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Climate Change and the Spanish Wine Industry:
What Can Wine Companies and Government do to Protect Spanish Wine?

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ABSTRACT

In the midst of an economic crisis and accelerating climate change, vineyards – the growers of Spain's most fragile agricultural product and the heart of the nation's wine industry – are extremely vulnerable. While studies have suggested that wine makers find drops in sales to be the most urgent problem they face, issues brought by climate change will nevertheless present obstacles in the future. The industry therefore, is divided in its attitude towards global warming and while some viticulturists prepare for the potential weather changes, others make different use of their resources. This essay looks at the Spanish wine industry in its entirety and estimates the severity of climate change's impact on its vineyards. Upon reaching an understanding of how global warming will affect Spain's grape growing regions, this paper will undergo an analysis of the various coping mechanisms to decide what can be done to prepare the vineyards for climate changes in the future. Among these coping mechanisms are technological changes and agricultural methods of adaptation within the vineyards themselves, as well as government action that can make these changes more feasible. Ultimately, this paper will outline recommendations for the viticulturist and the industry regulator wherein they will be able to maintain the reputation of good quality Spanish wine and thus exports – despite disruptions from climate change.

INTRODUCTION

To begin with, it is important to appreciate that this agricultural sector is extremely fragile and responsive to change. Variables in the process of wine production and grape growing are numerous and specific, a fact that challenges studies in understanding the implications of climate change. Regional differences and growing techniques will often yield varying results in surveys and studies. Even adjacent vineyards can produce completely different tastes and yields based on soil composition, vineyard orientation, shading or variety of grape. The "effects on wine production" section will look further into this phenomenon. Such variation among vineyards is the reason why it is necessary that this research paper perform a macro analysis of the industry as a whole; any assessment of a single vineyard would be of misplaced bias and unfit to represent an arena of competition that is based on vintage differentiation.

In order to determine the best response to climate change in the Spanish wine industry, it is imperative that the policies by which the industry functions are understood. Spanish wine is subject to rigorous regulation and is closely monitored by the government who wishes to gain control supply and demand. There is also an ongoing shift in the internationalization of the wine industry with demands changing from continental Europe to Asia and the Americas. While Spain deals with climate issues, it must also address the competition it faces from the up and coming vine cultures of the 'new world'; this papers concluding recommendations are in respect to current industry and economic conditions. After discussing the characteristics of the Spanish wine industry, this paper will contemplate the variation of climate change forecasts for Spain. Temperature and rainfall trends from the past fifty years can give an

idea of the direction that Spanish climate is heading in. However, there also exist projections that differ from recent trends and place an increased importance on spreading desertification. This paper will analyse these forecasts to determine the real impact on grape growing in Spain.

These first two sections of the research paper - the state of the industry and climate trends and projections - will provide a framework for the analyses of how Spain must prepare for the coming challenges. The sections that follow will determine reactions and solutions. This will be done by incorporating evidence from around the world regarding how climate changes have already affected vineyards. This includes the change in a grapes alcohol content and acidity and thus taste- as well as overall yield, due to temperature increases in the past 50 years. That being said, it must be acknowledged that some changes have had positive impacts in certain regions. In those regions that have suffered negative effects however, and in those innovative vineyards that anticipate the change, this paper seeks to understand their methods of adaptation. In this way the essay will outline possible coping methods and pro-active forms of adjusting to climate change. While this involves actions taken by the vineyards themselves, the last section of the paper will consider the possible actions of the Spanish government. Here it will become clear that certain regulatory policies restrict Spanish vineyards, while there are also aspects of Spanish agriculture that the government neglects and must reform.

STATE OF THE INDUSTRY

The Spanish wine industry is governed by multiple levels of jurisdiction. While Spanish vineyards find themselves subject to national regulations, some policies are shared by other wine producing nations in the EU such as France and Italy. These regulatory bodies shape the level of Spain's international competitiveness as global consumption patterns and production patterns rapidly change. Three forces that govern the value and quantity of Spanish wine exports are regulatory control, the market conditions and competitors.

