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# AMERICAN ASSOCIATION OF WINE ECONOMISTS

## AAWE WORKING PAPER
## No. 155
*Economics*

## An Exploratory Study of Climate Change Innovations in Wine Regions in Australia

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**May 2014**
ISSN 2166-9112

www.wine-economics.org

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ABSTRACT: The implications of climate change for regional innovation remains understudied. Exploratory in nature, this study examines climate change innovations in two regional wine clusters in Australia. In South Australia, the evidence suggests firms in the wine industry are implementing climate change innovations at a higher rate than their counterparts in Western Australia, even though Western Australian firms appear to be experiencing more disruptive effects of climate change. To help explain these differences, key variables are examined. Knowledge exchanges (including types of knowledge) in the region and firm-level absorptive capacity explain the uptake of climate change innovations in South Australian firms, whereas knowledge exchanges alone (including types of knowledge) explain innovations in Western Australian firms. A discussion of the findings is offered along with future research opportunities for climate change research in regional studies.

Keywords: absorptive capacity, Australia, climate change, comparative studies, knowledge exchange, regions, wine

## INTRODUCTION

Regional clusters are thought to be at the forefront of innovation and drivers of national competitiveness (Porter, 1990, 1998). Scholars have posited that network embeddedness and knowledge spillovers, influenced by the geographic proximity of regional clusters, facilitate this innovative frontier (Camagni, 1991; Keeble and Wilkinson, 1999). However, while innovation has been defined broadly (Van de Ven, 1986), research in the regional studies stream tends to rely on proxy measurements such as new product introductions or patents to measure innovation (Expósito-Langa *et al.*, 2011; Zahra *et al.*, 2000). Although new product introductions or patents may be important proxies of innovation for firms in some regional clusters, in others, the assessment of innovation levels requires a different perspective. For example, the wine industry faces significant challenges related to climate change, such that innovative response is likely required to ensure future survival (Galbreath, 2011; Hannah *et al.*, 2013). Hence, this paper's main research questions: to what extent are there differences in the implementation rates of climate change innovations in wine-producing regions and are there factors that might explain any differences in innovation levels between regions?

To advance the literature on regional studies, this study makes three contributions. First, climate change has been put forth as a 'great' economic and political issue facing the world (Knight, 2011). Yet little literature compares how firms in different regions are responding to the issue. This exploratory paper's point of departure is to study climate change innovations. The reason for this is these are generally new and/or novel innovations and as such should reflect differences in how firms in regions respond to external shocks, such as changes in the natural environment (Galbreath, 2011). Second, despite the historical and cultural significance of wine, the sources of competitive advantage (e.g., innovation levels) in the industry are understudied (Atkin *et al.*, 2012; Delmas and Grant, 2014). By relying on two wine-producing regions in

Australia, this study deepens understanding of how the wine industry innovates, and includes the exploration of micro (firm-level) and meso (regional-level) differences. Third, the sustainability of current wine-producing regions around the world may be under threat due to climate change. For example, in Australia, the locale of this study, scientists predict a potential drop in production of up to 74 percent by 2050 due to climate change (Hannah *et al.*, 2013). Hence, the study has important practical implications for future management strategies in the wine industry and regional responses to changing climatic conditions.

The paper proceeds as follows. First, some background is provided and research questions are developed. Then, the results are presented. Finally, the paper ends with a discussion of the results and offers conclusions.

## BACKGROUND AND RESEARCH QUESTIONS

### *Climate change*

Mainstream business models assume that current economic and social conditions will continue—in many instances flourish—regardless of unfavourable biophysical conditions in Earth's natural and climate systems (Gladwin *et al.*, 1995; Purser *et al.*, 1995). However, there is a growing body of research on climate change that challenges such linear assumptions. For example, virtually all business activity depends on the resource and economic inputs the natural environment provides (Dyllick and Hockerts, 2002). If these resources and inputs are disrupted, run out, or are otherwise put at risk as a result of climate change, sustainable development, for example, could be challenged (Stern, 2006; Zuindeau, 2006).

According to Pittock and Jones (2000), the nature of changes in climatic variables (e.g., temperature, precipitation, storminess) is complex and differs over time. Current climate models predict that in the next several decades there will be mean temperature increases, altered precipitation patters, and increased occurrence of extreme weather conditions (IPCC, 2007, 2014). However, these changes are likely to unfold unevenly across different world regions (Winn *et al.*, 2011); for example, some regions of the world will receive more precipitation, others will not (Hätel and Pearman, 2010). The perceived challenges of changes in climatic conditions include high costs to business and the public due to the increased frequency of extreme weather events, higher temperatures, health risks, and overall decreases in economic growth (Hätel and Pearman, 2010; Linnenluecke and Griffiths, 2010; Stern, 2006; Winn *et al.*, 2011). Perhaps indicative of the potential seriousness of the matter, some insurance companies are taking into account the effects of climate change and, in response, as part of their risk management strategies are developing specialized products (Mills, 2003; Okereke, 2007; O'Neill Packard and Reinhardt, 2000; Schultz and Williamson, 2005).

*Climate change and the wine industry*

Wine production is an industry very sensitive to climatic changes; for example, as little as a one degree Celsius increase in average temperature can dramatically affect which varieties can best be ripened where (Keller, 2010). Representative of these temperature effects, a major global study has found that in the world's top wine-producing regions, temperatures have risen in the last 55 years by an average of 1.26°C, and are expected to rise by an average of 2.04°C by 2050 (Jones *et al.*, 2005). Hence, any temperature increases above current levels may lead to temperature ranges that are higher than those within which wine grapes can be successfully grown (Jones *et al.*, 2005), potentially shifting wine-growing regions to new locations as an adaptive strategy.

Alternatively, increases in temperatures around the globe (in addition to other changing climatic events) are predicted to decrease the viability of existing wine regions (Hannah *et al.*, 2013). For example, according to a recent study in the *Proceedings of the National Academy of Science* (Hannah *et al.*, 2013), due to rising temperatures, in Bordeaux (France) and Tuscany

(Italy), a drop in wine production of 85 percent is possible by 2050; in California the figure is 70 percent; in South Africa the figure is 55 percent; and in Chile the figure is 40 percent. Further, increases in heat waves, more extreme heat days, and less annual rainfall are already negatively affecting wine-producing regions (Sivasailam, 2012; Webb *et al.*, 2007, 2010, 2012).

*Research questions*

Confirming the IPCC (2007), recent reports suggest that temperatures in Australia (the setting of this study) are increasing: the annual mean temperature is rising above the 1961–1990 average, and the monthly temperature anomaly for the grape-ripening month of April is a record 2.58°C higher than the long-term average (Webb *et al.*, 2007). The effects are clear: the wine industry in Australia is experiencing earlier harvests, reduced yields, and grape quality degradation due to higher temperatures and severe heat events in the south-east (Fenner, 2009; Malkin, 2009; Wahlquist, 2009; Webb *et al.*, 2011; Webb *et al.*, 2012). Alternatively, the south-western wine region of Australia has experienced decreases in annual rainfall since the 1950s, affecting the availability of water for wine production (Steffen *et al.*, 2013; Timbal *et al.*, 2006).

