Determinants of climate change innovation in the wine industry: A study of meso and micro-level perspectives

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ABSTRACT: *This study tests the drivers of climate change innovations in the wine industry. Taking a meso (cluster) and micro-level (firm) perspective, results of structural equation modelling analysis suggests that absorptive capacity (micro-level) is directly related to climate change innovations. Alternatively, absorptive capacity is directly related to knowledge exchange in the cluster (meso-level), which in turn is linked to climate change innovations. Hence, absorptive capacity has both direct and indirect effects. The study further finds that climate change innovations are related to firm performance and reductions in greenhouse gases: mitigative innovation impacts on greenhouse gas reductions while adaptive innovation impacts on firm performance. Implications of findings are discussed, along with future research directions and limitations.*

Keywords: Absorptive capacity, climate change, clusters, innovation, performance, wine

What drives innovation in clusters: meso or micro-level effects? Neo-Marshallian theorists and economic geographers posit that innovation is determined on an endogenous basis, mainly through external knowledge exchange, otherwise known as localised knowledge "spillovers" (Feldman 1994; Jaffe, Trajtenberg & Henderson 1993; Malmberg & Maskell 2002; Martin & Sunley 1998). This meso-level factor is thought to be important because interdependencies and geographic proximity facilitate an innovative milieu (Keeble & Wilkinson 1999). Alternatively, cluster theory has been criticised for treating firms as either "black boxes" or as irrelevant actors in the innovation process (Caniëls & Romijn 2003; Giuliani 2005; Martin & Sunley 2003). More specifically, micro-level theories argue that innovation is largely driven by a firm's capability to absorb and harness new knowledge (Cohen & Levinthal 1990). Without such a capability, firms are unable able to learn, exchange knowledge with other firms, or innovate. Surprisingly, few studies have examined, in combination, the meso and micro-level determinants of firm innovation.

This study makes three contributions to the literature. First, while a few studies do explore meso and micro-level determinants of *learning* in clusters, they do not actually test their effects on innovation (e.g. Giuliani & Bell 2005). Thus, there is limited knowledge on the extent to which these two factors do, or do not, interact to affect innovation. The present study explores meso and micro-level determinants by examining their impacts on climate change innovation in the wine industry. Because response to climate change is contested in the wine industry (e.g. Galbreath 2012), it provides an important distinctive outcome likely to reflect very specific choices of wine firms. Since different wine firms may make different choices surrounding response to climate change, relationships between meso and micro-level factors and innovation are posited to be more evident in implementation rates of climate change innovations.

Second, knowledge exchange between firms is a fundamental tenet of cluster theory. Yet, much of the literature uses terms like "knowledge in the air". This study takes the position that it is not meso-level knowledge exchanges that are important to innovation *per se*, but rather the *types* of knowledge exchanged that is important. Generally, "technical" knowledge is the focus of cluster theorists; however, knowledge is not limited to a singular type nor is technical knowledge the only type of knowledge expected to be exchanged in clusters (Sammarra & Biggiero 2008). By examining several different knowledge types, the study advances understanding of knowledge exchanges in clusters, determining if firms that engage in the exchange of diverse knowledge types have higher rates of innovation.

Lastly, Galbreath (2011, 2012) demonstrates that there are two types of climate change innovation: mitigative-based innovation and adaptive-based innovation. Yet little research demonstrates the benefits of these innovations. This study therefore examines the relationship between climate change innovation and business outcomes, offering practical insights into the value of both mitigative and adaptive innovation.

THEORY AND HYPOTHESES

A micro-level perspective of climate change innovation

In general, innovation consists of adopting or changing technologies, processes, specifications, or inputs to solve problems (Van de Ven 1986). Van de Ven (1986: 591) suggests that "an innovation is a new idea, which may be a recombination of old ideas, a schema that challenges the present order, a formula, or a unique approach which is perceived as new by the individuals involved". This definition suggests that innovation is a broadly defined term, which may be perceived differently from firm to firm and from industry to industry. Further, an innovation does not necessarily entail an "improvement", but rather a change in the current state (Strang & Macy 2001). In this study, it is acknowledged that the emerging effects of climate change will likely require wine producers to innovate to both mitigate, and adapt to, its effects (Galbreath 2011, 2012). Of importance is gaining an understanding of what might explain variations in climate change innovations.

