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RESPONSE TO THE RISK OF CLIMATE CHANGE: A CASE STUDY OF THE WINE INDUSTRY

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ABSTRACT

The wine industry faces significant risks climate change, such that the security of future production is under threat. To address this risk, in this paper, a framework is proposed to examine responses to climate change in the wine industry. Building upon the literature and relying on expert input, the framework takes into consideration mitigative and adaptive actions across market-based, regulatory/standards-based, and operational-based levels. To explore the framework, a case study is developed for Treasury Wine Estates (TWE), one of the world's largest wine producers. The case study reveals verification of the framework, with TWE relying on several technologies and unique processes to engage in many mitigative and adaptive actions across the proposed levels. The findings suggest several opportunities for future study.

Keywords

Australia; carbon emissions; climate change; greenhouse gases; strategy; wine

Introduction

Wine has been produced for centuries and has cultural and social significance the world over. However, wine producers currently find themselves in challenging times, perhaps not on a level seen before. For example, there is increasing pressure to reduce alcohol content without losing product quality or flavour (McIntyre *et al.*, 2015). Alternatively, rapidly changing consumer tastes around the world call for growth in organic and biodynamic wine markets, requiring producers to embrace technological change in their production and marketing processes and practices (Delmas and Grant, 2014; Schmidt *et al.*, 2013). Still yet, climate change is predicted to alter wine production in most of the world's leading wine regions, where future output could be reduced by as much as 85 percent in some locations due to higher temperatures and less rainfall (Hannah *et al.*, 2013).

As the wine industry confronts these challenges, perhaps its relationship with the Earth's ecosystem services (e.g., rainfall, rich soil, photosynthesis, temperature) is most pertinent, for access to ecosystem services ultimately has impact on consumer, production, and even regulatory strategies (Galbreath, 2014). For example, one theory related to the Earth's ability to self-regulate and provide the necessary ecosystems services to sustain life, the Gaia hypothesis, posits that the Earth's atmosphere and biosphere act to maintain a homeostasis, or balance, of the planet's physical conditions (e.g., atmospheric composition and temperature) (Kirchner, 2003). Recent evidence suggests this "preferred equilibrium" appears to be disrupted, as human activity increases the output of greenhouse gas (GHG) emissions (Lashof, 1989). This has resulted in changes in climatic conditions, such as higher temperatures and less rainfall, that deviate from documented long-term averages (IPCC, 2007, 2014). Given that average temperature increases of as little as 1° C can have a dramatic effect on what grape varieties can best be ripened where, and the quality of grape that

can be achieved (Keller, 2010), this suggests that mitigation and adaptation strategies are becoming necessary to secure future wine production.

Previous studies have looked at mitigation and adaptation to climate change in agriculture. However, these either tend to look at the issue from a broad agriculture perspective and therefore lack depth to specific agribusinesses (Fleischer *et al.*, 2011; Vermeulen *et al.*, 2012), or else they explore future impacts on crop yields under different CO_2 concentration scenarios (Tubiello and Fischer, 2007). This paper explores a different perspective. Specifically, as the production security of the wine industry is threatened by climate change disruptions, the aim of this paper is to propose a framework, modelled around the technology and process issues that wine producers can incorporate into practice to address sustainability. This includes a bundle of three areas: 1) market; 2) regulatory; and 3) operational. The framework is based on the strategy and sustainability work of Galbreath (2009) and Porter (1996), and therefore offers a well-grounded approach to addressing climate change in the wine industry.

To explore the proposed framework, a case study of one of the largest wine producers in the world is undertaken. Australian-based Treasury Wine Estates (TWE) is a nearly AUD$2B company and operates in 16 countries. Because of the global scope of TWE, the company serves as an excellent case given the heterogeneous nature of climate change around the world. Relying on key corporate documents (e.g., annual reports) and the corporate website, content analysis was undertaken to explore corporate actions related to the proposed framework. The findings are consistent with the framework: TWE undertakes several mitigative and adaptive actions related to climate change across the market, regulatory, and operational dimensions.