What might be the future impact of climate change for Australian wine production? Over the next 20–30 years, increasing temperatures could potentially shift the viable wine-producing regions further south, to areas such as Tasmania or the most south-western parts of Western Australian. The season duration (time from budburst to harvest) for most Australian wine-producing regions is expected to shorten (Webb *et al.*, 2007). Further, due to predicted warmer winters and warmer night temperatures, pest and disease pressure is likely to increase and also shift to new areas further south in Australia. This is supported by international experience (Tate, 2001). Similarly, there is increased risk of *phylloxera* spread based on the increased rate of emergence of the insect as a result of the warming of the soil, making the spread of the insect more probable. These effects will have obvious impacts on vineyard management strategies and winery infrastructure. In short, continuing temperature increases, along with other climatic changes (e.g., less rainfall, higher humidity, more extreme heat days), could have significant impacts on the Australian wine industry, to the point that by the middle of the century many regions are predicted to be too hot and arid to support large areas of vine (Hannah *et al.*, 2013). Hence, calls have been made for wine producers to innovate in response to climate change (Galbreath, 2011).

According to Galbreath (2011), , wine producers main responses to climate change can be: 1) *mitigative-based* innovation: designed to curtail and reverse climate change effects through the reduction of greenhouse gas emissions or through carbon sinks; and 2) *adaptive-based* innovation: to adjust to the adverse consequences of climate change or take advantage of opportunities that it may present. Wine producers that innovate around their production practices, to include mitigative and adaptive-based innovations, are best positioned to respond to climate change (Galbreath, 2011). However, given that climate change-related innovations are relatively new the expectation is that not all wine firms will have implemented them equally (cf. Zuindeau, 2006). Therefore, the first research question:

> *Research Question 1:* Is there evidence of differences in the extent to which wine-producing regions in Australia are innovating to both mitigate and adapt to climate change?

The second research question aims to investigate the factors that might explain differences in the rates at which climate change innovations are being implemented in regional wine production. While the evidence suggests the major wine-producing regions in Australia have increasingly experienced the effects of climate change (Fenner, 2009; Malkin, 2009; Wahlquist, 2009; Webb *et al.*, 2011; Webb *et al.*, 2012), the nature and types of such effects have varied. As noted, in southeastern regions (e.g., South Australia, Victoria) severe heat events have occured, while in southwestern Australia (i.e., Western Australia) rising temperatures and less annual rainfall have taken place. However, not all individual wine producers in Australia are equally concerned about climate change nor do they appear to be responding in equal measure (Galbreath, 2012, 2014). While there are potentially many factors that could explain such differences, this study concentrates on two key ones. First, evolutionary and resource-based theories argue that innovation results from factors *within* firms (Barney, 1991; Nelson and Winter, 1982). Such theories view firms as consisting of a bundle of resources and assets, and capabilities and competencies that put resources and assets to productive use through unique combinations (Barney, 1991; Galbreath, 2005; Teece *et al.*, 1997). More specifically, micro-level theories argue that innovation is largely driven by a firm's capability to absorb and harness new knowledge (Cohen and Levinthal, 1990). Without such a capability, firms are unable able to learn, exploit knowledge for their advantage, or innovate.

Second, following neo-Marshallian theorists and economic geographers, innovation is largely thought to be determined on an endogenous basis, mainly through localised knowledge spillovers (Feldman, 1994; Jaffe *et al.*, 1993; Malmberg and Maskell, 2002; Martin and Sunley, 1998). Therefore, where knowledge spillovers are weak, the capacity of firms within a particular region to innovate is undermined. For example, there is evidence to suggest that not all firms within a region share knowledge or cooperate with other firms in addressing problems that are relevant or common to the region's competitiveness or survival (Hassink and Wood, 1998; Huber, 2012; Staber, 2010). Hence:

> *Research Question 2:* Are there micro (firm) and meso (regional) factors that might explain any differences in the uptake of climate change innovations in Australian wine regions?

# EMPIRICAL STUDY

*Setting*

The focus of this study is on the Australian wine industry. Established in the eighteenth century, for well over a century the Australian wine industry was considered a sleepy, cottage-style New World enterprise, predominantly focused on domestic markets. Today, however, the Australian wine industry has become an important contributor to national economy, while having achieved success on the global stage. Australia is now one of the largest producers of wine in the world (it is the fourth largest exporter), generating over AUD$8 billion in overall sales (both grape growing and wine production) (Connell, 2012; Sivasailam, 2012). Further, for a good part of its history, Australian wine production consisted largely, although not exclusively, of sweet and fortified wines. However, this has shifted in the last 20 to 30 years, as Australia has rapidly become a world leader in both the quantity and quality of wines it produces (Smith and Marsh, 2007), including the world famous Penfolds Grange, which retails for more than AUD$500 a bottle.

*Sample and data collection*

Although the definition of a region is not clear-cut (McManus, 2008), within Australia, wine production is generally defined by geographical boundaries. More specifically, wine production is spatially defined and bounded by *State* (or Territory).[1] Hence, in the context of this study, 'regions' are defined by the State in which wine is produced, while within these regions, there are

[1] Territories include the Australian Capital Territory and the Northern Territory. However, the wine production output of these two Territories is extremely small and insignificant relative to other regions and to this study.

distinctive sub-regions (see the *knowledge exchange* variable below). For three key reasons, the regions of South Australia and Western Australia were chosen.

First, South Australia produces the most wine of any region in the country, accounting for nearly 50 percent of total production. While much smaller in terms of overall production (around 5 percent of the national total), Western Australia accounts for around 10–15 percent of wine value, mainly due to its focus on premium and ultra-premium wine. Second, South Australia is dominated by red wine grape varieties (70 percent of total production), while in Western Australia there is a balance between red and white wine grape varieties of 50 percent each (Mathews, 2011), thus providing some balance in the grape varieties grown by the wineries being studied. Third, according to scientists, both regions have experienced the effects of climate change and each region is predicted to continue to face climatic challenges in the future (Fenner, 2009; Malkin, 2009; Steffen *et al.*, 2013; Timbal *et al.*, 2006; Wahlquist, 2009; Webb *et al.*, 2011; Webb *et al.*, 2012). Hence, the wine-producing regions of South Australia and Western Australia offer both similarities and differences, and are well suited to comparative analysis.