A micro-level perspective suggests that firms' absorptive capacity levels explain innovation rates (Cohen & Levinthal 1990). Absorptive capacity refers to a firm's ability to identify, value, and apply new knowledge for commercial ends (Cohen & Levinthal 1990). Absorptive capacity permits firms to add new knowledge to the existing knowledge base, create new knowledge from a novel combination of new and existing knowledge, and apply knowledge for the purpose of innovation. As climate change is complex and cuts across a variety of weather-related impacts such as temperature, rainfall, extreme weather events, frosts, etc. (IPCC 2007), firms with high levels of absorptive capacity would be expected to interpret knowledge about the impacts of climate change to wine production, while generating a better understanding of the practices and processes that need to be put in place to mitigate and adapt to climate change. Similarly, firms with higher levels of absorptive capacity would also be expected to recognise the opportunities that climate change offers—or correct any deficiencies that might undermine their ability to compete under changing climate scenarios—thus engaging in climate change innovation. Therefore:

> *Hypothesis 1: Absorptive capacity is directly and positively associated with climate change innovations (including mitigative and adaptive innovation).*

A meso-level theory of micro-level influences on climate change innovation

Theories of absorptive capacity recognise that the ability to innovate is dependent upon pre-existing stocks of knowledge (Dierickx & Cool 1989). However, as firms use their pre-existing stocks of knowledge to innovative, absorptive capacity capabilities also permits them to recognise the need for new knowledge as environments change (Boal & Hooijberg 2000; Cohen & Levinthal 1990). While the source of new knowledge is open to interpretation in the absorptive capacity literature, cluster theory argues that the key means of knowledge acquisition is through knowledge exchange with other firms in the cluster (Jaffe et al. 1993; Malmberg & Maskell 2002).

Clustered firms develop a level of connectedness that develops trust, cooperation, social integration, and fosters commonality of knowledge (Mitchell, Burgess & Waterhouse 2010). This permits open communication and improves the efficiency of knowledge exchange throughout the cluster.

However, critical knowledge does not simply include substantive technical knowledge; it also includes a variety of knowledge types (Sammarra & Biggiero 2008). This would be particularly so where the object of innovation in the cluster is novel. For example, the evidence suggests that climate change is imposing conditions on wine production that many regions have never faced, such as temperatures above the long-term average, more extreme heats days, and significantly reduced rainfall (Webb, Whetton & Barlow 2007; Webb, Whiting, Watt, Hill, Wigg, Dunn, Needs & Barlow 2010). There is also evidence that consumers are increasingly demanding that wine producers demonstrate excellence in new areas of strategy and operations (e.g. in areas such as environmental management, including that related to climate change) (Galbreath 2011). The expectation would be that in novel domains, firms within clusters would readily engage in exchanges of a variety of types of knowledge to gain a broader and more complete understanding of the issue. Here, an "outward-looking" perspective of absorptive capacity would be expected to induce such exchanges of multiple knowledge types (Cohen & Levinthal 1990).

However, one of the main tenets of cluster theory is that innovation is determined on an endogenous basis, mainly through external knowledge exchange, or localised knowledge spillovers (Jaffe et al. 1993; Malmberg & Maskell 2002). In clusters, knowledge exchange occurs due to geographic, cognitive, and relational proximities (Mitchell et al. 2010). Hence, because knowledge becomes a public or "club good" within clusters (Capello 1999), an innovative milieu is created, one where innovation capacity is upgraded, advanced, and expanded, due to a continuous cycle of new knowledge flows. While it is recognised that, from a micro-level perspective, higher levels of absorptive capacity of individual firms are likely to induce the flow of various types of knowledge in and around clusters (Inkpen & Tsang 2005; Schrader 1991; von Hippel 1987), cluster theory implicitly implies that the "side effect", or positive externalities, of various knowledge type exchanges are higher levels of innovation (Marshall 1920; Maskell 2001). This is because knowledge, in its various types, is assumed to diffuse freely in the air in a way that it generates "diffuse innovative capacity" in the cluster (Allen 1983). Therefore:

Hypothesis 2: Knowledge exchanges in the cluster partially mediate the effect of absorptive capacity on climate change innovations (including mitigative and adaptive innovation).