The study contributes to the literature in two main ways. First, it extends generalist agriculture climate change response frameworks and models (e.g., Fleischer *et al.*, 2011; Vermeulen *et al.*, 2012). In this way, the framework incorporates three critical dimensions drawn

from the strategy and sustainability literatures (Galbreath, 2009; Porter, 1996): market, regulatory, and operational. This allows for the framing of a more context-specific perspective to climate change response, while incorporating both mitigative and adaptive actions. Second, the wine industry is studied. The story of how wine will react to climate change is one small but telling piece of the larger one of how agriculture as a whole will endure. While the effects of climate change on other agriproducts may be different, the framework and the results of the analysis provide insights and stimulates ideas for how other types of agriculture businesses can both mitigate and adapt, and therefore expands insights into agrifood security and technological change under climate change risks.

Background

Climate change and the wine industry

While climatic conditions have varied throughout the history of the world, recent evidence suggests that since the mid-1970s the global land surface temperature has warmed at a rate about twice the ocean surface temperature and, measured over the last 50 years, the world has warmed at nearly twice the rate of that of the past 100 years—the last decade being the warmest on record (IPCC, 2007, 2014). Scientists attribute this temperature change to increases in CO_2 and other greenhouse gas emissions (IPCC, 2007, 2014). Further increases in CO_2 and other greenhouse gas emissions are projected to lead to further effects (IPCC, 2007, 2014); however, effects are expected to vary. For example, climate models predict there will be mean temperature and rainfall *increases*, changes in *variability* of climatic conditions and changes in the occurrence of *extreme* weather conditions (IPCC, 2007). According to Barnett (2001), few environmental changes exhibit as much uncertainty and potential for disastrous consequences as those associated with climate change. For agriculturists, climatic changes can lead to disruptive effects on production, significantly altering future sustainability. This is perhaps particularly evidenced with wine production.

Most wine produced in the world falls in between the 30th and 50th parallels, the majority in highly biodiverse Mediterranean climates. This narrow growing region is because, as crops go, wine grapes are highly sensitive. They need a cold—but not too cold—winter. Wine grapes need mostly frost-free spring conditions during which their buds can safely emerge. They need a long, sunny growing season and eventual temperatures that are fairly warm—but not so hot that the grapes sunburn or ripen too quickly. Wine grapes also need fluctuation between daytime and night time temperatures, which enable the development of compounds that eventually become complex flavours in the wine. If these conditions are not met consistently, wine grapes do not perform well. Complicating matters is the fact that there are many different kinds of wine grapes (e.g., Cabernet, Chardonnay, Merlot, Shiraz), which are even more particular about where and under which conditions they will best grow. For example, if temperatures are above a certain threshold Pinot Noir cannot be grown successfully; go under a certain threshold and Cabernet Sauvignon will not ripen properly. Changes in temperature, then, are particularly critical (Keller, 2010).

Minor shifts in seasonal temperature can make the difference between a poor, good, or excellent vintage: temperatures slightly colder than normal lead to incomplete ripening with high acid, low sugar, and unripe flavours whereas temperatures slightly warmer than normal create overripe fruit with low acid, high sugar, high alcohol, and cooked flavours (Santisi, 2011). Such temperature shifts affect both red and white wines, altering the very grape chemistry so critical to a quality wine product (Keller, 2010). However, changes in temperature can also alter the micro-climates necessary to grow wine grapes in other ways. For example, changes in temperature may increase the presence of insects and insect-borne diseases. As the presence of certain pests increase, they can destroy vineyards (Tate, 2001).

While the impact of climate change (and particularly changes in temperature) is most evident in the vineyard, the process of actually making wine can also be impacted. For example,

there may be requirements of the addition of tartaric acid to address imbalances in acidity caused by warming in regions that decrease acidity in grape berries. Another aspect is the difficulty of fermentation to dryness with high sugar concentrations. Associated with the warming trends, higher sugar concentrations are leading to higher alcohol content (Godden and Gishen, 2005). Remediation of high alcohol content will likely require new yeasts that can ferment sugar without creating alcohol. In short, wine production (including grape growing and wine making) is an economic endeavour extremely sensitive to climate.