For the study, a purpose-designed survey was constructed, and two different versions for each region were used in order to capture specific sub-region knowledge exchanges (see *knowledge exchange* variable below).[2] The survey was mailed to the managing director of the firm. Following survey convention, several techniques were used to increase response rates and reduce method biases: 1) the survey was first pilot studied with a sample of 38 wine firms not participating in the comparative study and a few suggestions were made to increase content

[2] The only difference between the two versions related to the questions about knowledge exchanges, to account for the context-specific nature of the sub-regions under study (see Appendix).

validity; 2) a cover letter guaranteed anonymity to moderate respondents making socially desirable responses; 3) the cover letter stressed the importance of the research and that hundreds of the respondents' colleagues had participated in the university's previous studies in the wine industry; 4) careful attention was devoted to the wording of questions in order to avoid vague concepts, reduce items' ambiguity, and avoid any implied preferred response in the statements; 5) the study was sponsored by a local wine industry association; and 6) respondents were offered a reward for survey completion in the form of a copy of the results and a $500 cash prize draw.

Drawing company and respondent names from the Winetitles database in 2012 (Winetitles, 2012), the survey was mailed to all 666 South Australia wine firms listed in the database and all 389 Western Australia wine firms. Out of the 666 firms surveyed in South Australia, after accounting for undeliverables and eliminating those responses missing large amounts of data, 203 were useable resulting in an effective response rate of 34 percent. Out of the 389 wine firms surveyed in Western Australia, after accounting for undeliverables and eliminating those missing large amounts of data, 108 were useable resulting in an effective response rate of 30 percent. These results are well above the response rates of most wine industry studies (Atkin *et al.*, 2012).

*Variables*

*Innovation: mitigative and adaptive actions.* In general, innovation consists of adopting or changing technologies, processes, specifications, or inputs to solve problems (Van de Ven, 1986). Van de Ven (1986, p. 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 broadly defined and 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 and Macy, 2001). In this study, it is acknowledged that the emerging effects of climate change are likely to require wine producers to innovate to both mitigate, and adapt to, its effects. The use of mitigative and adaptive innovations is appropriate because these entail new and/or improved ways of responding to the risks and opportunities from the natural environment (Galbreath, 2011).

Following formative construct convention (Bollen and Lennox, 1991), for measurement, an extensive literature review was undertaken to create an index of the most widely discussed actions for both mitigative and adaptive innovations. This index was compiled and discussed with academic and scientific experts in the areas 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 represented mitigative and adaptive innovations (see 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 applicable to 7 = implemented (see Appendix). To assess these formative indicators, regression analysis revealed that significant collinearity was not present between the actions in the mitigative innovations index (highest VIF of 1.66) or for the actions in the adaptive innovations index (highest VIF of 1.78), providing *prima facia* evidence that formative indicators were suitable (Diamantopoulus and Winklhofer, 2001).

*Micro- and meso-level variables*

To capture micro- and meso-level features of regional clusters, this study relies on two key variables. First, following resource-based theories of the firm, absorptive capacity is measured to capture firm-level capabilities and, second, following the economic geography and regional studies literatures, knowledge exchange in the region is measured.

*Micro-level (firm): Absorptive capacity.* There is no universally agreed upon measure of absorptive capacity. However, following the seminal article of Cohen and Levinthal (1990), many researchers have used research and development (R&D) investment as a proxy of absorptive capacity. According to Godfrey and Hill (1995), using R&D as a simple proxy is problematic, as absorptive capacity is a complex capability of the firm and one that requires a more comprehensive measure. To create a more comprehensive measure, a scale was adapted from the study of Delmas *et al.* (2011), whose study served as an appropriate benchmark because of its focus on absorptive capacity as a multi-item construct, and because the authors examined the relationship between absorptive capacity and environmental strategies. Respondents were asked to assess 10 items on a seven-point Likert scale, ranging from 1 = strongly disagree to 7 = strongly agree (see Appendix). After item refinement (see Appendix), confirmatory factor analysis (CFA) indicated a good fit (CFI = 0.93; RMSEA = 0.059), and the loads for all the remaining items were significant ($p < .001$). The Cronbach alpha is 0.77, demonstrating sufficient reliability.

*Meso-level (region): Knowledge exchange.* Knowledge exchanges are flows of knowledge between firms in a regional cluster. In this study, knowledge exchange takes on two forms. First, emerging literature on wine production suggests an increasing emphasis on 'sub-regions' (Cross *et al.*, 2011; Costley, 2012; Schmitt, 2013). A sub-region is a unique, smaller-scale spatial location within a larger designated wine-producing region (e.g., the sub-region Napa Valley within the regional production centre of California) that has taken on its own identity, geographic boundary, and even brand name (cf. McManus, 2008). This finer spatial focus is important as clear distinctions of 'place' appear to be emerging in the Australian wine industry—which are increasingly captured in sub-region locations—and these distinctions could affect the extent to which knowledge about climate change is exchanged within a region (Costley, 2012; Schmitt, 2013).

To capture knowledge exchange about climate change among sub-regions, respondents were asked to consider the climate change issue and the extent to which they had exchanged any of their knowledge about climate change with firms in other sub-regions in the State (see Appendix). A four-point Likert scale was used to register responses, which ranged from ‘no knowledge exchange’ (1 on the Likert scale) to ‘very high knowledge exchange’ about climate change (4 on the Likert scale). Following Galbreath *et al.* (2013), any level of knowledge exchange was coded 1, 0 otherwise.

Second, according to Mattes (2012) and Sammarra and Biggiero (2008), knowledge exchange can take on many forms. That is, while ‘technical’ knowledge is described most in the literature, knowledge should not be treated as a homogeneous concept nor does it simply include substantive technical knowledge (Mattes, 2012); rather, it includes a variety of knowledge types (Sammarra and Biggiero, 2008). Hence, to measure this second aspect of knowledge exchange, a categorization of knowledge types based on a literature review was developed. Literatures from various disciplines (e.g., international business, marketing, innovation) were consulted. The types of knowledge identified were technical, industry, market, organizational, marketing, and strategy knowledge, each of which has been used in previous research (e.g. Boschma and Ter Wal, 2007; Kesidou *et al.*, 2009; Sammarra and Biggiero, 2008). Next, each knowledge type was contextualized to the issue of climate change (see Appendix). For measurement, the respondents were asked to consider knowledge exchanges about climate change identified in the previous question (see above), by identifying the knowledge *type* exchanged, which was represented on a four-point Likert scale that ranged from ‘no exchange’ (1 on the Likert scale) to ‘very high exchange’ (4 on the Likert scale). To assess if convergent validity was present, CFA indicated a good fit to the data (CFI = 0.95; RMSEA = 0.064). Reliability is sufficient with a Cronbach alpha of 0.89.

