

Full length Article

Wineries and wine quality: The influence of location and archetype in the Hunter Valley region in Australia

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Abstract

Geographical concentrations of wineries often occur within a region for obvious reasons of *terroir*. However, localised spatial concentrations of wineries may exist because of other factors. This paper explores whether co-location exists among wineries that have higher wine ratings in the Hunter Valley wine region in New South Wales, Australia. Key conclusions are that clustering of Hunter Valley wineries producing high-quality wines does not exist, the quality rating of a winery is influenced by its *terroir*, and wine quality among wineries in the region is higher for those producing the territorial brand wine of Semillon. Blending was found to have no impact on the quality of wine produced by a winery. © 2019 UniCeSV University of Florence. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Keywords: Wine quality; Archetypes; Wine cluster; Hunter Valley Australia

1. Introduction

Wine is a product for which reputation of quality and its impact on output price can influence business profitability. Evidence from analyses of the relationship between the reputation and ratings of wines and their price in Australia generally support this contention (Ling and Lockshin, 2003; Schamel and Anderson, 2003; Wood and Anderson, 2006; Fogarty, 2008).

Wineries are often located in close proximity to each other. Obvious reasons include geographic features and climate, or the *terroir* of a region. However, other factors

may also be important determinants of geographical concentrations of wineries because of the spatial dependencies or ‘spillover’ effects arising from cluster-specific resources and activities.

A cluster of wineries can be specified with or without regard for the quality of wines produced but our interest is in the alternative paths by which wineries in Australia can achieve a reputation for producing high quality wines. In the next section, we consider different viewpoints on achieving wine quality. Two wine quality archetypes are presented to represent alternative paths that wineries may follow. We then describe the attributes of these archetypes by focussing on major wine-producing areas in France and Australia. In section 3, we discuss factors that determine the extent to which wineries with a high-quality rating cluster in a major wine-producing area in Australia. The study area and analytical method are outlined in the fourth and fifth sections. Results are presented in section 6 together with tests of propositions developed in the second section. The paper is completed with a discussion of results and the main points to take from the findings.

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2. Viewpoints on wine quality

2.1. Wine quality archetypes

Two archetypes can be identified that represent poles of behavioural patterns in achieving high quality in wine production: location-based and science- and marketing-based. The former is associated with the so-called ‘Old World’ producers while the latter is associated with the so-called ‘New World’ producers.

2.1.1. Location-based archetype

For the location-based archetype, wine quality is dictated by *terroir* defined as ‘a group of vineyards (or even vines) from the same region, belonging to a specific appellation, and sharing the same type of soil, weather conditions, grapes and wine making savoir-faire, which contribute to give its specific personality to the wine’ (Terroir France, 2014). There remains a belief among some wine-producing regions that the best wines can only be produced in particular areas with favourable physiological attributes, and that knowledge of growing grapes and making wines derives from an intimate understanding of the interaction of these attributes that has been formed over a long period.

Nowhere is this Old World archetype belief stronger than in the European wine industry, for example France, Italy and Spain, where the ability to describe the quality of a wine remains tightly circumscribed. Wines of the highest quality are categorised as *Appellations d’Origine Contrôlée* (AoC) under the European categorisation of *Appellation d’Origine Protégée* (AOP) (Protected Designation of Origin (PDO)). Within this category, the highest quality wines are designated *Grand Cru* and other wines are *Premier Cru* (Wine Searcher, 2018). *Vin de Pays* (VdP) is now the only other category as the previously second highest category, *Vin D’origine Contrôlée Supérieure* (VDQS), and *Vin de Table* (VdT) were removed from the classification in 2011 (Wine Searcher, 2018). The exalted position of AOP wines exemplifies this spatial approach to classifying wine according to its quality. The appellation system has been in place since 1935 although the importance of the concept of *terroir* has been recognised for centuries. It is monitored and controlled by the *Institut National des Appellations d’Origine* (INAO, 2009).

Exploitation of the territorial brand is closely linked to the *terroir*-based archetype where *terroir* can be decomposed into three broad characteristics: climate, soil and vine (rootstock and cultivar) (Van Leeuwen et al., 2004). However, *terroir* is more than just the physiological characteristics of an area, including ‘winemaking based on vintners’ observations of why wines from different regions and vineyards are so different from one another in style and personality’ (Vins de Provence, 2015). It encompasses what Caple and Thyne (2014) termed ‘the cultural interposition of man concerning tradition, environmental orientation, and information and social exchange within wine regions in enhancing *terroir*’. The best wines are produced from wine grapes that represent the territorial brand, which is ‘associated with products that are bound up with the place in which they are made,

for environmental reasons, and which therefore cannot be reproduced elsewhere’ (Charters et al., 2011).

2.1.2. Science and marketing-based archetype

In respect of the science- and marketing-based archetype, the polar view is that high-quality wine can be produced anywhere in a wine region using scientific methods in viticulture and winemaking. The Australian wine industry has played a major role among New World wine producers since the 1980s in applying scientific method to ‘free’ wineries from having to produce and source wine grapes within a narrow band of locations while still being able to produce wines that are perceived by consumers to be of high quality. This polar archetype is not practised in its pure form in that wineries can exercise discretion in choosing where to locate in a wine region and from where they source wine grapes; but their choice is not subject to spatial restrictions on the quality of wine produced or maximum allowable yields of grapes using in winemaking.

