopt the capability for adaptation is not easily replicated by other firms (Becerra, 2008). CC adaptation necessitates the creation and utilization of distinctive, indispensable, and challenging-to-replicate assets, such as resilient infrastructure to withstand disasters, dependable supply chains, an established network of climate experts, and access to proprietary climate data across all their facilities (Oetzel & Oh, 2015; Pinkse & Kolk, 2012).

Finally, CC strategies are not easily substituted. Mitigation cannot act as a replacement for adaptation, as mitigation focuses on reducing the effects of CC (e.g., through reduction of greenhouse gas emissions) rather than responding to the anticipated changes in climate. While mitigation responses are incredibly important to lessen the changes in climate and can synergize with adaptation (IPCC, 2022), current actions for mitigation are insufficient to avert major future changes to climate (Bansal, 2019; Nordhaus, 2018). The adoption of CC adaptation strategies are necessary to respond to the inevitable environmental changes organizations are facing and will continue to face (Bowen et al., 2012; Schneider, 2011). Depending on the firms' location, the firm will face adverse conditions to differing degrees. Consequently, there will be differences in the threats and opportunities a firm faces. All of these aspects make it incredibly difficult for a firm to substitute CC adaptation with another response.

Because adopting CC adaptation strategies are valuable, rare, inimitable, and non substitutable, adopting these types of strategies can result in improved product quality that can be sold at a price premium. Therefore, we hypothesize:

Hypothesis 2 (H2). *The adoption of climate change adaptation strategies are directly and positively related to product price.*

We hypothesize that CC adaptation mediates the relationship between CC-related extreme events and firm product performance. First, CC adaptation strategies are directly affected by natural conditions. Recent work has established that CC adaptation strategies are influenced directly by natural environmental conditions (Rivera & Clement, 2019; Linnenluecke et al., 2012; McKnight & Linnenluecke, 2019; Pinkse & Gasbarro, 2019; Rivera et al., 2022; Tashman & Rivera, 2016). Extreme natural conditions can be a driver of firm CC adaptation to ensure that firms can continue to produce quality products and services. Second, the product performance of a firm is affected by how that firm adapts to CC. In support of this, firms rely on key natural resources that they can ensure the quality of through adaptation for their operations (Bergmann et al., 2016), so they can produce a superior product. CC adaptation is valuable, rare, inimitable, and non substitutable enabling the firm to sell a superior product at a price premium. Further, there will always be uncertainty around how extreme conditions affects firm activities which can lead to different assessments in the “value” of a resources needed for CC adaptation (Barney, 1986). The ability to combine resources in the face of extreme conditions and adapt is a source of value to the firm (Becerra, 2008). Thus, we hypothesize:

Hypothesis 3 (H3). *Climate change-related extreme events are directly and positively related to the adoption of climate change adaptation strategies which, in turn, directly and positively affect product price. In this way, the adoption of climate change adaptation strategies positively mediates the relationship between climate change-related extreme events and product price.*

METHODOLOGY

Data and Sample

First, we formed an initial list of California wineries from the *American Winery Guide*, *Winery Sage*, and the *Napa Wine Project*. We removed duplicates on the initial list. Second, we geocoded the location of each winery. California wine regulations, practices common in the California wine industry, and satellite imagery made it possible for us to geocode each winery and confirm that the winery grows grapes. Wineries with unconfirmed locations were dropped, yielding a total of 2,088 geocoded wineries that grow grapes. Third, wildfire perimeter data was

collected from CAL FIRE FRAP. Using GIS, 25 km buffers were created around each wildfire since wineries are unlikely to be burned down, and smoke damage is the main concern. The fire data was spatially connected to the wineries to count the number of wildfires. We then collected wine data from *Wine Spectator* which included release price, vintage, region, variety, and grape source. From that information, each varietal and vineyard source was coded; there are a total of 82,156 wine observations between the years 1906 and 2019. Finally, we then matched the wine level data with the geocoded wineries. 535 of the geocoded wineries had information from *Wine Spectator* for 50,156 wines. Overall, there are a total of 50,156 wine-winery-year observations for 535 wineries for the years 1981-2019, matched with fires.

Measures

Product price. Price is measured as the release price of a wine in USD and is adjusted for inflation to 2019 USD.