Regulatory Control

The context of the European wine industry exists within in the frameworks of the Common Market Organization (CMO) for wine. This organization is responsible for coordinating supply from European wine producers, as well as increasing the competitiveness of European wines on the global market. In preventing over-supply, the CMO enforces a prohibition on the planting of new vines, as well as restricts vineyards to designated regions (Montaigne, 2010). Another aspect of the reduction in grape harvest is a CMO led project to remove 175,000 hectares (5% of the European total) of European vineyards, replacing them instead with other suitable crops. This European attitude towards limiting production is particularly relevant to Spain because of the nation's comparative grape growing area (see Table 1 of Appendix). Spain has nearly a third of total European winegrape acreage and constitutes the largest wine growing region in the world. Consequently, just over half of the EUs budget for winegrape acreage reduction is dedicated to Spain (see Table 3 of Appendix), which is used to provide viticulturists with monetary incentives to pull their vines. It should be noted however, that the distribution of this budget is a nationalized decision. Because of the low value of these one-time monetary incentives, they are specifically targeted towards low yielding vineyards, of which there are many in Spain (Montaigne, 2010). Despite being the world's largest producer in terms of acreage, Spain is only the third largest producer in the world after France and Italy in terms of total litres produced suggesting a lack in productivity. The grape-growing regulations imposed on Spain by the CMO are of great importance in the sense that they can restrict vineyard manoeuvrability in response to climate changes. They will also affect agricultural decisions such as irrigation modernization, by aiming to maintain low productivity for supply reasons. While reduced rainfall and increasing temperatures make designated regions less

suitable for vintage wines, CMO policy encroaches on the bureaucratic level and can prevent what might be the best form of adaptation; relocation.

Market Conditions

While Spanish wine makers face a quick-changing climate, they are confronted with a faster changing global wine market. European wine consumption has decreased in recent decades with domestic wine per capita consumption falling 37% in Spain between 1989 and 2004. When this is coupled with the strong supply coming from southern European vineyards, the result is saturated domestic demand (Bardaji and Mili, 2009). On another note the emergence of foreign markets and the increases in disposable income that are associated with it has resulted in increased consumption outside of Europe. China, Southeast Asia and Eastern Europe are now leading in expected consumption growth. Ultimately, total global consumption increased by 9% percent between 2000 and 2008 according to the International Organization of Vine and Wine (OIV). A benefit to Spain, which excels in the production of "popular premium" and "super-premium" wines (sherry for example), is the trend in foreign markets' perception towards wine and alcohol in general. As Bardaji & Mili (2009) note, "Wine increasingly will be considered in foreign markets as a quality product whose moderate consumption could be beneficial for health", while "anti-alcoholic campaigns could increase" (Bardaji & Mili, 2009). This expectation suggests a transition from lower quality to higher quality alcoholic beverages such as wine. Among the results of the study by Berdaji & Mili (2009) on wine consumption trends, the general expectation was that foreign markets will demand more quality differentiated wines at average prices, as well as better differentiated styles of packaging and design. This consumer desire for differentiated packaging styles is incongruous with the mandatory labelling requirements imposed on wine producers in Spain, and highlights the need for the country to relax such regulations. As far as the international market for wine is concerned however, the largest areas of opportunity now lie outside of Europe in nations that have not yet been fully exposed to European wines. Despite the decrease in European consumption, Spanish wine exports have been increasing steadily to the extent that they have converged with Italian and French export levels (see Table 2 in Appendix).