*Additional variables*

Due to the nature of the wine industry, additional micro (firm) and meso (regional) variables need to be investigated. Aylward (2004) suggests that exporters and larger firms in the wine industry tend to demonstrate higher levels of innovation. Hence, an export orientation variable (firm-level) was measured for each firm, where 1 = do not export; 2 = 1–25 percent; 3 = 26–50 percent; 4 = 51–75 percent; and 5 = 76–100 percent. To capture another important micro-level (firm) variable, size was used, firms being coded according to the number of cases produced, where 1 = 1–2,499 cases; 2 = 2,500–19,999 cases; 3 = 20,000–99,999 cases; 4 = 100,000–1,499,999 cases; and 5 = over 1,500,000 cases. Both of these variables were collected from the Winetitles database (Winetitles, 2012).

Lastly, and importantly, this study also considers the climatic conditions in the two regions. To consider this meso-level (regional) factor, an index was created that accounted for changes in both temperature and rainfall, each of which is critical to wine production (Jones and Alves, 2012; Ashenfelter and Storchman, 2014). To calculate temperature changes, each sub-cluster within each region was examined to assess data availability. After factoring in all 15 sub-clusters across the two regions, the most complete data set was from the 1965 to 2012 period (the end of 2012 was when the survey was conducted, well after the harvest for Australian wine production). Given that a minimum baseline timeframe for examining climatic changes has been recommended as 30 years by the World Meteorological Organisation, the 1965–2012 (47 years) timeframe is adequate. Temperature and rainfall data for each sub-cluster within each region were collected from the Australian Bureau of Meteorology website (www.bom.gov.au) and, to calculate a score for temperature and rainfall for these sub-clusters, the annual mean for 1965 was subtracted from the annual mean for 2012. The same was done for rainfall. To calculate a score for temperature and rainfall, the annual mean for 1965 was subtracted from the annual mean for

2012 for each sub-cluster in each region. An overall mean change (which accounted for all sub-cluster calculations) was then taken for both regions for comparative purposes.

## RESULTS OF THE EMPIRICAL STUDY

Demographic statistics are presented in Table 1. As can be seen, firms in South Australia are older, generally larger, and tend to be bigger exporters. As for sub-clusters, South Australia is classified with six distinct sub-clusters within the region. Western Australia is classified with nine distinct sub-clusters within the region.

[insert Table 1 here]

*Univariate tests*

Given the importance of climate to wine production (Hannah *et al.*, 2013), any differences between the climatic variables in the regions were tested first. Results of the climatic variables do suggest differences (Table 2). Using *t*-tests, Western Australia demonstrates significantly higher temperature increases ($t$ = 5.628, $p$ = 0.000) than South Australia as well as significantly less rainfall ($t$ = 7.175, $p$ = 0.000). This suggests that, purely from a climatic perspective, wine firms in the region of Western Australia are likely to have a somewhat higher level of motivation to implement climate change innovations in order to both mitigate and to adjust to these changing climatic conditions. This is particularly the case given that very small changes in average temperature can significantly affect wine grape yields, wine quality and, ultimately, economic sustainability (Keller, 2010).

[insert Table 2 here]

Next, to examine the extent to which there are differences in climate change innovations, chi-square tests were used to compare South Australian to Western Australian firms. For this test, only those firms that indicated that they were active implementers (‘6’ and ‘7’ on the Likert scale) of climate change innovations were included. The results suggest that with the exception of two actions (alternative packaging and use of energy efficient technology in buildings), South Australian firms appear to be implementing mitigative actions at a higher rate than Western Australian firms, with all other comparisons statistically significant (Table 3). Similarly, with the exception of two actions (canopy management techniques that address potential increases in temperature and water saving techniques in the vineyard), South Australian firms also appear to be implementing adaptive actions at a higher rate than firms in Western Australia, with all other comparisons statistically significant (Table 3). This is despite the fact that since 1965 South Australia has seen fewer changes in climatic conditions that impact wine production than has Western Australia.

[insert Table 3 here]

Given that there are differences in the implementation rates of climate change innovations, micro- and meso-level factors were explored next, in an attempt provide insight as to why these differences exist. As for absorptive capacity, using a *t*-test to compare South Australian to Western Australian firms revealed no significant difference on each of the individual items ($t = 0.717$, $p = 0.474$). This suggests firms in each region have a similar level of development of their absorptive capacity capabilities. As for size, firms in South Australia appear to be larger than those in Western Australia (by number of cases produced—Table 2), where a *t*-test reveals a significant differences ($t = 2.094$, $p = 0.037$). The results also suggest that South Australian firms export more product than do firms in Western Australia, with a statistically significant difference found ($t = 5.282$, $p = 0.000$), while South Australian firms are also older than those in Western Australia ($t = 2.368$, $p = 0.019$).

[insert Table 4 here]

Lastly, because wine is produced in regional clusters (Galbreath *et al.*, 2013), a macro-level factor was examined; i.e., the extent to which firms in South Australia and Western

Australia exchange knowledge within their given regions (Table 5). First, the results of an examination of the firms within all the sub-clusters in each region (including both exchanges internal to the sub-cluster and those external to the sub-cluster within the region) suggest that South Australian firms are more actively engaging in knowledge exchanges within their region than are firms within the Western Australian region ($t$ = 3.226, $p$ = 0.001). Second, given that knowledge is not unidimensional (Mattes, 2012), exchanges by knowledge type within South Australia and Western Australia were compared. The results suggest that for technical knowledge ($t$ = 2.838, $p$ = 0.005), industry knowledge ($t$ = 2.750, $p$ = 0.006), market knowledge ($t$ = 1.995, $p$ = 0.047), organizational knowledge ($t$ = 3.300, $p$ = 0.001), marketing knowledge ($t$ = 2.841, $p$ = 0.005), and strategy knowledge ($t$ = 2.948, $p$ = 0.004), South Australian firms are more readily exchanging these knowledge types in their region than are their counterparts in Western Australia.

[insert Table 5 here]

*Multivariate tests*

To further explore the second research question, and given that South Australia appears to have higher implementation rates of both mitigative and adaptive innovations and that there are differences in some of the variables of interest between South Australian and Western Australian firms, the next step was to conduct a series of multivariate tests. Of interest was the extent to which the select variables predict mitigative and adaptive innovations. To determine this, the firms from both South Australia and Western Australia were divided into three groups: those that are *not considering* implementation of the actions (‘2’ on the Likert scale), those *assessing* implementation of the actions (‘3’ to ‘5’ on the Likert scale), and those that are *active implementers* (‘6’ and ‘7’ on the Likert scale). Because of space limitations, a mean of both mitigative and adaptive innovations was taken rather than investigating each action individually.