The effect of climate change innovation on business outcomes

Responding to environmental issues such as climate change requires significant investments of managerial time, financial capital, and know-how (York and Venkataraman, 2010). Given this level of commitment, firms expect to gain beneficial outcomes. Previous research does find, for example, that enhanced environmental practices improve firm performance (e.g. Klassen & McLaughlin 1996; Melnyk, Sroufe & Calantone 2003). Similarly, for two key reasons, implementation of climate change innovations would be expected to improve business outcomes such as firm performance. First, a growing community of consumers, and retailers, are signalling that they seek to purchase wine from those producers who demonstrate strength in environmental credentials, including actions that respond to climate change, such as the reduction of greenhouse gas emissions (Galbreath 2011). Second, climate change presents opportunities for some industries (Winn, Kirchgeorg, Griffiths, Linnenluecke & Günther 2011). Although the wine industry can be negatively impacted, it is also expected to benefit from opportunities presented from climate change, such as selling new, hotter climate varieties of wine while expanding growth through the development of wine production in new locations (Galbreath 2011, 2012). Hence, the implementation of mitigative and adaptive innovations is predicted to benefit the business outcomes of wine firms. Thus:

> *Hypothesis 3: Climate change innovations (including mitigative and adaptive innovation) have a positive effect on business outcomes.*

METHODS

Sample

The wine industry was chosen because it has emerged from being a traditional, motionless industry, to a dynamic and fairly knowledge-intensive one (Giuliani 2007). Wine producers in the South Australia cluster that were listed in the annual *Australian and New Zealand Wine Industry Directory* were included (Winetitles 2012).[1] The South Australia wine cluster was surveyed as it is considered central to Australia's wine production, and a hub of innovation activity (Aylward 2007).

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[1] While the geographic delineation of clusters and the relations between different spatial scales remains controversial (Martin & Sunley 2003), there is generally agreement amongst scholars that clusters are "geographically proximate"

A pilot study survey was first conducted with 38 wine producers who did not participate in the main study. Minor word changes were suggested to improve content validity. After making appropriate updates, the final survey was sent to a total of 666 wine firms, directed to the owners (who were asked to pass the survey on to a more qualified respondent in the firm as appropriate). After accounting for 73 undeliverable or returned surveys, 207 were useable. A further four had to be eliminated due to large amounts of missing data. This represents an effective response rate of 34 percent, which is outstanding in a country suffering from severe survey fatigue (Galbreath & Shum 2012). To test for non-response bias, early versus late respondents were compared on the absorptive capacity measure, the climate change innovation measures, and firm performance. No significant differences were found. Further, since the data were single sourced, a Harman's ex-post one factor test was also conducted (Podsakoff & Organ 1986). The test revealed the absence of a single general factor accounting for most of the observed covariance in the variables. Hence, common method bias appeared to be low for the data.

Variable measurement

Knowledge exchanges in the cluster. Knowledge is defined as "that which is known" (Grant 1996: 110). Knowledge can be held by individuals or firms, and can be encapsulated in books, journals, blueprints, etc. (Grant 1996; Liebeskind 1996). To measure knowledge exchanges in the cluster, first, a categorization of knowledge types based on a literature review was developed. Literatures from international business, management, marketing, strategy, and technology and innovation were consulted. The types of knowledge identified were technical, industry, market, organisational, marketing, and strategy knowledge, each of which has been used in previous research (e.g. Boschma & Ter Wal 2007; Kesidou, Caniels & Romjin 2009; Sammarra & Biggiero 2008). Next, to enhance content validity according to the research objective, each knowledge type was contextualised to the issue of climate change (see Appendix). Respondents were asked to consider any knowledge they held about climate change and were asked to indicate how much of this knowledge they had exchanged with other firms in

(Porter 2000: 16). In the case of Australian wine, production is delineated by geographic region, or more specifically, by state.

the South Australia wine cluster for each of the knowledge types (on a four-point Likert scale where 1 = no exchange; 2 = very little exchange; 3 = moderate exchange; and 4 = very high exchange).

Absorptive capacity. Absorptive capacity seeks to assess the degree to which firms identify, value, and apply new knowledge for commercial ends. For measurement, several studies were reviewed and scales were adapted from the study of Delmas, Hoffmann, and Kuss (2011). Their study was selected as a guide because of its focus on environmental strategy. Respondents were asked to assess each item on seven-point Likert scale, ranging from 1 = stronger disagree to 7 = strongly agree (Appendix).