Firm adaptation. We measure adaptation as the *number of vineyards* each winery has for a given year. Increasing the number of vineyards is a planned adaptation strategy done by wineries to ensure reliable long-term access to premium grapes to maintain the consistency and quality of their wines (Galbreath, 2011; Galbreath, 2014; Nicholas & Durham, 2012). Compared to the other types of adaptation responses, site selection strategies, such as increasing the number of vineyard sources, tend to have more beneficial outcomes for wineries for the long term in the face of greater biophysical changes (Nicholas & Durham, 2012; van Leeuwen et al., 2024).

Climate change-related extreme events. We examine CC-related extreme events through wildfire frequency measured as the number of wildfire events within 25 km of a winery for a given year to account for the adverse effects that smoke can have on grapevines and winegrapes.

Controls. On the product level, we created dummies for the most common types of varietals including *cabernet sauvignon*, *chardonnay*, *merlot*, *pinot noir*, *sauvignon blanc*, *syrah*, *zinfandel*, and wines with *no single varietal* (e.g., blends). We control for the age of the wine. On the firm level, we control for winery age, the number of varietals at each winery, and ecological uncertainty. We measure ecological uncertainty as the coefficient of variation of the average wildfire intensity (measured by distance in km) at each winery over the previous 10 years.

Analysis

We apply a path analytic approach using Seemingly Unrelated Regression. We included winery, region, and vintage fixed effects to control for time invariant differences across wineries, regions, and years. Due to human limitations with properly perceiving and evaluating climate impacts (Kaufmann et al., 2017; Moore et al., 2019), there may be a delay in decision making in response to climate conditions. To account for this, the independent variable and ecological uncertainty was lagged 1 year for the path connecting it to adaptation. We also calculated the indirect effects of wildfire frequency on wine price through the number of vineyards.

RESULTS AND DISCUSSION

Our results indicate that the adoption of CC adaptation strategies adds value to firms, enabling them to sell products at a premium price. We find that the adoption of adaptation strategies by wineries that increase the number of vineyard sources for wine grapes were positively related to wine price (H2). Wineries adopt these adaptation strategies in response to more frequent wildfires to ensure continued access to critical natural resources necessary for

producing high quality wine (H1). Furthermore, our research reveals that firm CC adaptation strategies mediate the relationship between wildfires and product prices (H3). We find evidence to suggest that wildfire frequency is indirectly and positively related to wine prices through the number of vineyards. Table 1 and 2 show the results.

Table 1 and 2 about here

Our study contributes to the RBV literature by expanding its application domain. We illustrate how previously overlooked capabilities and resources, such as strategies for adapting to CC-related natural disasters, can evolve into sources of value, resulting in price premiums. This also extends to the natural resource-based view (NRBV; Hart, 1995), which focuses on how environmental protection strategies can serve as sources of competitive advantage. Our research shifts the NRBV's focus toward assessing the reverse relationship between natural disturbances in the environment and sources of value. Our investigation into natural disasters exacerbated by CC also enhances the understanding of the RBV's boundary conditions, emphasizing the significance of extreme natural events in constraining the effectiveness of firms' deployment of their current valuable resources and capabilities for producing long-term quality products.

REFERENCES AVAILABLE FROM THE AUTHOR(S)

Table 1. Results^{a,b}

Variables	Control model		SUR model 1	
	<i>MV: Number of Vineyards</i>	<i>DV: Wine price</i>	<i>MV: Number of Vineyards</i>	<i>DV: Wine price</i>
<i>Predictor independent variables</i>				
Wildfire frequency				0.14 (0.26)
L.Wildfire frequency			0.05*** (0.01)	
Number of vineyards (Mediator)		0.62*** (0.11)		0.70*** (0.23)
Constant	-0.16 (1.59)	-37.75 (23.76)	6.66*** (0.49)	-15.13 (10.06)
R ²	0.78	0.64	0.84	0.67
Number of wineries	416	416	330	330
Observations	17,641	17,641	7,712	7,712

Note: ^aControls removed from table due to space constraints. Full results available upon request. ^bIncludes winery, region, and vintage dummies. MV = mediator variable. DV = dependent variable. *** p<0.01, ** p<0.05, * p<0.1

Table 2. Effects

Path	Effect coefficient	Percent of effect
Indirect effect: Wildfire frequency → number of vineyards → wine price	0.0368**	20.8%
Direct effect: Wildfire frequency → wine price	0.14	79.2%%

Note: Calculated with 1000 iterations. *** p<0.01, ** p<0.05, * p<0.1