[insert Table 6 here]

MANOVA is appropriate to assess the differences between the group means (‘Not considering’ versus ‘Assessing’ versus ‘Active implementers’), while maintaining control over the error rate and any inter-correlation among the dependent variables (Hair *et al.*, 1998). Tables 6 and 7 present the results. A few noticeable patterns emerge. First, given the impact of climate on wine production, surprisingly, changes in temperature and rainfall do not appear to influence the implementation rates of either mitigative or adaptive innovations. Second, absorptive capacity influences the extent to which South Australian firms implement climate change innovations (mitigative $F = 9.493$, $p = 0.000$; adaptive $F = 16.927$, $p = 0.000$), while in Western Australia firms it appears to have no impact (mitigative $F = 1.475$, $p = 0.235$; adaptive $F = 1.216$, $p = 0.302$). Third, knowledge exchanges impact the implementation rates of both mitigative and adaptive innovations (mitigative $F = 3.912$, $p = 0.022$; adaptive $F = 3.119$, $p = 0.042$) in South Australian firms. For Western Australian firms, knowledge exchanges impact adaptive innovations only (adaptive $F = 3.465$, $p = 0.036$).

Lastly, the *type* of knowledge exchanged within the region appears to influence implementation rates. With respect to South Australia, for both mitigative and adaptive innovations, exchanges of all knowledge types are significant (see Tables 6 and 7). As for Western Australia, for mitigative innovations, industry, market, marketing, and strategy knowledge are significant; for adaptive innovations, all knowledge types are significant (see Tables 6 and 7). As for the other variables, firms size is significant for South Australian firms (mitigative $F = 4.448$, $p = 0.013$) as is firm age (adaptive $F = 4.574$, $p = 0.012$).

[insert Table 7 here]

## DISCUSSION AND CONCLUSIONS

In light of the predicted impacts of climate change on regional businesses (Winn *et al.*, 2011), this study sought to determine: 1) if there is evidence of firms in different regions innovating to both mitigate and adapt to climate change and 2) which micro (firm) and meso (regional) factors might explain any differences in the uptake of climate change innovations by firms in different regions. To explore these research questions, two wine regions in Australia (South Australia, Western Australia) were studied.

According to Winn *et al.* (2011), climate change will affect different regions differently. This appears to be the case in Western Australia as compared to South Australia. Since 1965, the firms studied in Western Australia have experienced yearly temperature increases of nearly 2°C, along with close to 250 mm less annual rainfall, compared to an increase of 0.2°C in yearly temperature and 213 mm more annual rainfall in the firms under study in South Australia over the equivalent time period. Based on the work of Hannah *et al.* (2013) and Keller (2010), this level of temperature increase and such reduced rainfall create problems for the production of quality wine and, ultimately, if the pattern continues, these can lead to unsustainable production (note that even too *much* rainfall can be problematic to wine health, which suggests that South Australia is not immune to the effects of increases in rainfall levels since 1965). Yet, neither climate variables appear to have had an effect on the implementation rates of mitigative and adaptive innovations in Western Australia, nor in South Australia.

One explanation for the above findings could relate to the temporal orientation of climate change (Slawinski and Bansal, 2012). According to Slawinski and Bansal (2012, p. 1537), 'Time is central to climate change'. For example, experts such as the IPCC (2007) claim that the worst effects of climate change could be over 50 years away. Given climatic changes can be slow-moving and often have long lag times, action on the part of businesses can be hampered (Keith, 2009). With respect to this study, firms in the sample from Western Australia are, on average, just under 22 years old. By contrast, for firms that are much older and have more experience with changing environmental conditions—such as those in South Australia—any perceived changes in climatic conditions could be relatively minimal (cf. Slawinski and Bansal, 2012). In addition, adjustments to changing climates are likely to be slower for perennial crops such as vines, which have a productive lifetime of more than 25 years, full production not being attained until five or six years after planting (Cooper *et al.*, 2012). Alternatively, Galbreath (2014) suggests that some wine producers in Western Australia view climate change as a positive for wine production, and therefore they will engage only in mitigative or adaptive innovations if there is a clear economic benefit—which some suggest is not currently forthcoming.

Exploring more deeply the impact of micro- and macro-level factors revealed several noteworthy patterns. In a departure from traditional cluster theory, Guiliani and Bell (2005) provide evidence that suggests that a firm's absorptive capacities appear to be more important than cluster-level knowledge exchanges in influencing innovation levels of firms within a regional cluster. The present study finds that *both* firm-level absorptive capacity and knowledge exchange within the region independently impact on climate change innovations in South Australia. Alternatively, absorptive capacity appears to play no role for firms in Western Australia, while knowledge exchanges within the region influence adaptive innovations (but not mitigative innovations). Further, in both South Australia and Western Australia, the types of knowledge exchanges within the regions have a significant impact on climate change innovations. While the findings do offer support for traditional cluster theory in that knowledge exchanges (and particularly the type of knowledge exchanged) in the region are important to firms' innovation levels with respect to climate change, the interesting feature here is that despite having similarly developed absorptive capacities as South Australian firms, in Western Australian firms these capacities do not significantly affect climate change innovations.

In perhaps somewhat of a counter-argument to Guiliani and Bell (2005), the differences between South Australia and Western Australia on the role of absorptive capacity raises an interesting issue; namely, the *relative* need of absorptive capacity for innovation (Lane and Lubatkin, 1998). For example, firms in regional wine clusters tend to be small and many operate with limited resources. Wine production is also a craft-based community, in which relational proximity is just as important as geographic proximity (Giuliani, 2007). Relational proximity is expected to develop trust among firms in regional clusters enabling them to cooperate more comprehensively and to engage in shared risk-taking initiatives (cf. Gambetta, 1988; Mayer *et al.*, 1995). Here, as firms innovate in response to a novel domain such as climate change, the expectation is that they will rely on trusted colleagues in the cluster, who have 'been there and done that' (Martinez-del-Rio and Céspedes-Lorente, 2014).

As knowledge is exchanged and a given firm learns about a specific practice or technology that has enabled an adaptive innovation, for example, the firm is more likely to implement in-kind because of its trust in a colleague and in what has worked for her (cf. Boschma, 2005; Mitchell *et al.*, 2010). In this sense, the extent to which any latent absorptive capacity would need to intervene to influence the impact of exchanged knowledge in the cluster on the innovation output of given firm is unclear (Lane and Lubatkin, 1998). In part, this could explain the non-significant effect of absorptive capacity on climate change innovations in Western Australia, along with the significant effect of knowledge exchanges in the region. However, one has to keep in mind that in the case of South Australia, both absorptive capacity *and* knowledge exchanges significantly impact climate change innovations. Given that firms in this region are implementing climate change innovations at a *higher* rate than those in Western

Australia, the importance of the two factors should not be underestimated. It could be, for example, that firms in South Australia, because they are both older and larger have more mature capabilities to combine their absorptive capacities with their engagement in knowledge exchanges with other regional firms, resulting in increased capacities to more readily implement climate change innovations. Firms in South Australia may also have, relative to Western Australian firms, more experience related to innovation practices in general, which could afford them the opportunity to better exploit their absorptive capacities (Hoang and Rothaermel, 2005; Jensen and Szulanski, 2007; Yang *et al.*, 2010).