Caple (2011, p. 79) summed up the contrast between the Old World and New World archetypes:

New World and Old World winemakers have different approaches to wine production. The Old World continues to rely on the belief that they create superior wines by adhering to restrictive regulations, therefore consumers will buy them. The New World has taken a more proactive marketing approach and identified how consumers define wine excellence. With this marketing focus, the New World has employed vineyard technology and varietal blending to produce large quantities (in some regions) enabling producers to sell wine at reasonable prices and quality.

A recently initiated project funded by Wine Australia (2016) exemplifies the Australian approach to the science of wine quality in which it is planned to ‘assess differences between two premium quality grades of Shiraz fruit and establish chemical and spectral indicators which define premium quality in vineyards’.

2.1.3. Challenges to both archetypes

The efficacy of both archetypes has been challenged, suggesting that the optimal path to producing high-quality wines may comprise elements of both (more on this compromise later). The prescriptive nature of the European systems has long been the subject of controversy such as the failure of wines produced by some wineries in France to be granted a top-quality rating despite the fact that wine judges and other experts consistently rate their wines highly and they sell their wines for very high prices. For example, in the AOP system in France, the Burgundy winery, Clos St Jacques in Gevrey-Chambertin, is classified as only Premier Cru despite the fact that it is ‘widely considered to be of Grand Cru quality, as is its immediate neighbor, Les Cazetiers [and consistently produces] some of the village’s most expensive wines, some rival even those of the world-class Chambertin Grand Cru vineyard’ (Wine-Searcher, 2014).

Nor is the science- and marketing-based approach to producing quality wines without its limitations. Coelli (2014) observed that the reputation of Australian wine exports has suffered in recent years from a lack of attention to wine quality and neglect of the importance of quality indicators at the regional level. Anderson (2010, p. 8) noted that despite the fact that ‘the quality of wine output has improved hugely during the past two decades, relative to the cost of production’, average export price fell even in nominal terms during the 2000s for a number of reasons including, in particular, greater competition from other New World producers. Anderson (2010, p.11) stressed the need for Australian wine producers to graduate to higher quality, more differentiated wines of place to improve profit margins.

To Australian wine industry authorities, it is a matter of improving wine quality perceptions in domestic and international markets to ‘heighten understanding and appreciation of our fine wine credentials...and improve commercial returns...’ (2014, p. 8).

But it is also about exploiting differences in the physiological attributes of particular wine-growing areas (regions and sub-regions) in pursuit of quality – a nod towards the continuing importance of *terroir*. Wine Australia (2012–2013) acknowledged the importance to the industry of a ‘strategy to build a stronger perception of the quality of Australian wine’ (p. 5) based on the three dimensions of ‘quality, diversity and regionality of wines’ (p. 6). Obviously, authorities in the Australian wine industry believe that maintaining improvements in wine quality is crucial to its future success, and ‘place’ is a key component of this process.

Blending of wines transcends place-versus-science and marketing issues – most French wines are blends and ‘are the result of a long historical evolution and traditions’ (The French Cellar, 2015) as are many Australian wines such as those in the Hunter Valley (see below). According to Cutler (2012):

One way [to make wines] more flavorful and more complex is by blending. Blending has evolved into high art. Some winemakers make single-vineyard wines but pick each block separately and then blend those blocks to maximize complexity. Other winemakers start with field blends, where different grapes grow side by side but are pic...

We choose a well-known and long-established wine-producing area in Australia – the Hunter Valley – to test the above propositions and thereby assess whether the ability of a winery to produce high-quality wines is restricted by its location and the vineyard or vineyards from which it sources its wine grapes.

2.2. Characteristics of Australian wineries

Wineries in the Hunter Valley are reasonably typical of most wineries across Australia. Unlike, for example, the situation in Burgundy, the vineyard and winery activities are not necessarily integrated or co-located. Some wineries obtain their wine grapes from a number of different sources, both within and outside the study area. Others source their grapes

from a single vineyard but it may be from a site distant from the winery. An extreme example of the cleavage between winery ownership and location is the virtual wineries that have sprung up in recent years with the owners located at neither the winery nor the vineyard(s) from which grapes are sourced, sometimes separated from these locations by a thousand kilometres or more.

3. What determines the extent of clustering of high quality rating wineries?

3.1. Countervailing spatial patterns

A key issue is whether clustering contributions to high wine quality in the case study wine region are negated by factors that relax the locational constraints on producing high-quality wine. Examples of these factors include the absence of environmental constraints, notably a warm climate, diverse varietal opportunities, widespread knowledge of suitable grape-growing and winemaking requirements enabling winemakers to exploit the synergies between grape varieties and growing conditions in particular environments, and ready access to skilled labour.