Competitors

Though the decrease in European wine consumption is putting stress on Spanish wine producers, the particularly damaging 'second blow' is the surge of imported wines from outside the continent. Argentina, Chile, the United States, South Africa and Australia have recently become formidable competitors, and whose quality wines have resulted in decreased public support for European brands in Europe (Bardaji & Mili, 2009). Traditionally, European brands have used territory as a base for product differentiation, as many quality wines are recognized specifically by their region of origin. It is in this manner that the industry has a decentralized control over production resulting in higher barriers to international distribution; Spain's top 5 companies for example, control only 10% of production. New world companies on the other hand have more centralized control with the top five companies in the United States controlling 73% of its production and the top five in Australia controlling 68%. New world companies further differentiate themselves from European producers by making more homogenous brands (marketing wine by grape variety for example) and by using high business concentration to their advantage for international marketing (Bardaji and Mili, 2009). Although European brands maintain the lead in international wine sales, the centrally organized structure of the new world wine companies and their innovative growing techniques have resulted in what Bardaji & Mili (2009) deem a "competitive crisis" for European wine producers.

The pressures on the Spanish wine industry are substantial when considering the strains of regulation, global supply and demand and increasing competition. The external forces that impact the industry's export levels can be best summarized by the business environment diagram in Table 4 of the Appendix.

CLIMATE TRENDS & PROJECTIONS

Jones, White, Cooper and Storchmann (2005) note that:

> *"While individual weather and climate factors can affect grape growth and wine quality (e.g., solar radiation, heat accumulation, temperature extremes and precipitation) growing season lengths and temperatures are critical aspects because of their major influence on the ability to ripen grapes to optimum levels." (Jones et al., 2005).*

The direct impacts of climate change that most concern the grape growing regions of Spain are increasing temperatures and projected reductions of rainfall. In tandem these issues are causing "desertification" in several regions of the country. The severity of global warming's impact on wines will vary between grape varieties and regions in Spain. Agriculture in the southeast for example, is at higher risk of desertification than the north, while the centre of the Iberian Peninsula is expected to face the greater temperature increases. This section will review the various evidences that forecast the overall effect of climate change in Spain in respect to temperature, and rainfall and water security.

Temperature

As the Spanish grape harvesting season typically takes place in August, it is the changes in summer temperatures that are most relevant to the industry. In fact, temperature increases in the past 50 years have not been equal in winter and summer seasons. According to the Instituto Technológico Agrario of Spain (the Agrarian Technological Institute), temperatures are increasing at a trend of 0.4°C per decade during the winter and 0.6-0.7°C in the summer. This trend is supported by the findings of climate change researchers Schar & Jendritzky (2004), who warn that the average temperature of Spain's central regions could increase by 5°C over the next 100 years (see Table 5 of Appendix). In fact, in the past 50 years temperatures have increased an average of 2°C resulting in grape harvesting as much as one month earlier (Wood, 2008; Alonso & O'Neill, 2011). As would be expected, longer term predictions come with greater variability in results. The higher estimate of temperature change comes from Jose Manuel Moreno, a professor of climatology at the University of Castilla La Mancha who has estimated an increase 7°C by the end of the century (Mulier, 2006). Summer temperatures are also subject to increasing intensity and frequency of heat waves (Iglesias, 2009). Despite this slight variability in projections the majority are consistent, and the point remains that temperatures in Spain are on the rise and that global warming is expected to affect average temperatures severely. While the temperature itself will have a direct impact on the composition of Spanish grapes, it is also inextricably linked to the amount of UV radiation, to water resource availability and ultimately desertification.

Rainfall and Water Security

The projections of annual rainfall are by no means positive for Spain in the next century. When observing rainfall levels from 1960-1990, the projections of 2050 levels show as much as a 40% decrease in precipitation in southern Spain, with a slight increase in rainfall in the north (Iglesias, 2009). The UN has also released its own projections that report a total national reduction of 40% by 2070 (Almendral, 2009). Predictions by the Agrarian Technological Institute can be seen in the Appendix in Table 7 and show similar estimates. Ana Iglesias (2009), an agricultural economist at the Universidad Politécnica de Madrid states that the reductions in precipitation rates are "the most important factor in determining