There is also another notable finding regarding knowledge exchanges within the region. Traditional cluster theory uses terms like ‘knowledge in the air’ to describe knowledge flows within regional clusters. Yet, too often such terms poorly identify the kinds of knowledge exchanged and which of these matter to innovation (Hervas-Oliver and Albors-Garrigos, 2009; Huber, 2012; Ibrahim *et al.*, 2009). Even more in-depth discussions of knowledge exchanges in clusters do not adequately capture, empirically, the types of knowledge that are in fact exchanged (Tallman *et al.*, 2004). As noted by Mattes (2012), knowledge is not unidimensional and takes on many forms. 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. In the present study, not only does the *act* of knowledge exchange appear to impact on the implementation of climate change innovations, but so too do the types of knowledge exchanged, including technical, industry, market, organizational, marketing, and strategy knowledge. This suggests that it is not only the act of exchange (‘knowledge in the air’), but also the types of knowledge that actors are willing to exchange as they interact within regions. Both appear to have an impact, which provides further evidence to scholars who acknowledge the importance of which types of knowledge are used in regional clusters, and how these impact on innovation and competitive advantage (Sammarra and Biggiero, 2008).

In conclusion, this study sought to determine how different regions are responding to the climate change issue through innovation, and whether firm- and/or cluster-level factors explain differences in the implementation rates of climate change innovations across regions. Given the relative newness—if not novelty—of climate change innovations, this is one of the first known studies to explore this aspect of innovation from a regional perspective and is exploratory in nature. Differences between regions are found: the South Australian region of wine production demonstrates firms that are implementing climate change innovations at a greater rate than their counterparts in Western Australia. This is a noteworthy finding given that firms in Western Australia are experiencing higher temperature increases and less rainfall than those in South Australia; therefore, from a wine production perspective, they should be more motivated to implement climate change innovations. Critical differences are also found between the level and type of knowledge exchanges, with firms in the South Australian region demonstrating higher levels of knowledge exchanges than those in the Western Australian region. There is no difference in the absorptive capacity between the two regions.

With respect to which variables predict climate change innovations, for South Australian firms, absorptive capacity and knowledge exchanges (also including the exchange of different knowledge types) are critical, while for Western Australian firms only exchanges of knowledge (including different knowledge types) within the region appear critical. What is not entirely clear is why *both* absorptive capacity and knowledge exchanges predict climate change innovations in South Australia while in Western Australia they do not. A limitation of the study therefore is that any dynamic capabilities or prior related experience that might be necessary to fully exploit absorptive capacities at the firm-level, and knowledge exchanges at the regional level, for innovation purposes were not studied. This is an area for future research. Another limitation is that only two wine regions were studied—two wine regions in the Southern Hemisphere. However, as argued, there is reasonable contrast between the two therefore making them suitable for study. Future research could consider more than two wine regions, and could investigate regions in the Northern Hemisphere in which climatic conditions vary. Future research could also consider regional clusters other than wine—for example, regional manufacturing clusters—to further explore how firms are innovating in response to climate change. Lastly, this study did not consider normative approaches to climate change, such as stewardship approaches towards the natural environment (Galbreath, 2014), that could influence implementation rates of climate change innovations. As different regions might place a higher moral or ethical priority on a collective response to the natural environment (cf. Etzion and McMahon, 2012; Martinez-del-Rio and Céspedes-Lorente, 2014), this could be a fruitful area of future research.

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# APPENDIX

*Mitigative innovations*[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 (e.g., night-time air cooling, timing of loads).
4. Energy efficient technology in buildings (e.g., variable speed devices, computer-controlled lighting; use of thermal efficient materials).
5. Minimizing the use of agrichemicals (e.g., petiole analysis, optical weed spray controllers).
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 innovations*[a]

1. Sales of hotter climate varieties.
2. Water–saving techniques in the winery (e.g., water treatment and reuse).
3. Canopy management techniques that address potential increases in temperature (e.g., sprawl trellis systems, leaf-canopy shading, inter-row swards).
4. Establishing vineyards in locations predicted to be less vulnerable to climate risks.
5. Application of vineyard orientations that address potential temperature increases (e.g., east—west row orientation, vineyards planted at angles).
6. Water–saving techniques in the vineyard (deficit irrigation techniques, partial root zone drying).
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.

*Absorptive capacity*[a]

1. Our business experiences difficulties in implementing changes required to meet market demands (reverse coded).
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. We regularly interact with other firms in the region to acquire new knowledge.
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.
8. We have difficulty in grasping opportunities for our business from new external knowledge (reverse coded).

9. We constantly consider how to better exploit 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.

*Knowledge exchange**

Please best estimate *how much knowledge* you believe your business has exchanged with other wine businesses in South Australia about the *climate change issue* (note that knowledge exchange can take place through formal or informal conversations, email correspondence, phone calls, site visits, exchanges at educational forums or industry symposia, etc.).

| | No knowledge exchange | Very little knowledge exchange | Moderate knowledge exchange | Very high knowledge exchange |
|---|---|---|---|---|
| With wine businesses in the Barossa Valley | 1 | 2 | 3 | 4 |
| With wine businesses in the Clare Valley | 1 | 2 | 3 | 4 |
| With wine businesses in the Fleurieu Peninsula | 1 | 2 | 3 | 4 |
| With wine businesses in the Riverland | 1 | 2 | 3 | 4 |
| With wine businesses in the Limestone Coast | 1 | 2 | 3 | 4 |
| With wine businesses in the Southern Flinders Ranges | 1 | 2 | 3 | 4 |

*This is the version for South Australia. The Western Australia version of the survey was identical excepting the use of different sub-clusters.

*Knowledge types*

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, how competitors are responding to climate change, impacts of climate change on grape yield, quality, and price.
4. *Organizational knowledge*: how your company has coordinated and supervised organizational 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 related to climate change.

*Export orientation*

Percentage 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.

*Firm size*

The number of cases of wine produced, where 1 = 1–2,499 cases; 2 = 2,500–19,999 cases; 3 = 20,000–99,999 cases; 4 = 100,000–1,499,999 cases; and 5 = over 1,500,000 cases.

*Firm age*

Calculated as the year of founding subtracted from the year 2012.