Warmth during the growing season is a factor that differentiates most New World producers from Old World producers and is especially evident in Australian wine regions. This difference is apparent in the study area, and is neatly summed up by Halliday (2015a) in respect of another wine region in Australia, Heathcote, with a reputation for producing wines of high quality:

...the varietal/regional choice in Europe has been historically determined by the amount of warmth in the growing season, just sufficient for the permitted varieties to achieve full ripeness. ...in the southern hemisphere-Australian context, most regions have ample warmth to ripen multiple varieties...

Not only can a number of different high-quality wine varieties be produced on a wine estate but also they are regularly blended, either from within the estate or with wine grapes from nearby vineyards. A common varietal blend in Australia relevant to the Hunter Valley wine industry and popular with Australian wine drinkers is Semillon-Sauvignon Blanc (Robinson, 2016).

There is no prescription of minimum levels of alcohol, maximum yields, vine age or vineyard planting densities in Australia. Nor do regulations define the grape yield, harvesting and vinification techniques or winemaking practices to which wineries must adhere. Finally, and of most importance for this study, there are no restrictions on where wine grapes for high-quality wines must be produced and cellars located.

3.2. Previous studies on wine clusters and wine quality

The wine industry has received considerable attention in terms of cluster analyses related to a diverse range of issues (Migone and Howlett, 2010). While numerous studies have

been conducted on wine clustering, the term tends to be vague with various adopted interpretations of what constitutes a cluster. In this study, we adopt the definition of Swann and Prevezer (1996) which states that a cluster is a group of firms in a given industry based within a certain geographical proximity or area. Montaigne and Coelho (2012) point out that clusters can be a source of positive externalities through the establishment of linkages within a geographical location, the increase in innovation and the differentiation of wine clusters by *terroirs*.

The key reference in the literature regarding geographic clustering is Porter (2000). The California wine cluster is a well-known example of geographic clustering that has been discussed in depth by Porter (1998, 2000) and Porter and Bond (2008). Porter (1998, 2000) developed and explained the complex linkages producing a cluster, combining intense competition, innovative capacity and leadership. This provides rationale that the Californian wine industry exhibits clustering behaviour but empirical evidence has been lacking. In their ground-breaking study, Yang et al. (2012), using Geographic Information System (GIS) data found there was a strong clustering effect of wine ratings and price in West Coast wineries in the US. However, while there is a strong spatial tendency for wineries to cluster (Miyares, 2017), this reason cannot be solely contributed to the *terroir* endowment of a location. Hira and Swartz (2014) found that while geographical and biophysical qualities might be assumed to be the reason for clustering of high quality wineries, this alone does not explain the clustering of high quality wines. While *terroir* and natural comparative advantage does play some role, they found that the clustering effect of social capital and entrepreneurship leading to technological advances was a central factor to the production of high quality of wines in the Napa Valley.

Dana et al. (2013) in a study of wine clustering in New Zealand found that the competition of wineries in close proximity had the effect of moving those firms in the cluster to produce higher quality wines through a competitive mindset to better each other. They also looked at the influence of winery size on the cluster and found that large prominent players did not necessarily pose a threat to the other neighbouring wineries, but rather, facilitated the increase in knowledge within regions. These findings were consistent with those of Alant and Bruwer (2010), who found that wineries benefited from the clustering effect of being in close geographic proximity to prestigious competitors.

Research by Harfield (1999) found that an additional positive characteristic of clustering in wineries is the support network provided and the ‘pulling together’ that occurs in clusters during critical events such as diseased grape vines and unfavourable weather events. Social capital networks are an important characteristic of innovation in the wine industry (Aldecua et al., 2017) with many authors presenting evidence to suggest that wineries exhibit clustering behaviour by facilitating information flows, technology adaptation and innovation (Aylward et al., 2006; Giuliani, 2011; Giuliani and Bell, 2005). However, Morrison and Rabellotti (2009), in a

study of Italian wineries, found that these information flows tended to be restricted to tightly connected communities, suggesting a geographical limitation to the size of an optimal cluster.

Yang et al. (2012) employed a hedonic framework to estimate a spatial lag model of factors influencing the quality of wines produced by neighbouring wineries. They tested for spatial relationships among neighbouring wineries using wine prices and tasting scores as proxies for quality. Global and local spatial autocorrelations were assessed between wineries and results suggest significant benefits from the presence of neighbouring wineries regardless of the number of neighbours. Yang et al. identified significant cluster benefits associated with the price and ratings of the wines from these regions with price exhibiting stronger clustering than that of ratings.

Because we are concerned primarily with the regional clustering of wineries with a high quality rating, the study by Hira and Swartz (2014) provides useful information in that it focuses on the impact of clustering on wine quality in the Napa Valley in California. Hira and Swartz found that ‘while *terroir* or natural comparative advantage has evidence behind it, social capital and entrepreneurship behind technological leadership are central to Napa’s competitive advantage’ (p. 37).

While numerous studies on wine and winery clustering exist, this study particularly attempts to determine if there is an optimal geographical proximity to neighbouring wineries in Australia and whether this aids in the production of high quality wines. Rather than taking a state-wide cluster approach, such as that employed by Yang et al. (2012), we apply the methodology to region-specific clusters.