the likely impacts on the Mediterranean region". These changes will also increase the variability in extreme weather patterns including droughts, which will ultimately lead to higher demand and competition for water resources (Iglesias, 2009). The threat of reduced water resources however, go beyond reductions in precipitation. Much of Spain's fresh water comes from the glaciers of the Pyrenees which according to the Spanish Environmental Ministry have seen 90% of their mass disappear in the last 100 years. At that rate the glaciers could be gone within the next 10 to 20 years (Tremlett, 2009). This will prove especially problematic for the vineyards of the northeast at the foothills of the Pyrenees, whose water reserves are fed by those glaciers (see Table 6 in Appendix). Among these regions are La Rioja and the Penedés, which are the densest and highest producing regions in Spain (Alonso & O'Neill, 2011).

The combination of higher temperatures, loss of glacier mass and reduced precipitation ultimately makes "Spanish water delivery systems…increasingly unstable and vulnerable" (Iglesias, 2009). This belief is backed up by the projections that Spanish watersheds will reduce flow by 40% in the next 100 years (Iglesias, 2009). Table 8 of the Appendix shows the forecasted disparities between supply and demand of water in the various regions. As Spanish aquifers continue to dry up and annual rainfall decreases, the risk of desertification intensifies (Almendral, 2009). This process has been further accelerated by increased demand for fresh water in arid coastal tourist destinations that see high prevalence of pools and golf courses (Almendral, 2009). Additionally, increasing temperatures can further aggravate the symptoms of desertification by accelerating evaporation and decreasing soil moisture (Iglesias, 2009). A drought in 2007 resulted in the depletion of a major reservoir outside of Barcelona, while another in 2008 nearly saw the loss of a reservoir in Saint Llorenç de Morunys (Almendral, 2009). The Spanish Environmental Ministry proposes that one third of Spain is currently at risk of desertification. These forecasts speak to all of Spanish agriculture, but especially to the wine industry that has only 25.2% coverage in irrigation systems (Bardaji & Mili, 2009; Alonso & O'Neill, 2011).

EFFECTS ON WINE PRODUCTION

The processes behind grape growing and wine making are extremely particular and dependant on the type of flavour and aroma a wine maker is trying to achieve. Especially in Southern Europe where wine companies rely heavily on vintage quality and product differentiation, specific levels of sugar, acidity and flavour need to be achieved to realize a given style. To reach these desired levels, viticulturists conduct various methods of growing techniques such as pruning vine leaves to adjust the amount of direct sunlight on grape bunches. Others will tamper with nitrogen levels by reducing or increasing fertilization (Somers & Quirk, 2008). Despite wine makers' attempts to control chemical content at ripening however, many 'optimum ripening levels' are only possible in very narrow geographic regions with specific micro-climates; hence the popular recognition of quality wines by location (Jones et al., 2005). The fragility of wine quality can be fully appreciated in the findings of Jones et al. (2005), who went so far as to suggest that flavours of a vintage brand can be altered by changes in carbon dioxide an oak tree absorbs when the vintage is cured in barrels made from its wood.

The level of intensity of the effects of global warming can result in differing chemical compositions in grapes and vines. For example, changes in skin color and accumulated sugars are an indicator of warmer temperatures whereas extreme highs in temperatures can impede sugar accumulation. Concurrently, while direct sun is often associated with more concentrated "fruitier" flavours, excessive UV radiation has been reported to cause leaf burn and smaller berry size (Somers & Quirk, 2008). Such effects are numerous and highly particular. This research paper however, will be placing an emphasis on the overarching impacts of global warming on tastes and yields as they relate to the economy of the Spanish wine industry.