Climate change innovation. Innovation in this study is defined as "a new idea, which may be a recombination of old ideas, a schema that challenges the present order, a formula, or a unique approach which is perceived as new by the individuals involved" (Van de Ven 1986: 591). An innovation does not necessarily entail an "improvement", but rather a change in the current state. Climate change "innovation" in the wine industry consists of two types of innovation: mitigative and adaptive (Galbreath 2011, 2012). The use of mitigative and adaptive innovations is appropriate because these entail new ways/improvements to responding to the natural environment. Following formative construct convention (Bollen & Lennox 1991), for measurement, an extensive literature review was undertaken to create an index of actions for both mitigative and adaptive innovations. An index of the most widely discussed actions was compiled and discussed with an academic and scientific expert in the area of wine production and climate change. Based on this consultation and continual reference back to the literature, each index was narrowed down to seven actions that best formed mitigative and adaptive innovations (Appendix). Hence, mitigative and adaptive innovations are formative constructs, each consisting of seven actions. Respondents were asked to assess the state of implementation of each action on a seven-point Likert scale, ranging from 1 = not considering to 7 = implemented (Appendix).

Business outcomes. To assess the impact of climate change innovation on business outcomes, this study sought to capture both firm and environmental performance items. After reviewing the literature, a scale was adapted from the study of Pullman, Maloni, Carter, and Dillard (2010), given its relevance to the wine industry. Business outcomes consisted of ten items and respondents were asked to assess each one on a seven-point Likert scale, ranging from 1 = strongly disagree to 7 = strongly agree (Appendix).

Control variables. Because of their potentially confounding effects on business outcomes, controls included three key variables. First, age was measured in number of years since founding. Second, to control for size, number of cases produced was used, where 1 = 1 to 2,499 cases, 2 = 2,500 to 19,999 cases, 3 = 20,000 to 99,999 cases, 4 = 100,00 to 1,499,99 cases, and 5 = over 1,500,000 cases. Lastly, to control for export orientation, firms where coded on the basis of their percent of export sales, where 1 = do not export, 2 = 1-25 percent, 3 = 26-50 percent, 4 = 51-75 percent, and 5 = 76-100 percent. Data for the control variables was collected from secondary sources; namely, the Winetitles database (Winetitles 2012).

RESULTS

Means, standard deviations, and correlations are presented in Table 1. The correlation table suggests that none of the variable intercorrelations are high enough—generally .80 or higher—to indicate concern over multicollinearity (Licht 1995).

[Insert Table 1 here]

Using AMOS software, confirmatory factor analysis (CFA) assessed the reflective constructs. An initial estimation with the latent factors demonstrated a poor fit (CFI = 0.79, RMSEA = 0.06). After an iterative process of item elimination (Appendix), the final model demonstrated a good fit to the data (χ^2 = 177.09, df = 98, ratio = 1.807; CFI = 0.95, RMSEA = 0.06). Note that the results indicated a two-factor solution to business outcomes, a 5 item factor labelled “firm performance” and a one item factor labelled “GHG reductions” (GHG = greenhouse gas). Reliability was acceptable, where knowledge exchange α = 0.90, absorptive capacity α = 0.79, and the firm performance α = 0.85. Convergent validity for the constructs was acceptable, with factor loadings for each reflective construct above 0.50 (Table 2), which is significant (Hair, Anderson, Tatham & Black 1998). Discriminant validity was also acceptable (Table 2), as the square root of the average variance extracted (AVE) of each construct is larger than its correlation with the other constructs (Fornell & Larcker 1981). To assess the formative indicators, regression analysis revealed that collinearity was not present between the actions in the mitigative innovation index (highest VIF of 1.66) or for the actions in the adaptive innovation index (highest VIF of

1.78), providing *prima facia* evidence that formative indicators were suitable (Diamantopoulus & Winklhofer 2001).

[Insert Table 2 here]

To explore the fit of the model, structural equation modelling (SEM) using AMOS was employed, with the maximum likelihood estimation method as the analysis technique. The hypothesized model demonstrates a good fit to the data (χ^2 = 289.81, df = 170, ratio = 1.705; CFI = 0.93; RMSEA = 0.05). As for the control variables, age (path loading = -0.21, t = -2.31, p < .05) and exports (path loading = -0.23, t = -2.25, p < .05) are negative and significantly related to firm performance. Alternatively, size (path loading = 0.30, t = 2.65, p < .01) is positive and significantly related to firm performance. None of the control variables load on GHG emissions.