# TABLES

## Table 1. Demographic statistics

| South Australia demographics (n = 207) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Age of winery | | Firm size | | Export orientation | | Firms by sub-cluster | |
| Mean | s.d. | Cases | (%) | Cases exported | (%) | Sub-cluster | (%) |
| 29.31 | 38.52 | > 1,500,000 | 1.3 | 76-100% | 7.9 | Barossa Valley | 43.2 |
| | | 100,000-1,499,999 | 6.3 | 51-75% | 10.5 | Clare Valley | 12.6 |
| | | 20,000-99,999 | 19.6 | 26-50% | 25.7 | Fleurieu Peninsula | 30.1 |
| | | 2,500-19,999 | 39.9 | 1-25% | 42.1 | Riverland | 2.9 |
| | | > 999-2,499 | 32.9 | Do not export | 13.8 | Limestone Coast | 9.7 |
| | | Total | 100 | | 100 | Southern Flinders Ranges | 1.4 |
| | | | | | | | 100 |

| Western Australia demographics (n = 108) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Age of winery | | Firm size | | Export orientation | | Firms by sub-cluster | |
| Mean | s.d. | Cases | (%) | Cases exported | (%) | Sub-cluster | (%) |
| 21.46 | 15.94 | > 1,500,000 | 0.0 | 76-100% | 2.6 | Blackwood Valley | 6.5 |
| | | 100,000-1,499,999 | 1.2 | 51-75% | 1.3 | Geographe | 13.9 |
| | | 20,000-99,999 | 12.3 | 26-50% | 15.8 | Great Southern | 13.0 |
| | | 2,500-19,999 | 50.6 | 1-25% | 39.5 | Manjimup | 0.9 |
| | | > 999-2,499 | 35.8 | Do not export | 40.8 | Margaret River | 40.7 |
| | | Total | 100 | | 100 | Peel | 1.9 |
| | | | | | | Pemberton | 6.5 |
| | | | | | | Perth Hills | 2.8 |
| | | | | | | Swan Valley | 13.9 |
| | | | | | | | 100 |

Table 2. Additional variables of interest

| | Differences in additional variables of interest | | | |
|---|---|---|---|---|
| | South Australia | Western Australia | *t* -test | significance |
| Temperature change (1965-2012) | +0.2°C | +1.77°C | 8.783 | 0.000* |
| Rainfall change (1965-2012) | +212.53mm | -247.41mm | 7.175 | 0.000* |
| Export orientation | 2.61 | 1.87 | 5.282 | 0.000* |
| Firm size | 2.11 | 1.89 | 2.094 | 0.037* |
| Firm age (in years) | 29.31 | 21.46 | 2.368 | 0.019* |

Note: Means provided for all variables

* Statistically significant

Table 3. Differences in climate change innovations uptake (by % uptake) between regions

| | Mitigative innovations implementation (%) | | | |
|---|---|---|---|---|
| Action | South Australia (%) | Western Australia (%) | $\chi^2$ | significance |
| Alternative energy sources | 58.5 | 42.9 | 9.66 | 0.002* |
| Alternative packaging | 45.3 | 57.6 | 22.72 | 0.000* |
| Reduction of refrigeration loads | 86.3 | 81.4 | 14.44 | 0.000* |
| Energy efficient technology in bulidings | 85.1 | 87.1 | 10.90 | 0.001* |
| Minimizing use of agrichemicals | 93.4 | 85.7 | 7.22 | 0.007* |
| Alternative fuel use | 15.2 | 10.3 | 25.56 | 0.000* |
| Use of carbon sinks/sequestering | 80.0 | 75.6 | 13.13 | 0.000* |

* Statistically significant

| | Adaptive innovations implementation (%) | | | |
|---|---|---|---|---|
| Action | South Australia (%) | Western Australia (%) | $\chi^2$ | significance |
| Sales of hotter climate varieties | 46.2 | 39.3 | 7.14 | 0.008* |
| Water saving techniques in the winery | 90.9 | 74.1 | 8.43 | 0.004* |
| Canopy management techniques | 88.9 | 90.2 | 11.77 | 0.001* |
| New vineyard locations | 47.3 | 35.3 | 12.25 | 0.000* |
| Vineyard orientations | 60.4 | 55.2 | 22.90 | 0.000* |
| Water saving techniques in the vineyard | 93.5 | 88.9 | 2.00 | 0.157 |
| Growing new grape varieties | 60.2 | 52.2 | 14.38 | 0.000* |

* Statistically significant

Table 4. Differences in absorptive capacity (micro-level)

| Item | Absorptive capacity by mean (s.d.) | | | |
|---|---|---|---|---|
| | South Australia | Western Australia | *t* -test | significance |
| 1. Our business experiences difficulties in implementing changes required to meet market demands (reverse coded). | 3.61 (1.73) | 3.89 (1.67) | 1.352 | 0.177 |
| 2. Our business quickly recognizes the usefulness of new external knowledge to existing knowledge. | 5.20 (1.45) | 5.39 (1.44) | 1.126 | 0.261 |
| 3. Our business regularly reconsiders technologies and adapts them accordant to new knowledge. | 5.11 (1.47) | 4.96 (1.55) | 0.842 | 0.400 |
| 5. We regularly interact with other firms in the region to acquire new knowledge. | 5.56 (1.38) | 5.42 (1.39) | 0.840 | 0.401 |
| 6. Newly acquired knowledge is documented and stored for future reference. | 4.82 (1.60) | 4.96 (1.38) | 0.730 | 0.446 |
| 7. Our business regularly considers the impact of changing market demands in terms of new products and/or modifications of existing ones. | 5.37 (1.54) | 5.19 (1.54) | 0.971 | 0.332 |
| 8. We have difficulty in grasping opportunities for our business from new external knowledge (reverse coded). | 3.32 (1.65) | 3.52 (1.64) | 1.049 | 0.295 |
| 9. We constantly consider how to better exploit knowledge. | 5.27 (1.28) | 5.14 (1.40) | 0.811 | 0.418 |
| *Overall absorptive capacity construct* | 4.98 (1.01) | 4.89 (1.02) | 0.717 | 0.474 |

Table 5. Differences in knowledge exchanges between regions (meso-level)

| | Overall knowledge exchanges by mean (s.d.)[a] | | | |
|---|---|---|---|---|
| | South Australia | Western Australia | *t* -test | significance |
| Exchanges across all sub-clusters | 0.29 (0.04) | 0.19 (0.37) | 3.226 | 0.001* |

[a] Where any level of exchange equals 1, 0 otherwise

* Statistically significant

| | Type of knowledge exchange by mean (s.d.)[a] | | | |
|---|---|---|---|---|
| Type | South Australia | Western Australia | *t* -test | significance |
| Technical | 2.26 (0.86) | 1.97 (0.87) | 2.838 | 0.005* |
| Industry | 2.23 (0.89) | 1.94 (0.86) | 2.750 | 0.006* |
| Market | 1.98 (0.82) | 1.78 (0.87) | 1.995 | 0.047* |
| Organizational | 2.19 (0.99) | 1.83 (0.89) | 3.300 | 0.001* |
| Marketing | 2.05 (0.93) | 1.75 (0.86) | 2.841 | 0.005* |
| Strategy | 2.17 (0.95) | 1.86 (0.85) | 2.948 | 0.004* |