3.3. Research questions

The research questions we address in this study are three-fold: (i) do Australian wineries with higher wine ratings tend to be localised in spatial concentrations; (ii) to what extent does Australian wine production conform to either of the above archetypes; and (iii) is the quality rating of a winery adversely affected if its top wines contain blends of wine varieties? We set four propositions to answer these questions:

1. Wineries of high quality are distributed in clusters in designated Australian wine regions.
2. The quality rating of a winery in a designated wine region in Australia is influenced by its *terroir*.
3. Wine quality is higher for wineries producing a territorial brand wine.
4. Wineries producing wines containing blends of varieties rate lower in quality than wineries not blending their wines.

4. Study area

The Hunter Valley region is located in New South Wales approximately two hundred kilometers north of Sydney (Fig. 1). It is Australia’s oldest producing wine region with vineyards dating back to the 1860s (Wine Australia, n.d.) and

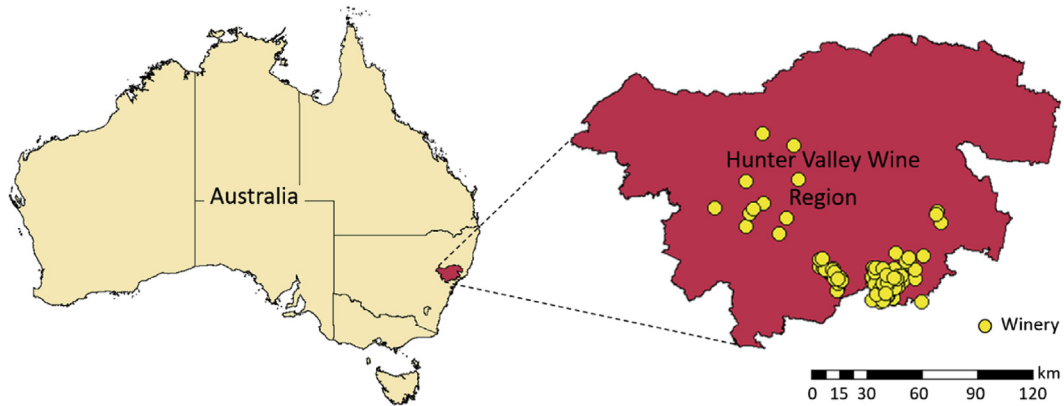


Fig. 1. Hunter Valley wine region.

comprises 21,492 square kilometers (ABS, 2017). Of this area agricultural land occupies 14,116 square kilometres, or 66 per cent of the region, with vineyard area of approximately 2300 ha (Wine Australia, n.d.). In 2014, the Hunter Valley had 201 recognised wineries that accounted for less than 3 per cent of Australia's annual grape crush (Halliday, 2014; Robinson, 2015). While its importance to the national crush has diminished over the past century, the Hunter Valley remains a jewel in the crown of the Australian wine industry renowned for its unique Sémillon, Shiraz, and Chardonnay.

The Hunter Valley wine region fits between the two extremes of wine quality archetypes. On one hand, it is consistent with the Old World viewpoint of a wine region dominated by a signature varietal, Semillon, even if it is not formally specified as a territorial brand. On the other hand, it is free from regulations restricting the conditions under which wine grapes may be grown and processed into wine.

5. Method and data

In order to assess the geographical distribution of Hunter Valley wineries, both globally and with respect to their rating, data were collected on the ratings, latitude and longitude of 200 Hunter Valley wineries. The James Halliday winery system was chosen following the work of Schamel and Anderson (2003) who employed the Halliday measure of quality. Oczkowski (1994) found that there was a significant positive correlation between the price received for table wine and the Halliday rating. This finding was later corroborated by Schamel and Anderson (2003) who discovered that there was a significant price premium associated with the Halliday rating scale (Fleming et al., 2014). The Halliday rating system was also chosen as precise definitions for the star ratings and individual winery ratings are embodied in the rating system. These definitions allow for a consistent measurement of wine and winery quality, helping to address some of the arbitrary nature that is associated with consumer preferences and reputation.

The location of each winery in the study area was determined by following a systematic identification approach. The first step included a comprehensive search through a variety

of sources including company websites, tour brochures, wine companion books, company listings and general internet searches to determine the address for each winery. Each address was then visually checked against satellite imagery from Landsat 8 satellite through Google Maps. The coordinates for the centroid for each winery were then derived and set to be the point location of each winery. The geographical distribution of Hunter Valley wineries using latitudinal and longitudinal coordinates is shown in Fig. 1.