Lastly, what does the future hold for wine production under climate change? One study finds that many wine regions around the world have reached an optimal growing season temperature threshold above which vintage quality tends to decline (Jones *et al.*, 2005). In fact, longer term predictions about the effects of climate change upon the wine industry are not positive. For example, in modelling from 2000 to 2049, increasing temperatures are expected in all 27 major wine producing regions, with an overall global change in the magnitude of 2.04° C (temperature changes above 1° C can be very problematic for wine production) (Jones *et al.*, 2005; Keller, 2010). This is supported by the research of Hannah and colleagues (2013), who forecast that due to rising temperatures, in Bordeaux (France) and Tuscany (Italy), a drop in wine production of 85 percent is possible by 2050; in Australia the figure is 74 percent; in California the figure is 70 percent; in South Africa the figure is 55 percent; and in Chile the figure is 40 percent. Such analyses highlight significant challenges to the wine industry with respect to climate change. Therefore, assessing strategic options for responding to the risks climate change pose to wine production warrants investigation.

Wine and climate change response: A framework

Firms can respond to climate change along a continuum, from doing nothing to doing much. In the case of the wine industry, there is evidence to suggest that climate change is altering weather

patterns to the point that the security of future production is under threat (Hannah *et al.*, 2013; Jones *et al.*, 2005). This suggests that action is needed now, let alone in the future. To explore the levels of action possible, this paper proposes a framework that systematically examines: 1) the two processes of wine production (grape growing and winemaking); 2) the types of response (mitigation and adaption) across the two processes; and 3) the types of actions (market-based, regulatory/standards-base, operational-based) across the two processes and the two types of response. In doing so, this paper more closely examines the technological and process changes required to address climate change, with special emphasis on the wine industry.

Following the strategy work of Porter (1996), firms that attempt to address climate change require actions and choices that will meet the nature of any of its effects. One way that this can be achieved is to consider the industry context (Porter, 1980, 1985). For example, it has been established in this paper that climate change is altering wine production currently, and is expected to continue to do so in the future. As the risks of climate change are addressed, the industry context provides a means to explore the extent to which climatic changes will impact on the types of grape varieties grown, and whether or not adaptation (e.g., adopting new varieties) is warranted. That is, not all industries face the exact same risks of climate change (Winn *et al.*, 2011). By understanding any unique risks to wine production, insights are provided that inform adaptive actions.

Another factor for consideration is the institutional environment (DiMaggio and Powell, 1983; Scott, 2001; Scott and Meyer, 1994). Institutions (e.g., governments, NGOs) influence regulation and voluntary standards, or are otherwise in positions to pressure firms to conform to societal norms, such as responses to the natural environmental. Climate change is a key issue being attended to by various institutions today, and the regulation of carbon emissions and the setting of voluntary targets is becoming more prevalent around the world (Griffiths *et al.*, 2007; Hoffman,

2005; Pinske and Kolk, 2010). Firms therefore need to understand the institutional environment, and the regulatory and voluntary standards needed to address climate change.

Lastly, the process of value creation by firms can impose negative externalities on society, such as carbon emissions (which are argued to be a leading contributor to climate change). According to Porter and Kramer (2006), one way that firms can reduce their carbon footprint is by examining their value chain activities (value chain activities include activities a firm performs to produce a product). As they do this, technologies and processes are more easily identified that can be applied to reduce carbon emissions, or eliminate them altogether.

With respect to the wine industry, a framework was developed for climate change response. While based on a generic framework developed by Galbreath (2009), a literature review was conducted, assessing both scientific and business-related research on the matter of climate change in the wine industry (Ashenfelter and Storchmann, 2014; Barnett, 2001; Galbreath, 2014; Godden and Gishen, 2005; Hannah *et al.*, 2013; Keller, 2010; Santisi, 2011; Tate, 2001). Organizational bodies and professional associations in the wine industry (including the California Sustainable Winegrowing Alliance and the Winemakers' Federation of Australia) were consulted to review policies and reports on climate change issues (CSWA, 2009; WFA, 2007). Lastly, a leading Australian academic with a background in viticulture and oenology, and with a special interest in climate change, was invited to join the research team to offer expert advice on the development of framework.