[a] On a four-point Likert scale

* Statistically significant

Table 6. MANOVA results for mitigative innovations (dependent variable)

| | South Australia group differences: Mitigative innovations (dependent variable) | | | | |
|---|---|---|---|---|---|
| Independent variables | Not considering (n = 13) | Assessing (n = 69) | Active implementers (n = 63) | *F* | Sig. |
| Δ Temperature (1965-2012) | 0.36 | 0.38 | 0.40 | 0.275 | 0.760 |
| Δ Rainfall (1965-2012) | 237.29 | 214.16 | 218.02 | 1.931 | 0.149 |
| Absorptive capacity | 3.93 | 4.81 | 5.23 | 9.493 | 0.000* |
| Firm size | 1.92 | 1.90 | 2.37 | 4.448 | 0.013* |
| Export orientation | 2.69 | 2.43 | 2.70 | 1.012 | 0.366 |
| Firm age | 20.23 | 22.23 | 34.27 | 2.231 | 0.111 |
| Knowledge exchanges | 0.16 | 0.29 | 0.39 | 3.912 | 0.022* |
| Technical knowledge | 1.77 | 2.06 | 2.52 | 8.280 | 0.000* |
| Industry knowledge | 1.77 | 1.96 | 2.48 | 8.160 | 0.000* |
| Market knowledge | 1.46 | 1.81 | 2.27 | 9.060 | 0.000* |
| Organizational knowledge | 1.62 | 1.84 | 2.54 | 12.777 | 0.000* |
| Marketing knowledge | 1.38 | 1.81 | 2.32 | 8.750 | 0.000* |
| Strategy knowledge | 1.31 | 1.91 | 2.54 | 15.755 | 0.000* |

Note: Means provided for all variables
* Statistically significant

| | Western Australia group differences: Mitigative innovations (dependent variable) | | | | |
|---|---|---|---|---|---|
| Independent variables | Not considering (n = 8) | Assessing (n = 36) | Active implementers (n = 36) | *F* | Sig. |
| Δ Temperature (1965-2012) | 1.52 | 1.57 | 1.57 | 0.022 | 0.978 |
| Δ Rainfall (1965-2012) | -188.62 | -215.75 | -263.40 | 1.512 | 0.227 |
| Absorptive capacity | 4.69 | 4.78 | 5.15 | 1.475 | 0.235 |
| Firm size | 1.38 | 1.92 | 1.94 | 2.125 | 0.126 |
| Export orientation | 1.75 | 1.81 | 1.94 | 0.290 | 0.749 |
| Firm age | 18.25 | 20.33 | 20.47 | 0.106 | 0.900 |
| Knowledge exchanges | 0.13 | 0.22 | 0.25 | 0.720 | 0.490 |
| Technical knowledge | 1.63 | 2.00 | 2.19 | 1.585 | 0.211 |
| Industry knowledge | 1.63 | 1.94 | 2.28 | 2.501 | 0.089* |
| Market knowledge | 1.13 | 1.64 | 2.28 | 9.821 | 0.000* |
| Organizational knowledge | 1.75 | 1.83 | 2.03 | 0.522 | 0.595 |
| Marketing knowledge | 1.38 | 1.72 | 2.08 | 2.897 | 0.061* |
| Strategy knowledge | 1.50 | 1.69 | 2.17 | 3.769 | 0.027* |

Note: Means provided for all variables
* Statistically significant

Table 7. MANOVA results for adaptive innovations (dependent variable)

| | South Australia group differences: Adaptive innovations (dependent variable) | | | | |
|---|---|---|---|---|---|
| Independent variables | Not considering (n = 21) | Assessing (n = 57) | Active implementers (n = 67) | *F* | Sig. |
| Δ Temperature (1965-2012) | 0.37 | 0.36 | 0.42 | 2.042 | 0.134 |
| Δ Rainfall (1965-2012) | 211.73 | 216.35 | 221.18 | 0.535 | 0.587 |
| Absorptive capacity | 3.95 | 4.78 | 5.32 | 16.927 | 0.000* |
| Firm size | 2.05 | 1.95 | 2.25 | 1.666 | 0.193 |
| Export orientation | 2.90 | 2.37 | 2.64 | 2.064 | 0.131 |
| Firm age | 17.00 | 20.16 | 36.57 | 4.574 | 0.012* |
| Knowledge exchanges | 0.24 | 0.28 | 0.39 | 3.119 | 0.042* |
| Technical knowledge | 1.86 | 1.96 | 2.58 | 13.058 | 0.000* |
| Industry knowledge | 1.76 | 1.96 | 2.46 | 8.567 | 0.000* |
| Market knowledge | 1.67 | 1.77 | 2.25 | 7.940 | 0.001* |
| Organizational knowledge | 1.81 | 1.84 | 2.46 | 8.787 | 0.000* |
| Marketing knowledge | 1.67 | 1.70 | 2.34 | 9.897 | 0.000* |
| Strategy knowledge | 1.62 | 1.72 | 2.64 | 25.232 | 0.000* |

Note: Means provided for all variables
* Statistically significant

| | Western Australia group differences: Adaptive innovations (dependent variable) | | | | |
|---|---|---|---|---|---|
| Independent variables | Not considering (n = 10) | Assessing (n = 40) | Active implementers (n = 30) | *F* | Sig. |
| Δ Temperature (1965-2012) | 1.59 | 1.52 | 1.62 | 0.219 | 0.804 |
| Δ Rainfall (1965-2012) | -194.67 | -248.58 | -228.96 | 0.613 | 0.544 |
| Absorptive capacity | 4.73 | 4.83 | 5.16 | 1.216 | 0.302 |
| Firm size | 1.70 | 1.80 | 2.03 | 1.192 | 0.309 |
| Export orientation | 1.70 | 1.98 | 1.77 | 0.666 | 0.517 |
| Firm age | 15.40 | 21.63 | 19.87 | 1.011 | 0.369 |
| Knowledge exchanges | 0.04 | 0.24 | 0.26 | 3.465 | 0.036* |
| Technical knowledge | 1.40 | 1.97 | 2.28 | 4.843 | 0.010* |
| Industry knowledge | 1.20 | 2.07 | 2.28 | 6.920 | 0.002* |
| Market knowledge | 1.20 | 1.90 | 2.07 | 3.974 | 0.023* |
| Organizational knowledge | 1.30 | 1.93 | 2.10 | 2.914 | 0.060* |
| Marketing knowledge | 1.30 | 1.88 | 2.00 | 2.453 | 0.093* |
| Strategy knowledge | 1.30 | 1.88 | 2.10 | 3.358 | 0.040* |

Note: Means provided for all variables
* Statistically significant