5.1. Tests for evidence of clustering

Spatial autocorrelation tests were undertaken to gain an understanding of the geographic association among wineries in the study area. A number of methods for the estimation of spatial dependence of industries and firms have been developed including Moran's I, Geary's c; Getis and Ord's G, Ripley's K, Getis and Ord's G_i and G_i^* (Getis, 2008). Global Moran's I test, developed by Moran (1948, 1950), is the most commonly applied method to test for geographical clustering (Anselin, 2001, p. 323; Getis, 2008; Yang et al., 2012) and can be thought of as a joint count statistic to prove neighbor distributions occur more often than can be explained by chance alone (Getis, 2008). The test for spatial correlation utilises a distance weighted matrix to measure the spatial autocorrelation present between all data points and determines whether the dataset more broadly experiences clustering behaviour.

The general form of the Global Moran's I statistic is:

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} z_i z_j}{\sum_i (X_i - \bar{X})^2}$$

where N is the number of spatial units indexed by i and j ; where z_i is the deviation from the mean i of the variable of interest and w_{ij} is the spatial weight between i and j .

A value of -1 represents perfect dispersion and a value $+1$ represents perfect clustering. Inference testing is based on a normal approximation and Z-scores are used in deciding whether to reject the null hypothesis of no evidence of spatial clustering (Yang et al., 2012).

The weighted distance matrix is first derived through the calculation of the maximum Euclidian distance between wineries calculated as:

$$E_{distance} = \sqrt{[(X_{max} - X_{min})^2 + (Y_{max} - Y_{min})^2]}$$

where X represents the longitudinal coordinates and Y represents the latitudinal coordinates of a location. Using the Euclidean distance calculated above, the following $n \times n$ spatial weighted matrix (W) is calculated:

$$W = \begin{pmatrix} w_{i,i} & w_{i,j} & w_{i,k} & \dots & w_{i,n} \\ w_{j,i} & w_{j,j} & w_{j,k} & \dots & w_{j,n} \\ w_{k,i} & w_{k,j} & w_{k,k} & \dots & w_{k,n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ w_{n,i} & w_{n,j} & w_{n,k} & \dots & w_{n,n} \end{pmatrix}$$

where $w_{i,j}$ represents the spatial relationship between location i and location j . The spatial weighted matrix is also subjected to the following condition:

$$w_{i,j} = \begin{cases} 1 & \text{if } 0 \leq d_{i,j} \leq d_{max} \\ 0 & \text{if } d_{i,j} > d_{max} \end{cases}$$

This condition stipulates that if the Euclidean distance is greater than the specified d_{max} , the observation is excluded from the model. It allows for the specification of regions of interest and for testing of industrial cluster densities.

5.2. Model

Ordered logit regression models were created in *Stata* (StataCorp, 2014) to assess the factors affecting the wine quality ratings of Hunter Valley wineries. The underlying process to determine the rating of any individual winery used the following latent variable ordered logit regression model:

$$r_i^* = \mathbf{x}_i\beta + e_i$$

where r_i is the rating of winery i , \mathbf{x} is a vector of independent variables, β is a vector of regression coefficients which are estimated and e is the error term.

The categories of response were observed by dividing r^* into the six ordinal categories:

$$r = \begin{cases} 0 & \text{if } r^* \leq 0, \\ 1 & \text{if } 0 < r^* < \mu_1, \\ 2 & \text{if } \mu_1 < r^* < \mu_2, \\ \vdots & \\ 6 & \text{if } \mu_5 < r^* \end{cases}$$

where the cut points μ_0 to μ_6 are estimated and assume $\mu_0 = -\infty$ and $\mu_6 = \infty$.

A category for observed ratings change occurs when r^* crosses a cut point. The probability of a rating for a given set of explanatory variables corresponds to the region of the cumulative distribution curve where r^* falls. The results from the model are reported as odds ratios which present the regression coefficients as the change in the cumulative probability of an

event occurring due to the change in a regression variable (Hill et al., 2008). This makes the odds ratio a more practical measure of empirical relationships when outcomes are non-divisible such as in the case of an ordinal variable.

5.3. Dependent variable

The James Halliday (2015b) winery rating system is used to obtain a rating for each winery. A high-quality winery is specified as one that achieves a 5-star rating according to this system. The two most highly rated wines produced by the winery and subject to tasting from 2011 onwards are used for this purpose. The Halliday ratings are as shown in Table 1.

5.4. Explanatory variables

Explanatory variables are needed to test the first proposition on the extent of clustering of wineries according to their quality rating. Variables included to test this proposition are a set of what Neumayer and de Soysa (2011) called spatial lag variables, which capture the dependent variable by a link function connecting each winery to other wineries. For high-quality wineries, it is defined as the number of wineries for this category within the buffer in the study area. It is used as an indicator of the proposition that top-quality wineries are tightly clustered, circumscribed by their ability to exploit their physiological, cultural and knowledge advantages.

A second set of explanatory variables in the model relevant to the spatial heterogeneity of wine quality is *terroir*, included to test the second proposition. While it would have been desirable to include all physical elements of *terroir*, data limitations restricted us to the use of only soil variables from national soil attribute maps (CSIRO, 2014), which serve as a proxy for all elements. Soil quality variables included in the estimated model at a depth of 30 cm, with expected sign for improving wine quality, are soil pH (positive), effective cation exchange capacity (positive), silt content (negative), phosphorus content (positive), available water capacity (negative), bulk density – whole earth (negative), clay content (positive), nitrogen content (negative) and sand content (positive). A lack of winery-specific climate data was a concern but is mitigated by the relative consistency of climatic factors across the sample and the possibility that its effect will be picked up in the winery clustering variables.