Effects on Flavour

The most obvious effect of higher temperatures on grapes is early ripening, and thus an advanced harvest season. This entails an alteration of sugar and acidity concentrations within the grape and ultimately a change in flavour. Earlier ripening can also result in harvests before seeds and skins (which are largely responsible for flavour) are fully developed (Faris, 2011). However, studies by Jones et al, (2005) and Alonso & O'Neill (2011) have agreed that not every variety's flavours will be negatively impacted by rises in temperatures and that in fact, some will experience positive changes. While cooler climates in northern Spain may find that more varieties of grapes become viable for ripening as a result of higher temperatures (such as a new ability to grow Mediterranean grapes), they may also benefit in yields of more "consistent vintage quality" on existing varieties (Jones et al., 2005). This was expressed most convincingly in "Climate Change and Global Wine Quality", in which Jones et al, (2005) compared the vintage ratings of wines from around the world with the average temperatures of the season in which they were grown. The results showed a strong correlation between the two and also that "vintage quality wines (that) were obtained in the world's highest quality wine-producing regions…incidentally had experienced growing season warming trends" (Jones et al., 2005). A wine maker surveyed by Alonso and O'Neill (2011) was not unique when he reported that "The drought situation in previous years has reduced volume of production but has increased the quality of the grapes". As it turned out in the studies, many of the climates were previously too cold for the type of grape being grown there (Faris, 2011). Of those surveyed by Alonso & O'Neill (2011), 17% had noticed positive effects of climate change whereas only 6.4% had noticed negative effects. These results support the notion that changes are highly variable depending on region. They also suggest that further research and education is needed in terms of correlating climate change with its symptoms.

These positive results are largely dependent on the variety of grape being grown, and what its optimal ripening conditions are. Varieties whose tastes were improved by upward temperature trends were clearly not at their optimal period before the increases. Jones et al (2005) stipulates that most Mediterranean vintages that are known for their regions micro-climate are already at their optimum ripening conditions. These better recognized wines are Spain's "high quality" brands, which are also the most valuable in the sector. Should these "ideal" conditions change, "grapevines can have more rapid phonological development that results in loss of acidity and….unbalanced or 'flabby' wines" (Jones et al., 2005). A plant that receives too little water for example will experience higher stress levels and thus lower concentrations of flavours in the grape (Alonso and O'Neill, 2011). Effects like these could be devastating for high quality brands that are well established in their micro-climate.

It should be noted that in Jones' study, the observed vintage ratings increased in conjunction with an average 1.7 degree Celsius rise, while the global warming forecasts predict much more severe temperature changes in the next 50 years. At some point temperature increases will become a matter of yield rather than taste, as it "may become too warm to produce high quality wines of any kind" (Jones et al., 2005). According to projections, this is most likely to occur in the center and south of Spain in regions such as La Mancha, Alicante and Valencia (see Table 6 in Appendix).

Effects on Yield

Global warming can both explicitly and implicitly affect yield quantity. Directly, over-heating of the vineyard areas and reductions in precipitation has reduced volume by moving forward the harvest date (Alonso & O'Neill, 2011). In Australia, Somers and Quirk (2008) found that extended high temperatures and drought caused a 20-50% decrease in overall yields. An increased sense of danger has been applied

to vineyards that are on steep slopes (Schultz, 2010). These vineyards are more susceptible to drought and soil erosion causing further decreases in volume (Alonso & O'Neill, 2011).

Intense heat waves can cause "cracked berries", exposing grapes to diseases that ultimately make a portion of the crop unsuitable for harvest (Schultz, 2010). This is an example of an implicit reduction to yields. Milder winters can also make vines more susceptible to diseases, and vulnerable to pests and infestations (Jones et al., 2009; Alonso & O'Neill, 2011). This was already the case in the region of Sardinia that faced damaging pest increases due to a milder off-season in 2003 (Alonso & O'Neill, 2011). Grape growing regions in the center and south of Spain will find that they face the most severe symptoms of climate change and are most likely to suffer impacts that extend beyond variations in wine tastes, and slight reductions in yield. There are legitimate concerns that some of Spain's best vintages will be ruined. Alonso & O'Neill (2011) warn that "Spain's wine regions are particularly vulnerable to global warming. Moreover, Spain could be one of the first wine growing areas in the world where grape growing becomes unviable".