After reviewing the literature, the research team held several meetings to categorize and group key emergent themes. For example, one clear theme that emerged from the literature review was the nature of response to climate change, which includes both mitigation and adaptation. Another clear theme related to the level, or breadth, of climate change responses. These include *how* wine producers can respond within mitigation and adaptation strategies. This generally

consists of actions (both mitigative and adaptive) that account for market-facing, regulatory, and operational considerations. Market-facing refers to the portfolio of products of a firm, including how these products are brought to market; regulatory refers to the governmental and other institutional codes and standards related to environmental management (e.g., management of carbon emissions); and operational refers to how products are actually produced, including inputs. In this sense, looking across the value chain can help identify areas where mitigation and adaptation are required. For example, inputs into production could include chemicals or other synthetic products that emit high levels of GHG gases. By identifying these through value chain analysis, they could either be eliminated or alternative natural inputs found as a mitigative action, for example. Lastly, wine production consists of both grape growing and winemaking processes. Thus, a *process* theme emerged that was included in the framework.

After a reflective and iterative process, a framework was developed that takes into account two primary levels. First, the wine industry can address climate change both through mitigation and adaptation actions. Mitigation involves efforts that are intended to reduce the magnitude of the contribution to climate change, mainly by reducing greenhouse gas emissions or using greenhouse gas sinks. Adaptation consists of efforts undertaken to adjust to the adverse consequences of climate change, as well as to harness any beneficial opportunities it might afford. Second, following the literature (Griffiths *et al.*, 2007; Hoffman, 2005; Jones *et al.*, 2005; Pinske and Kolk, 2010; Porter, 1980, 1985, 1996; Winn *et al.*, 2011), mitigation and adaptation efforts are framed within the context of market-based, regulatory/standards-based, and operational-based actions. In this way, actions are more closely linked with the concepts of sustainability and strategy as suggested by Galbreath (2009). Lastly, actions are also delineated by the processes of grape growing (vineyard) versus winemaking (winery) for a finer level of demarcation.

Drawn from the literature (Barnett, 2001; CSWA, 2009; Galbreath, 2014; Godden and Gishen, 2005; Hannah *et al.*, 2013; Hadartis *et al.*, 2010; Keller, 2010; Santisi, 2011; Tate, 2001; Webb *et al.*, 2007; WFA, 2007), a number of actions were identified. For example, one of the biggest contributors to greenhouse gas emissions in the wine industry is the use of conventional fuel in tractors, trucks, and other machinery, which are relied upon to perform operational tasks in the vineyard. One means to mitigate conventional fuel use is to use alternatives such as biodiesel, ethanol, or vegetable oil. Another key source of GHG emissions in the grape growing process comes from the spraying of nitrogen-based chemicals. Use of low-volatile organic compound (VOC) products is one means to reduce GHG emissions from the use of chemicals/fertilizers. Similarly, the use of technology such as optical weed control sprayers or weather-based decision indices can reduce the amount of greenhouse gases emitted in cases where nitrogen-based chemicals are used, because smaller amounts are required, or the chemicals are applied only when absolutely necessary. Lastly, evidence demonstrates that climatic changes are already affecting the quality of grapes, reducing yields and, in extreme cases, wiping out entire vintages (Fenner, 2009; Malkin, 2009; Wahlquist, 2009). As a means of adaptation, planting later-harvested varieties or varieties better suited to hot climates is considered a market-based action.

As for the winery, the main source of GHG emissions comes is energy needed to produce wine. As a means of cutting such greenhouse gas emissions alternative energy sources such as solar, wind, cogeneration, and geothermal are all potential options. Another contributor to greenhouse gas emissions in wineries is the production of packaging, although packaging-related emissions would be considered indirect as many wineries do not produce their own packaging (Coleman and Päster, 2009). Recently, new packaging alternatives such plastic PET bottles have been developed. These produce as much as 65 percent less GHG emissions than glass bottles (Brown, 2009). Lastly, transport of the finished product from the winery to end customers can be

a significant contributor to the carbon footprint of the wine industry, depending on the type of transport (Coleman and Päster, 2009). As a means to address this matter, for example, a country like Australia could pursue and develop new markets that are closer to home (e.g., South-East Asia), rather than rely on traditional export markets such as the UK or the US. Further, the use of container or reefer ships to transport wine decreases the carbon footprint more than the use of trucks or airplanes (Coleman and Päster, 2009).