[Insert Figure 1 here]

To test the hypothesized relationships, the model was assessed in terms of explanatory power and significance of paths (standardized path coefficients) among the constructs. The constructs and their path statistics are presented in Figure 1. The results demonstrate support for Hypothesis 1: absorptive capacity is positive and significantly related to climate change innovations (for mitigative innovation the path loading = 0.29, t = 3.43, p < .001; for adaptive innovation the path loading = 0.36, t = 4.13, p < .001). For Hypothesis 2, absorptive capacity is positive and significantly related to knowledge exchanges in the cluster (path loading = 0.43, t = 4.54, p < .001). Knowledge exchanges in the cluster are also positive and significantly related to climate change innovations (for mitigative innovation the path loading = 0.35, t = 4.42, p < .001; for adaptive innovation the path loading = 0.25, t = 3.16, p < .001). Hence, given the significant paths for absorptive capacity to knowledge exchanges in the cluster, the significant paths for knowledge exchanges in the cluster to mitigative and adaptive innovations, and the significant paths for absorptive capacity to mitigative and adaptive innovations, the effect of absorptive capacity on climate change innovations is partially mediated by knowledge exchanges in the cluster. This suggests support for Hypothesis 2. As for business outcomes, mitigative innovation have a positive and significant effect only for GHG reductions (path loading = 0.57, t = 5.55, p < .001). Alternatively, adaptive innovation has a positive and significant effect only for firm performance (path loading = 0.20, $t = 2.07$, $p < .05$). Thus, Hypothesis 3 is partially supported.

DISCUSSION

This study offers three main contributions. The study of innovation is advanced by combining a meso and micro-level approach. The study also offers expanded insight into knowledge exchange in clusters. Lastly, the findings have practical implications for the value of investing in climate change innovations. Each of these contributions is discussed below.

First, climate change is a contested issue with a wide range of opinions on the extent to which it is happening, and what its causes are (Hoffman 2011). At the same time, climate change has been cast as one of the greatest economic, political, and moral challenges of the times (Carrell 2012; Knight 2011). Hence, stakeholder pressure for business response to climate change is increasing (Enkvist & Vanthournout 2008; Levy & Egan 2003). Response, through mitigative and adaptive innovation, can range from a minimalist to proactive approach (Jeswani, Wehrmeyer & Mulugetta 2008). While the research shows that factors influencing the implementation of climate change innovations range from economic motivations, to moral commitments, and to stewardship approaches towards the natural environment (Boiral, Henri & Talbot 2012; Galbreath 2012), this study's point of departure was to examine the combination of cluster (meso) and firm-level (micro) effects.

The results suggest that the tension between meso and micro-level effects is unfounded (Caniëls & Romijn 2003; Giuliani 2005). As firms develop high levels of absorptive capacity, they are able to exploit knowledge for innovation purposes (Cohen & Levinthal 1990). Here, the firm does not simply depend on the external environment for new knowledge; rather, the firm relies on prior knowledge and internal sharing and communication to develop its innovation processes. This is referred to as "inward-looking" absorptive capacity (Cohen & Levinthal 1990). Alternatively, firms with high levels of absorptive capacity also recognise that new knowledge is essential, particularly where the need to innovate is in novel domains. This enacts the firm's "outward looking" absorptive capacity to seek out new knowledge (Cohen & Levinthal 1990). Following cluster theory, new knowledge is generated through inter-firm knowledge exchanges (Jaffe et al. 1993; Malmberg & Maskell 2002). As knowledge is exchanged, a creative milieu is developed within the cluster that leads to higher levels of innovation for all firms. In this case, knowledge drives innovation. The findings of the present study confirm that micro and meso-level factors are *both* necessary conditions to influence climate change innovations. As firms demonstrate strength in absorptive capacity, they create the internal capabilities necessary to put in place innovations that respond to climate change. Alternatively, the absorptive capacity of individual firms stimulates the search for a range of knowledge about climate change. This knowledge, gained through inter-firm exchanges in the cluster, advances managers' mental models and a firm's cognitive capacity, leading to higher innovation levels. The findings therefore have significant implications for the debate on the meso and micro-level determinants of innovation in clusters (e.g. Caniëls & Romijn 2003; Giuliani 2005, Giuliani & Bell 2005; Hervas-Oliver & Albors-Garrigos 2009; Martin & Sunley 2003).