Table 1
Ordinal transformation of halliday ratings.

Ordinal rating	Equivalent Halliday rating (stars)
6	5 star + winery
5	5 star winery
4	4.5 star winery
3	4 star winery
2	3.5 star winery
1	3 star winery

Source: Halliday (2014).

Table 2
Moran's global I statistic for all hunter valley wineries.

Variable	I statistic	E(I)	Sd(I)	Z-score
Halliday rating	0.147*	-0.005	0.084	1.817

n = 200.

*p < 0.05.

The third proposition was tested by including a categorical variable valued one for those wineries that have Semillon as one or both of their top wines and zero for those wineries that do not.

Because some top-rating wines were made with wine grapes sourced off-site, a dummy variable is included to pick up any effects that origin of wine grapes may have on the quality rating of a winery.

Other explanatory variables considered for inclusion in the estimated model are: age of wine being assessed (plus an interaction with the variable for Semillon for which aging is a crucial influence on quality, as noted above); age of winery; size of winery (measured by volume of throughput), closest 'first family' winery²; red wine categorical variable (Shiraz base); white wine categorical variable (Verdelho base); and production of blended wine varieties. The latter is included to test the fourth proposition.³

6. Results

6.1. Cluster analyses

The results of the Global Moran's I test on all Hunter Valley wineries presented in Table 2 indicate the existence of a statistically significant cluster of wineries at the 5 percent significance level with an I-statistic > 0. However no evidence of clustering behaviour was found among high quality wineries (Table 3). Potential reasons for this result are that many of these wineries have been established for a long time and were thus formed irrespective of clustering influences, or that the quality and rating of these wineries are the results of non-

² The First Families of Australian Wine, two of which originate in the Hunter Valley with a third also producing grapes and wine in the region (Halliday, 2014; Zhang, 2003) are, by virtue of their age and reputation, considered leaders in the Australian premium wine market (AFFW, 2012).

³ Variables included in the regression, were chosen on the availability of data and based on a theoretical model of factors influencing wine adapted from Jackson and Lombard (1993). A number of variables including soil nitrogen, available water capacity, clay, and the bulk density of soils (g/cm³) were excluded from the final model as they were shown in preliminary models to not significantly affect winery ratings and to contribute to multicollinearity. Climatic variables such as temperature, rainfall and humidity were also excluded from the model for two reasons: (i) the inclusion of precise climatic data taken at daily or even hourly rates is impractical due to the cross-sectional nature of the model and (ii) given the density of the wineries involved the variation in locations of wineries is relatively small, hence climatic extremes are likely to affect the vast majority of wineries observed. The logistic regression framework employed in this study is consistent with the approach used by Fleming et al. (2014).

Table 3
Moran's global I statistic for high quality wineries.

Variable	I statistic	E(I)	Sd(I)	Z-score
Halliday Rating	-0.026	-0.023	0.045	-0.065

n = 45 = 45.

*p < 0.05.

geographic factors such as the age of the producing vines and reputation.

6.2. Influences on wine quality

Odds ratios along with z-scores and p-values are reported in Table 4. A value of one for an odds ratio reflects no impact, a value less than one reflects a negative impact and a value greater than one reflects a positive impact. Statistically significant at 0.05 significance level are the age of the winery and a number of soil related variables.

6.3. Tests of propositions

Proposition 1. Wineries of high quality are distributed in clusters in designated Australian wine regions.

This proposition was tested by examining the coefficients of the 5-star wineries spatial lag variable in the Hunter Valley wine region. While it is slightly greater than unity (1.074), implying that a 5-star winery is likely to be found near other 5-star wineries, it is highly insignificant. Nor is there any evidence that wineries with 5-star rating cluster with wineries of almost as high quality ratings (4-star and 4.5 star).

Table 4
Ordered logit regression results.

Regressor	Odds ratio	z	p
Unrated wineries	1.021	0.22	0.825
3-star wineries	1.658	1.12	0.264
3.5-star wineries	0.647	-0.84	0.403
4-star wineries	0.683	-0.81	0.420
4.5-star wineries	1.119	0.42	0.672
5-star wineries	1.074	0.63	0.531
Average age of wine	1.441	1.21	0.225
Volume of wine produced	1.000	-1.40	0.162
Age of winery	1.018	1.97	0.049
Sourcing of grapes	1.555	0.62	0.538
Closest 'first family'	1.000	1.05	0.292
Semillon	48.25	4.49	0.000
Whites other than Verdelho	3.017	1.65	0.100
Reds other than Shiraz	0.703	-0.51	0.608
Blending	0.660	-0.49	0.633
Soil pH	1.542	0.18	0.860
Effective cation exchange capacity	1.700	1.93	0.054
Silt	0.524	-1.95	0.052
Phosphorus	2.138	0.48	0.630
Available water capacity	0.297	-1.91	0.056
Bulk density - whole earth	0.000	-1.66	0.097
Clay	1.418	2.24	0.025
Nitrogen	0.000	-2.85	0.004
Sand	1.294	1.34	0.180

Proposition 2. The quality rating of a winery in the Hunter Valley wine region is influenced by its terroir.