Finally, as with most other industries, firms in the wine industry have the option of implementing standards-based programs to address climate change, such as an environmental management system (EMS). An EMS can be implemented by regional or by internationally-certified programs such as ISO 14001 (Allen, 2009; Silverman *et al.*, 2005). Certified programs ensure that firms are attending to GHG emissions and other environmental impacts and therefore represent both mitigation and adaptation strategies (e.g., management of water is considered an adaptive action and is part of most EMS requirements). In addition, an international wine carbon calculator is now available to the wine industry (Provisor, 2008), offering both grape growers and wine makers an avenue to more stringently account for their carbon emissions. The expectation is that those firms who apply such tools and processes will reduce hazardous emissions, and in the process demonstrate mitigative actions.

Exploring the framework: A case study from the wine industry

The framework proposed in this paper is the product of a context-specific literature review, insights gained and recommendations made from an expert academic in the fields of viticulture and oenology, and the adaptation of a previous, generic framework proposed by Galbreath (2009). To explore the framework, I took a case study approach (Eisenhardt, 1989; Yin, 2003). According to Eisenhardt (1989, p. 534), a case study focuses on understanding the "dynamics present within single settings". The choice of the case study approach was influenced by the exploratory nature of

the work. In such a situation, case studies are an appropriate research method to gather necessary information because they can reveal deeper results to currently known phenomenon (Eisenhardt, 1989; Oxley *et al.*, 2010; Yin, 2003). Data were collected through annual reports and supplemental reports (i.e., CSR report), and the corporate website.

The case profiles climate change responses of Australian wine company Treasury Wine Estates (TWE). TWE was chosen because it is one of the biggest companies in the global wine industry and has grape-growing and wine-producing regions all over the world, including in Australia, the United States, France, and Italy. Given the many regions TWE operates in, its exposure to the effects of climate change are more evident and varied, making the company ideal to study.

As a company, TWE is the world's largest pure-play listed wine company. The company owns a large number of wineries, over 11,000 ha of vineyards and 4 packaging and bottling sites located in Australia, California, Italy, and Chile. TWE generates nearly AUD$2 billion in annual sales and employs more than 3,500 winemakers, viticulturists, sales, distribution, and support staff across 16 countries. The company's portfolio of premium wine brands includes Penfolds, Wolf Blass, Rosemount, Lindemans, Saltram, Seppelt, Wynns, and Yellowglen from Australia; Beringer, Etude, Stags' Leap, and Chateau Souverain from North America; Matua Valley and Secret Stone from New Zealand; Castello di Gabbiano from Italy; and Maison de Grand Espirt from France.

Procedure

In the absence of readily obtainable third-party sources to explore how TWE responds to climate change, content analysis of the annual report, the CSR report, and the company website was carried out over the 2011–2013 period. Annual reports, for example, are useful in the study of organizational behaviour and strategy because they provide an account of a firm's activities (Arndt and Bigelow, 2000; Bettman and Weitz, 1983; Salanick and Meindl, 1984). For assessment, a list

of keywords was established as an outcome of the development of the framework, including "mitigation", "mitigative", "adaptive", and "adaptation", as well as a corpus of actions that relate to climate change response in the wine industry.

To conduct the coding, the annual report and CSR report were downloaded electronically. Searches for keywords were then conducted to identify matches. Where matches were found, they were documented. Additionally, after exhaustive keyword searches, the entire documents were read to note any additional findings that related to climate change actions. In such cases these were documented. As one last step, the keywords were searched on the company website site (this included links to levels from the home page such as "Corporate Governance", "TWE Global", and "Corporate Responsibility"). This not only revealed some new findings, but helped to corroborate some of the findings in the annual and CSR reports. The corpus of data was then examined jointly by the author and the viticulture and oenology expert. Through reflection back to literature, all actions were classified based on the dimensions of the framework. In cases of disagreement, these were discussed and reconciled.

Findings

This section highlights the results from the content analysis. As an overview, in Figure 1, the findings related to TWE are presented as a reflection of the proposed conceptual framework.

Insert Figure 1 about here

Market-based actions

Market-based actions are those actions related to product, including how product is brought to market. In the case of TWE, southern and south-eastern wine-producing regions of Australia have especially suffered from prolonged drought and increased temperatures (Malkin, 2009; Wahlquist, 2009). Much of TWE grape growing and production activities occur in south-eastern Australia.