COPING MECHANISMS

In responding to changes in climate, vineyards have reacted both pro-actively and apathetically. Alonso and O'Neill (2011) noticed during their study of vineyards in Spain's three densest regions that only 41.5% of those surveyed reported noticeable changes to production as a result of global warming. Furthermore, only 6.5% of respondents considered the effects of climate change to be a "main challenge" that they face. Drops in sales on the other hand received a 64.9% response rate (Alonso & O'Neill, 2011). When this standpoint is compared to the financial solvency of the companies that are being pro-active, it is clear that only the most successful wine makers can afford the costs associated with adaptation. A handful of wine companies have reacted to projections by installing "green" technology such as solar panel electrical systems to reduce their own carbon footprint (Roberts, 2009). While these actions attempt to get at the root of global warming, this research paper will concern itself primarily with direct coping techniques that are about *survival* and not *responsibility*. Those that have taken initiative to protect their vines have undertaken short term solutions, varietal and regional adjustments as well as more comprehensive research.

Short Term Adaptation

Direct activities that can reduce the effect of drought and increased temperatures are just as numerous as the symptoms. The most obvious change to production practices according to the study by Alonso & O'Neill (2011) is early ripening which necessitates logistical changes within the company. Viticulturists can also alter their levels and styles of pruning, conduct soil moisture retention techniques, apply canopies for shading purposes and adjust fertilizer application (Somers & Quirk, 2008). Most of these activities are normal agricultural practice however, and represent only moderate adjustments to changing weather patterns. Bolder techniques for adjusting to sun exposure and temperature are displayed when vineyards rotate the orientation of the vines so that they receive a differing amount of shade. In a method that can protect vines from both excessive UV radiation and temperatures, some vineyards are conducting reforestation projects around their vineyards that provide natural shade, carbon dioxide absorption, and a moderate cooling affect (Alonso & O'Neill, 2011; Wood, 2011; Somers & Quirk, 2008). Gramona Vineyards near Barcelona makes sparkling wine which is especially sensitive to heat. To protect fresh harvests from unusually high temperatures, Gramona has begun to harvest it's grapes at night (Wood, 2008).

These forms of adaptation are mostly in response to effects that threaten the *taste* of wine, rather than the yield. Although they will help vineyards adjust to slight changes in growing conditions, they will be

insufficient when more severe increases in temperature and extreme levels of drought make yield and survival of greater consequence. To respond to these demands, vineyards must undertake long term adjustments.

Grape Variety and Regional Shifts

A form of long term adjustment that is occurring throughout European vineyards is the experimental use of different varieties of grapes. Cooler regions are taking advantage of temperature changes and are starting to plant grapes such as Chardonnay and Pinot Noir that were traditionally grown in relatively warmer regions (Roberts, 2008). Vineyards that existed in micro climates ideal for pinot noir in turn are swapping their vines for the more heat resistant zinfandel (Faris, 2011). Of those vineyards that were surveyed in Alonso & O'Neill's (2011) study, 8.5% were experimenting with grape varieties that are more resistant to heat. Particularly innovate was the creation of a strain called 'ruby cabernet' – a cross between cabernet sauvignon flavours and carignan heat resistance that was developed in California (Faris, 2011). Spanish wine maker Miguel Torres, owner of the Bodegas Torres Wine Company, has operations in multiple regions of Spain and is among top national wine exporters. Torres is expecting the relocation of his Merlot vines to northern areas at higher altitude (Wood, 2008). He has also taken precautions a step further and begun to purchase land in the cooler regions of the Pyrenees with the intention of using them for vineyards in the future (Faris, 2011). By these actions, he is using property in cooler regions as a hedge against his 'bets' on climate change. With sales of over 42 million bottles per year, the Bodegas Torres wine company is one of the few wine companies in Spain that can dedicate a budget of this kind towards adaptation to climate change, which also includes five million Euros towards offsetting company emissions (Faris, 2011). Similar regional shifts are occurring in other wine growing nations that look to be impacted by climate change, specifically Australia (Alonso & O'Neill, 2011). Jones et al. (2005) similarly noted that "Spatial modeling research has indicated potential geographical shifts and/or expansion of viticulture regions with parts of southern Europe becoming too hot to produce high quality wines and northern regions becoming viable once again". Ultimately, this suggests that the regional landscape for wine growing in Spain (see Table 6 of Appendix) could experience a substantial shift in size, productivity levels, density and flavour through the century. These changes represent the most natural form of adaptation to climate change. To assist wine makers with these changes which can be economically traumatic, better research and policy changes are necessary.