Second, cluster theory largely treats knowledge as that which is "technical" in nature (Huber 2012; Munari, Sobrero & Malipiero 2012). While technical knowledge can be broadly defined, there is evidence to suggest that firms in clusters are more active in the types of knowledge they exchange. For example, in their study of 32 firms in the aerospace cluster in Rome, Sammarra and Biggiero (2008) find that knowledge exchange includes technological, market, and managerial knowledge. One reason for this broader level of knowledge exchange might be due to the embeddedness of firms in clusters, such that trust and cognitive and relational proximities are established (Mitchell et al. 2010). As greater forms of proximity are developed within the cluster, this likely influences the type of knowledge exchange, including knowledge which is "public", or more explicit in nature, and knowledge which is "private", or more tacit in nature (Tallman, Jenkins, Henry & Pinch 2004). However, of importance is that virtually no studies to date have explored the types of knowledge exchanged about climate change. The key implication of the findings suggest that knowledge is not unidimensional in cluster exchanges (i.e. limited to technical knowledge exchanges), nor are knowledge exchanges *per se*, or "knowledge in the air", necessarily important to innovation. Rather, the *types* of knowledge in the exchanges might be the critical dimension that develops the innovation capacity of clustered firms.

The third contribution is practical in nature. Previous research demonstrates that some firms in the wine industry are hesitant to invest in climate change innovations because they are not clear on the benefits, economic or otherwise, that can be obtained from such investments (Galbreath 2012). The results of the present study suggest that climate change innovations do have business benefits; however, the type of climate change innovations appears to make a difference. For example, research demonstrates that consumers are interested in the environmental credentials of firms, including how they respond to climate change (Barber, Taylor & Strick 2009). However, from a climate change perspective, this appears to be mainly related to GHG reductions (Galbreath 2012). The expectation is that when firms invest in innovations that address GHG emissions, they would be in a position to reduce such emissions. The findings of this study confirm that mitigative innovation is positively related to GHG reductions. On the other hand, adapting to climate change, or attempting to take advantage of any opportunities, appears to lift firm performance. This might be due to the fact that as wine firms recognise and address opportunities arising from climate change, such as selling hotter climate varieties or expanding production to new locations, they position themselves for growth and increased profitability. The results suggest that firms need to closely weigh the advantages and disadvantages of their investments in climate change innovations, and consider the trade-offs in the types of business outcomes they seek.

LIMITATIONS, FUTURE RESEARCH, AND CONCLUSIONS

This study is not without limitations. First, the study examines a single industry in a single location. While the wine industry is important from a climate change perspective, further research needs to examine other industries to test the micro and meso-level determinants of climate change innovations. Second, a single national context is taken into consideration. Given differences in regulation around the world, particularly with respect to GHG emissions, studying only one country is a limitation. Future research could expand to other nations of the world. Lastly, the study is cross-sectional. Clearly, climate change effects are time-based and can take decades to unfold. Future research therefore needs to capture longitudinal data, which would allow a more dynamic investigation of the interactions between climatic changes, knowledge exchange, and absorptive capacity influences on climate change innovations.

In conclusion, this study sought to answer the question as to what drives innovation in clusters. By looking at climate change innovations in the wine industry, the findings suggest that a micro-level influence, namely, a firm's absorptive capacity, is positively related to climate change innovations.

Alternatively, absorptive capacity is positively related to knowledge exchange at the cluster, or meso-level, which in turn influences climate change innovations. The findings are significant, and offer confirmation that both micro and meso-level influences are necessary to drive climate change innovations. Further, the findings suggest that climate change innovations have different, yet complimentary, impacts on business outcomes. Hence, the research advances both resource-based and cluster theories of innovation, and for economic geographers and strategy researchers, offers future research opportunities for those with an interest in climate change and environmental strategies.

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APPENDIX

Variable measurement

Knowledge exchanges in the cluster[a]

1. *Technical knowledge*: insight on technologies, technical enhancements, vineyard and/or winery techniques that relate to climate change.
2. *Industry knowledge*: know-how gained from peak industry bodies, specialist sources, or employees/peers on addressing industry requirements or government policies on climate change.
3. *Market knowledge*: knowledge about the size of opportunity for consumer markets sensitive to producers' environmental credentials, retailer purchasing trends of organic and biodynamic wine, impacts of climate change on grape yield, quality, and price.
4. *Organisational knowledge*: how your company has coordinated and supervised organisational resources and processes so that climate change impacts are addressed efficiently and effectively.
5. *Marketing knowledge*: how your company specifically addresses customer preferences, marketing and branding, and new product development as they relate to any climate change requirements.
6. *Strategy knowledge*: insight on your company's strategy, planned competitive moves, long-term business plans, and ability to manage change as related to climate change.

a. 4-point scale where 0 = no exchange; 1 = very little exchange; 2 = moderate exchange; and 3 = very high exchange.