With respect to grape growing (Figure 1), the company has, for example, planted new wine grape varieties, such as Spanish Tempranillo, which is better suited to hotter climates (Fenner, 2009). TWE has also bought land in Tasmania and highland Victoria (areas in Australia less affected by rising temperatures), as well as have replanted land decommissioned 10−15 years ago because it was considered too cool for viable grape production. As climate change affects temperatures in wine-producing regions, alternative varieties as well as new grape-growing areas less susceptible to rising temperatures are necessary (Hannah *et al.*, 2013; Keller, 2010; Santisi, 2011). The findings here confirm the actions posited in the conceptual framework, suggesting TWE have taken actions to adapt to changing temperature scenarios in their product (market) strategies.

In other market-based actions, specifically in the winemaking process (Figure 1), TWE has relied on new packaging. The Wolf Blass brand, for example, is using plastic PET bottles, which weigh 51 g compared to 515 g for the industry standard 750 ml glass bottles. This 90 percent reduction in weight reduces GHG emissions during production by 65 percent and by 34 percent during transport. In examples of other actions, TWE has cooperated with freight partner J.F. Hilderbrand to reduce the carbon emissions associated with the movement of containers between port of entry and UK distribution centres. This new rail system has reduced road transport by 50 percent while cutting carbon emissions by 30 percent. Based on the posited framework, reductions in GHG emissions is a mitigative action with respect to climate change, and, according to Colman and Päster (2009), is something that the wine industry should engage in as part of their contribution to lowering overall emissions globally. The evidence here suggests that TWE appears to take this call to climate change mitigation seriously.

Regulatory/Standards-based actions

The institutional environment is placing pressure on firms, including those in the wine industry, to put into practice systems and processes (both mandated and voluntary) that meet certain standards

with respect to the management of GHG emissions, including reductions as well as elimination where possible (Griffiths *et al.*, 2007; Hoffman, 2005; Pinske and Kolk, 2010). In addition, as the availability of water becomes more of a concern given climate change affects, regulation and voluntary standards also consider the management of water use, which is particularly focused on adaptation. In this sense, regulatory bodies as well as national and international standards-bodies are developing norms with respect to both mitigative and adaptive actions, which are captured in the proposed framework.

With respect to TWE, the analysis revealed a few key ways the company is engaging in regulatory/standards-based actions. For example, under TWE's FutureFARM scheme, all of its Australian-based grape growers must have an environmental management system (EMS) that complies with Federal and State government regulations. Similarly, in the US, TWE wineries (i.e., Asti and Chateau St Jean wineries in the Sonoma region and Beringer and Etude wineries in Napa county) are certified under their local governments' "Green Business Program," which focuses on environmental compliance, conserving resources, preventing pollution, and minimizing waste. Such actions are helping to reduce TWE's carbon footprint, and therefore demonstrate a mitigative action. Alternatively, in both the grape growing and wine making processes in Australia, TWE complies with the Queensland government's Water Efficiency Management Plan (WEMP) and the Victorian government's Energy and Resource Efficiency Program (EREP). Consequently, as water use is managed and adapted to lower annual rainfall in many wine-producing regions in Australia, TWE demonstrates adaptive actions.

Lastly, in what appears to be a response to institutional pressure for legitimacy, TWE also provides voluntary annual reporting on its management of and contribution to climate change impacts under the Carbon Disclosure Project (CDP), London Benchmarking Group, the Corporate

Responsibility Index, and the FTSE4Good index. The company continues to receive gold accreditation from the Corporate Responsibility Index, and retains its FTSE4Good index ranking.

Operational-based actions

The operational dimension of the framework is interested in how products are actually produced, including critical inputs into production. With respect to grape growing in Australia, because TWE follows the same operational procedures in all of its vineyards (called the FutureFARM program), the Robe vineyard in South Australia is a suitable representative and will be used to describe the operations-based actions TWE has employed to address climate change at this level.

First, Plant Cell Density (PCD) images, created using the ratio of infra-red to red reflectance, are used in part to determine water needs. Based on these images, subsurface water drip lines can be manipulated to divert water from vines growing in deep soils (thus conserving water) or where a rising water table poses a salinity threat. Second, Digital Elevation Modelling (DEM) assists TWE vineyards in the mapping of water movement, through a site pre-installation of drains or drainage bores, or in mapping movement of saline water through a property and its future potential impact on vine health. DEM is being used to determine the most suitable locations for installing frost fans to maximize protection from frost associated with the increased frequency of extreme weather events. In this sense, as climatic changes shift and affect grape growing, TWE demonstrates its ability to engage in adaptive actions to address risks from climate change.