Research and Education

In another precaution to global warming, Bodegas Torres monitors two climate controlled greenhouses to test projected weather patterns on new varieties of grapes:

> *"In one (greenhouse), temperatures are kept at the historic average. In the other, the air is made an average 3 degrees C hotter…half of the vines in each greenhouse are given half the usual amount of water to simulate the drop in rainfall that is expected to hit the region." (Faris, 2011).*

This kind of research and development is imperative for the future of Spanish wines. Jones et al. (2005) concluded their study by suggesting that "focused research is needed in…climate simulations more appropriate for assessing microclimates critical for grape growing". Such research will lessen the trauma experienced by vineyards in the future by better preparing them for the changes.

A viticulturist in Alsonso and O'Neill's (2011) study commented that "From our side we have not adopted any change in the way we grow the vineyards. We have, however, noted certain changes with regard to pests, but we cannot conclude that such phenomenon is related to climate change". This common scenario highlights the need for more scrupulous monitoring of Spanish vineyards to find the

correlation between their health and reduced precipitation or increased temperatures. Clearly, recognizing the symptom is different from diagnosing the cause. Gramona Vineyards north of Barcelona has installed an entire weather station in one of their vineyards that connects to the vines via a series of cables. This monitoring system can then read the sugar and acidity levels and directly correlates them to changes in climate (Wood, 2008).

The two types of research privately undertaken by Gramona and Bodegas Torres are providing valuable information to vineyards in Spain. Their forms of study emphasize how little is really known about the effects of climate change, and also that more scrupulous research is needed. As Alonso and O'Neill (2011) noticed, a substantial class of global warming "non-believers" existed in their survey. Together, stronger education and research will increase preparedness of vineyard collectives. Alonso and O'Neill (2011) summarized their study in saying "the research community needs to double up efforts and closely monitor the effects of climate change on vineyards". Furthermore, "those who refuse to accept scientific fact or are sceptical about the real effects of climate change refuse to alter their operations. Whether this is as a result of obstinacy or fear of change, the need for education at all levels is clearly a factor". The Spanish case is well compared to the Australian case, as Australian vineyards are facing severe effects of global warming as well. However, the relatively new industry in Australia is not as "traditionally entrenched" as that in Spain (Schultz et al., 2010). Research, information and training is readily available to vineyards in the form of the Australian "Grapevine Management Guide" (2008) that uses a collective staff of over 70 experts from throughout the industry. Spain would do well to have an equivalent organization that provides science based vineyard outreach.

GOVERNMENT INOLVEMENT

As seen in the previous sections, only companies such as Gramona and Bodegas Torres have the means to be proactive in response to climate change or to conduct expensive research. With the drop in sales suffered by 64.9% of vineyards surveyed in the study by Alonso and O'Neill (2011), it is clear that the investments required for new viticulture techniques, research and varietal experimentation are too costly for the majority vineyards. Additionally, vineyards in Spain must work under conditions set by EU policies that aim to reduce production and limit the planting of new vines in designated regions. These policies may be prohibitive to movements that are beneficial to an independent vineyard. It becomes clear that for the Spanish wine industry to cope with costs of change, they will need some form of government intervention. This section outlines two fundamental ways that the CMO and Spanish government can assist vineyards in adapting to climate change. The first method discusses protecting vineyards from reduced precipitation by strengthening irrigational infrastructure. The other addresses potential changes in regulation and policy that will help vineyards to adapt.