The model was estimated with and without the soil variables to test the proposition that soils influence the quality of wine produced by a winery in the Hunter Valley wine region. Results of a likelihood ratio test confirmed that this set of variables have a significant and varied impact on winery quality, and lends support to the proposition. Certain elements of the soil measured at 30 cm were found to be important in explaining wine quality. Notably, effective cation exchange capacity, clay content and (marginally) sand content have positive impacts and silt content, available water capacity, bulk density and nitrogen content have a negative impact. In general, soil appears to be an important factor influencing a winery's ability to produce a high-quality wine. The importance of soil as a clustering factor for high-quality wineries was reaffirmed by the estimates of the model without the soil variables. As expected, the spatial lag variable for 5-star wines in the buffer zone now became significant (z-score of 2.11) with an odds ratio of 1.20 that is well above one.

Proposition 3. Wine quality among wineries in the Hunter Valley wine region is higher for those producing the territorial brand wine of Semillon.

The inclusion of Semillon in the two rated wines is an exceptionally strong factor in determining wine quality.

Proposition 4. Hunter Valley wineries producing wines containing blends of varieties rate lower in quality than wineries not blending their wines.

Blending appears to have no impact on the quality of wine produced by a winery. The coefficient for the blending variable in the estimated model is highly insignificant.

7. Discussion

After controlling for soil conditions and the territorial brand wine of Semillon (suited to particular parts of the region), there is no evidence that Hunter Valley wineries producing high-quality wines are located in clusters. This finding contrasts with that by Yang et al. (2012) of a quality cluster for wineries in the US states of California and Washington.

The four most likely explanations for this result are: (1) a favourable environment exists for producing high-quality wines in the Hunter Valley; (2) the mastering by grape growers of climatic interactions with viticulture; (3) a long experience of wineries in the heuristics of selecting grape varieties to suit the environment; and (4) good use made in the study area of the results from region-based research and development into winemaking and grape growing in Australia.

A favourable environment exists for producing high-quality wines with careful selection of varieties to suit the landscape. Warmth during the growing season in the Hunter Valley reduces the constraints on growing wine grapes suited to local

conditions. While inherent differences may exist in planted varieties in the study area, the vine has shown itself to be highly adaptable and resilient to its environment, demonstrated by its importation and the broad soil classes and climates in which grapevines are grown generally in Australia and specifically in the Hunter Valley. Higher latitude grapes require a specific slope and orientation to allow grapes to grow and ripen effectively whereas grapes grown on the Mediterranean coast receive almost too much sunlight (Wilson, 1998, p. 22).

Grape growers have successfully mastered the interactions of the macroclimate, mesoclimate and microclimate to produce good-quality grapes suited to a specific location, grape maturation and growth rates, and the concentration of sugars and acids in grape juices (Dry and Coombe, 2004, pp. 90–92; Jackson and Lombard, 1993). The impact of climatic restrictions on efforts to produce wines of high quality is thereby reduced. The extent to which the microclimate directly influences the ripening processes of grapes and the susceptibility of vines to disease varies between varieties and genetic predisposition of individual vine clones. As stated above, it is largely determined by the effective management of soils and vines (Dry and Coombe, 2004, p. 92). Short-term extreme temperatures do not typically affect vines in the Hunter Valley because of the capacity of selected varieties to acclimatise to spatial extremes although they may have significant impacts on young vines or new growth of established vines that have yet to develop sufficiently and to acclimatise (Dry and Coombe, 2004, pp. 93–95).

Vineyard and winery management skills have been developed and refined over a long period, with wineries with a longer period in existence performing better than newer wineries in producing high-quality wines. Hunter Valley wineries are indeed more fortunate than wineries in many parts of the world in that the various impacts on grape quality of the *terroir* can be largely managed by grape growers and winemakers. Long experience in countering adverse climatic occurring locally and developing varieties suited to physiological conditions have helped in maintaining good wine quality regardless of the weather extremes that are experienced and variations in soil conditions. The steeper the topography on which vines are grown the less the variation in the maximum and minimum temperatures to which vines are exposed due to characteristics of valleys as air traps, with cold air drawn into the valley, allowing warm air pockets to stabilise on hillslopes (Dry and Coombe, 2004, pp. 91–92).

Research and development processes have probably helped control for climatic variations in temperature, wind, rainfall, sunlight exposure and humidity, although evidence of the application of successful research outcomes in Australia are currently lacking. Evidence from outside the Hunter Valley suggests it is possible to use research outcomes to manage these variations.