As climate change not only requires adaptation, but mitigation as well, TWE also demonstrates response here as well. First, careful zonal management practices are followed and include the introduction of chickens into vineyards to control earwig and weevil numbers. This action has resulted in a 50 percent reduction in chemical applications. Second, the use of petrol in the vineyard has been reduced through the adoption of three-row herbicide and fungicide equipment. Because this requires fewer passes in the vineyard, less petrol is used, which reduces

GHG emissions. Zonal management practices and newer spray technology represent mitigative actions, and helps TWE to reduce its carbon footprint.

With respect to the winemaking process, operations at each TWE production unit are assessed by the Energy and Water Efficiency Project (EWEP), a program introduced to identify energy and water saving opportunities. Under the scheme, the Lindeman's Karadoc winery, for example, has identified ways to minimize steam loss and water use by reviewing traditional methods of removing oak bags from wine tanks. Water re-use and storm water catchment are extensively employed at all TWE wineries, enabling greater water self-sufficiency. As water stresses increase as a result of climate change (Keller, 2010), TWE is positioning itself to be more self-reliant through engaging in adaptive actions. Alternatively, as energy use is the single biggest contributor to GHG emissions at the winery level (Coleman and Päster, 2009), TWE also demonstrates actions aimed at mitigation. For example, alternative energy sources are being introduced to wineries in the Napa Valley of California. Solar energy systems have been installed at four Californian wineries including the Beringer Vineyard, which also uses geothermal energy to heat buildings. Solar and geothermal sources of energy both reduce the output of GHG emissions (CSWA, 2009), thereby providing TWE a means to reduce its carbon footprint in the winemaking process.

Conclusions

The aim of this paper was to examine response to the climate change risks in the wine industry. To do this, a framework was introduced and an exploration of one of the world's largest wine producers was undertaken. Hence, this paper makes two main contributions. First, previous climate change response frameworks tend to aim at agricultural industries in general (Fleischer *et al.*, 2011; Vermeulen *et al.*, 2012), and therefore lack specific approaches to the wine industry, or else they explore future impacts on crop yields under different CO_2 concentration scenarios (Tubiello and

Fischer, 2007). This paper combined literatures in climate change, strategy, and wine production to develop an alternative perspective—and introduced a framework specific to the wine industry. The framework accounts for both mitigative and adaptive responses across the two processes of grape growing and winemaking. Additionally, actions are captured across market-based, regulatory/standards-based, and operational-based dimensions.

Second, a case study from the wine industry was used to examine the proposed framework. Using content analysis of various company reports (i.e., annual report, CSR report) and the company website, the results suggest that Treasury Wine Estates (TWE) is engaged in multiple actions across mitigative and adaptive responses in both their grape growing and winemaking processes. The findings suggest close alignment with the described processes and levels, demonstrating the validity of the framework as a means to examine response to climate change risks in the wine industry.

There are limitations to this study. First, a single company was studied in the wine industry, limiting generalizability. However, while the findings from TWE may not be generalized to other industries, the framework is flexible such that it can be applied to other industries. Second, TWE does not have operations in every wine-producing country and the findings are therefore limited to its countries of operation. Yet, the findings tend to corroborate climate change studies in the wine industry in other countries (e.g., Alonso and O'Neill, 2011; Battaglini *et al.*, 2009; Nicholas and Durham, 2012), demonstrating that producers around the world are attempting to respond to climate change risks. Lastly, given that the analysis is derived solely from annual reports, CSR reports, and the company website, there is the possibility of "greenwashing" or inflating material provided. However, as TWE is a public company this is unlikely as such companies can be held to their disclosures and commitments (Krut and Munis, 1998). Further, evidence suggests there is a

correlation between what is disclosed in company reports and objective measures of those disclosures (Clarkson *et al.*, 2008; Patten, 2002).