Absorptive capacity[a]

1. Our business experiences difficulties in implementing changes required to meet market demands (reverse coded).[b]
2. Our business quickly recognizes the usefulness of new external knowledge to existing knowledge.
3. Our business regularly reconsiders technologies and adapts them accordant to new knowledge.
4. Practical experiences are rarely shared in the business (reverse coded).[b]
5. It is clearly known how activities within our business should be performed.[b]
6. Newly acquired knowledge is documented and stored for future reference.
7. Our business regularly considers the impact of changing market demands in terms of new products and/or modifications of existing ones.[b]
8. We have difficulty in grasping opportunities for our business from new external knowledge (reverse coded).
9. We constantly consider how to better exploit new knowledge.
10. Staff periodically meet to discuss the consequences of market trends to the business.[b]

a. 7-point scale ranging from 1 = strongly disagree to 7 = strongly agree.
b. Item eliminated based on refinement procedure.

Mitigative innovation[a]

1. Use of alternative energy sources (e.g., "green" power, solar, wind) in the overall production of wine.
2. Use of alternative packaging to bottle wine (e.g. use of lightweight glass bottles, plastic PET bottles, recycled bottles).
3. Reduction of refrigeration loads.
4. Energy efficient technology in buildings.

5. Minimizing the use of agrichemicals.
6. Alternative fuel use (e.g. biodiesel, ethanol) to power tractors, utility vehicles, machinery, etc.
7. Carbon sinks/sequestering (e.g. reduced tillage, use of compost, planting of shrubs, hedgerows, or trees).

Adaptive innovation[a]

1. Sales of hotter climate varieties.
2. Water saving techniques in the winery.
3. Canopy management techniques that address potential increases in temperature.
4. Establishing vineyards in locations predicted to be less vulnerable to climate risks.
5. Application of vineyard orientations that address potential temperature increases.
6. Water saving techniques in the vineyard.
7. Growing grape varieties that are better suited to hot temperatures.

a. 7-point scale were 1 = not applicable, 2 = not considering, 3 = future consideration, 4 = assessing suitability, 5 = planning to implement, 6 = implementing now, and 7 = implemented.

Business outcomes[a]

1. Our sales have improved.
2. We have served new markets in Australia.
3. Customer satisfaction and loyalty has improved.
4. Our company's image and reputation has improved.
5. We have increased our access to international markets.[b]
6. Product quality has improved.[b]
7. We have successfully introduced new products.[b]
8. Greenhouse gas emissions have been reduced.
9. Some of our input costs have decreased.[b]
10. Company profitability has increased.

a. 7-point scale ranging from 1 = strongly disagree to 7 = strongly agree.
b. Item eliminated based on refinement procedure.

TABLES

Table 1. Descriptives and correlations

Variable	*Mean*	*S.D.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1. Firm performance	5.08	1.22	1.00								
2. GHG emissions	4.55	1.56	0.14	1.00							
3. Mitigative innovation	4.21	1.24	0.14	0.49**	1.00						
4. Adaptive innovation	4.18	1.39	0.18*	0.33**	0.47**	1.00					
5. Knowledge exchange	2.15	0.73	0.13	0.37**	0.45**	0.40**	1.00				
6. Absorpive capacity	5.10	1.13	0.27**	0.43**	0.37**	0.41**	0.39**	1.00			
7. Firm age	29.31	38.52	-0.05	0.07	0.08	0.14	0.09	0.12	1.00		
8. Firm size	2.03	0.95	0.07	0.19*	0.27**	0.15	0.23**	0.20*	0.41**	1.00	
9. Export orientation	2.57	1.10	-0.10	0.06	0.06	0.02	-0.01	-0.02	0.05	0.52**	1.00

* $p = 0.05$; ** $p = 0.01$

Table 2. Correlations and AVE of reflective constructs

Variable	KE	AC	FP	GHG
Knowledge exchange (KE)	0.57			
Absorptive capacity (AC)	0.41	0.52		
Firm performance (FP)	0.19	0.39	0.53	
GHG reductions (GHG)	0.55	0.58	0.19	0.59

Non-diagonal numerals are correlations and diagonal numerals are AVEs

FIGURES

Figure 1. Main effects test