Temperature is arguably the primary climate control for vine production in the mesoclimate because of its effect on vine phenology dictating the dormancy, budburst, flowering, setting, veraison and ripening of vines. It also plays a crucial

role in controlling the productivity of vines through photosynthesis and dry matter growth (Wilson, 1998, p. 37; Zufferey et al., 2000). Temperature has been shown to affect the pH, total acidity, and sugar content of grapes. Warmer climates wines exhibit higher sugar content and higher pH than their cool climate counterparts. Experimental evidence suggests that in order to maintain low pH and higher acidity in warm climates, greater temperature variation is required between day and night (Jackson and Lombard, 1993) that suits conditions in the Hunter Valley.

The impact of wind on vines in the Hunter Valley is greatest in spring, where strong winds can damage young vine growths. Hot continental winds that have a significant impact on vines, especially in non-coastal locations where heatwaves may last for protracted periods, tend to be rare. The combination of hot northerly continental winds and cool southern winds has been shown also damage vines by limiting the capacity for acclimation and hastening the onset of vine stress. By contrast, less extreme winds are beneficial for grape vines, improving sunlight penetration and ventilation of the canopy thereby enabling grape growers to reduce the likelihood of disease (Dry and Coombe, 2004, p. 103, Wilson, 1998, pp. 40–41).

The timing and volume of rainfall has been shown to be a significant impact on the quality of wines produced by influencing the acidity, sugar content, rate of ripening and disease susceptibility of grapes. Oversupply of water to the vine can result in decreases in grape colour and sugar content, and negatively influence grape pH (Chaves et al., 2007). Soil moisture deficits after veraison increase the sugar content of grapes without affecting yield in Müller-Thurgau grapes (Jackson and Lombard, 1993). Mistimed rainfall can also have a significant impact on grapes by hindering ripening and causing fungal disease, grape rot and rapid grape swelling that may lead to the splitting of grape skins (Dry and Coombe, 2004, p. 99; Robinson, 2015; Wilson, 1998, p. 39).

Exposure in grapevines is affected by the volume of sunlight to which grapes and leaves are exposed and the rate of photosynthesis and grape ripening. More exposure to solar radiation hastens photosynthesis and the metabolic activity of the vine, and promotes the ripening of grapes. But this positive effect of increased exposure can also inhibit photosynthesis at higher light intensities (Dry and Coombe, 2004, pp. 96–99).

Humidity influences the likelihood of the vine experiencing fungal disease, especially at higher temperatures and dew points. Higher relative humidity also leads to increased water efficiency of vines through reduction in the evaporation from leaves (Dry and Coombe, 2004, p. 103).

In sum, our findings suggest that the optimal path to producing high-quality wines in the Hunter Valley comprises elements of both archetypes presented in the paper. It appears that winemakers and grapegrowers have successfully managed to produce high-quality wines over a range of different environmental conditions. The quality of wines produced is not influenced by winery size, where grapes are sourced or proximity to a first family winery.

Finally, blending is shown neither to constrain nor to enable the production of high-quality wines. There are two contrary views propounded about the merits of blending as an influence on wine quality. Proponents of blending argue that it enables the right acid level to enhance flavours, aroma, colour and ‘mouthfeel’ (Winemaker’s Academy, 2013). As well as adjustment to the pH, sugar content, titratable acidity and tannins can be manipulated through blending to improve wine quality (Winemaker’s Academy, 2013). Possible disadvantages are the potential complexity of the blending process, the fact that single varietal wines are commonly perceived to be of superior quality, and the limits imposed by terroir that favour a single grape type (The French Cellar, 2015). This result suggests further research is needed to tease out the different effects of blending on wine quality, particularly in relation to the different types of blending undertaken and the sources of the blended grapes.

8. Concluding comments

Although no evidence was found to suggest the existence of a high-quality wine cluster in the Hunter Valley our findings do demonstrate that the Hunter Valley may be classified as a significant winery cluster. A strong tourism industry has developed around the wine industry as can be seen through the importance of Hunter Valley tourism to the NSW economy, with the Hunter Valley being the most visited area in NSW after Sydney, a major drawback being the quality and history of Hunter wineries (Hunter Valley Wine and Tourism Association, 2013). Hunter Valley wineries benefit from co-location with neighbours of varying quality and the specific terroir of the region. This empirical evidence suggests that there are substantive benefits from operating in an environment of like firms and supports the case for further promotion of geographical clustering of wineries and information flows between industry agents. Soil results indicate that there are substantial benefits on winery ratings and subsequently wine quality from the maintenance of sound soil health. This evidence suggests that firms and regulators should promote and undertake sustainable methods of grape production and of maintaining and improving soil health, not just for environmental reasons but also for economic reasons.

Further analysis of winery quality could be undertaken through the inclusion of other variables, such as the experience and education of the winemaker and the age of producing vines, to gain a broader picture of the relationships affecting winery quality. The current literature pertaining to quality and winery ratings using spatial econometric methods is significantly underdeveloped. There is scope for the application of these methods to other significant wine regions. More broadly these methods can be applied to measure the degree of clustering in other industrial agriculture segments. Expanded analyses can better enable policy makers to effectively promote the quality and formation of strong clusters, providing significant benefits to the broader local economy.

Declaration of competing interest

The authors declare no conflict of interest.

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