Several future research opportunities exist. First, a key question that remains unanswered is whether or not the actions described in this paper lead to improved outcomes for wine producers. Research in the wine industry could therefore operationalize the three actions proposed in the framework—including items discussed in this paper—to develop constructs and to test relationships with outcome variables such as decreases in carbon emissions, sales growth, reputation, wine quality, and profitability. Second, there remains some question as to what determines why firms in the wine industry might pursue the types of actions espoused in this paper. Hence, antecedent variables, such as micro-climates, export markets served, strategic flexibility, and innovation capacity/culture could be examined through survey or qualitative research. This could be particularly informative through conducting comparative studies between different wine-producing regions around the world. Fourth, geographic proximity is argued to have an important influence on how firms perceive and respond to the effects of climate change (Galbreath *et al.*, 2014). However, little is known about how spatial closeness facilitates mitigation or adaptation action. Future research, for example, could study how exchanges of knowledge between firms in regional clusters affect responses to climate change in the wine industry, or in other industries as well.

Lastly, the framework presented in this paper could be extended to other agriculture industries. For example, research demonstrates that the effects of climate change are heterogeneous around the world, affecting different industries differently (Winn *et al.*, 2011). In this sense, mitigative and adaptive response is likely to be different in different contexts and for different purposes. However, the framework presented here provides for flexibility. For example, the processes of grape growing and wine making could be substituted with feedlot and processing

processes in the beef cattle industry. In another example, dairy farms and milk production could be substitutes in the dairy processing industry. Importantly though, the dimensions related to market-based, regulatory/standards-based, and operational-based actions remain consistent. Here, regardless of the agricultural industry, both academics and practitioners alike have a mechanism through which thought can be stimulated around the types of actions required to both mitigate and adapt to climate change, regardless of the industry's core processes.

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FIGURES

Figure 1. TWE responses to climate change

		Type of action		
Wine Process	*Type of response*	Market-based	Regulatory/Standards-based	Operational-based
Grape Growing	Mitigation	▪ Culling non-core vineyards under management to re-focus on higher-quality, premium brands (eliminating overall carbon footprint)	▪ EMS that complies with Federal and State regulations (Australia) ▪ Voluntary reporting under Carbon Disclosure Project, Corporate Responsibility Index, FTSE4Good index rating, and London Benchmarking Group ▪ Use of carbon offset plans (Greenfleet, Markaranka) in Australia	▪ Strict fertilizing regimes (reduces chemical use) ▪ Use of control tactics in land management practices (introduction of chickens to control earwig and weevils—reduces chemical use) ▪ Carbon sinks/sequestering (Biodiversity Guidelines that include the maintenance of native vegetation) ▪ Three-row sprayers (reduces petrol use)
	Adaptation	▪ Planting hotter climate varieties (Tempranillo) ▪ Purchasing land in areas less effected by rising temperatures (Tasmania, highland Victoria) to plant new vineyards	▪ Compliance with Water Efficiency Management Plan (Queensland) and Energy and Resource Efficiency Plan (Victoria)	▪ Use of PCD (Plant Cell Density) images to pinpoint water needs in vineyards (helps reduce water use) ▪ Planted midrows of deep sandy soil with lucerne (reduces water use) ▪ Use of DEM (Digital Elevation Modelling) to protect vine health against extreme weather events
Wine Making	Mitigation	▪ Use of new packaging (plastic PET bottles, lightweight glass bottles) that helps reduce carbon footprint ▪ Modified processes in transport (rail system which reduces road transport) in the UK that cuts carbon emissions by 30 percent ▪ Increasing sales to closer export markets (i.e., South East Asia) reduces carbon emissions in transport	▪ Compliance with National Packaging Covenant (Australia) ▪ Certification under Green Business Program (United States) ▪ Voluntary reporting under Carbon Disclosure Project, Corporate Responsibility Index, FTSE4Good index rating, and London Benchmarking Group ▪ Use of carbon offset plans (Greenfleet, Markaranka) in Australia	▪ Use of solar and geothermal energy ▪ Packaging recycling ▪ Grape marc and spent yeast converted to by-product and reused in wine making ▪ ELT (Environmental Leadership Team) in place across wineries to develop strategies to ensure energy use is reduced over previous years
	Adaptation	▪ Increasing reliance on grapes sourced from vineyards in locations less susceptible to rising temperatures		▪ Water reuse ▪ Storm water catchment (reduces reliance on potentially depleted public water sources) ▪ ELT (Environmental Leadership Team) in place across wineries to develop strategies to ensure water use is reduced by per unit of production over previous levels