Irrigation Systems

While vineyards may be able to change varieties of grapes or shade their vines to protect themselves from increased temperatures, very little can be done to protect themselves from the projected 40% decrease in precipitation by 2070. Spanish vineyards are especially exposed to this change as only 25.2% of their total surface is currently irrigated. In the absence of rain only an irrigated system can deliver water to the vines and therefore a more widespread and strengthened irrigation system will be needed. Alonso and O'Neill (2011) recognize that "with the increasing pressures due to population growth and depletion of key natural resources, efficient use of water might be critical in slowing the effects of climate change". To really address the problem of water security, the current irrigation system which is riddled with inefficiencies must be updated entirely. Greenpeace claims that lack of maintenance and out-dated systems result in 18.5% of water being lost due to leaks (Almendral, 2009). Additionally, 45%

of total water extraction in Spain is attributed to illegal wells which are estimated to be over half a million nation-wide (Almendral, 2009).

The Spanish government would be well off to strengthen its irrigational infrastructure; however such an investment cost is unimaginable in the current wake of the Euro-zone crisis and widespread economic austerity. Were the European Union to adopt a more Keynesian approach to the situation, irrigation investment would be of great value to the underproductive Spanish agricultural sector. Iglesias (2009) summarized her study by stating that improved land use and water management were essential to the well-being of the Spanish agriculture sector. Updating the current system will lead to more efficient use of the scarce water there is, while also providing agriculture with water during times of drought. Eva Fernandez, an economics Professor at the University of Carlos III de Madrid, specializes in the field of agriculture and the Spanish wine industry. In response to the possibility of the Spanish government installing an improved irrigation system she notes:

> *The problem with strengthening irrigation systems across the board is that it would increase yields and production, which goes against the main European Union and CMO policies that want to cut down the supply. So I think it is unlikely that they would finance an operation like this. The wine sector is divided into two main subsets. You have high quality wines and low quality wines. The European Union is trying to keep the low quality wine sector in a state of low productivity because especially in Italy and Spain that sector is bloated, so they want to control the production and force prices up. But in southern Spain, if the sherry industry has problems with lack of water the government will do what it can to protect them because they are an important and highly recognized sector in Spain. (Personal Interview, November 10th, 2011)*

Clearly, the Spanish government runs on separate policies that favour quality Spanish wines over lower quality 'table wines'. While the industry benefits from low productivity among poor quality wine producers, it is important to protect the highest quality wines that are the only sector experiencing increased sales in Europe (Bardaji & Mili, 2009). Therefore, to maintain supply levels and to assist highest quality wines adapt to climate change, the Spanish government should prioritize regions for updating irrigational systems. Meanwhile, they may find that their mandate to reduce yields in Spain is in fact being helped by climate change.

CMO Policy

As was suggested in the 'coping mechanisms' section of this paper, Spain should expect a substantial movement in the prominence of "quality" grape growing regions. It is likely that the country will see a movement of grape growing from southern based vineyards to more northern based vineyards, as well as expanded viticulture on the Pyrenees as new regions become viable. To allow for wine companies to relocate, the CMO prohibition on new plantations that is set to expire near the end of 2015 will inevitably have to be modified. It should be noted that major geographical changes in terms of the vineyard landscape may take decades, offering the CMO plenty of time before they are forced to amend the policy. When the time comes, it is possible that prohibition to reduce yields will no longer be necessary. However, for the sake of high quality grapes and their survival it would also be appropriate if limited planting be permitted today. Planting in new regions can be helpful for research purposes and varietal experimentation, and will ease transitions in the future.

In addition to the amendments on prohibition of planting, Spain must consider what it does with its vine removal budget of 252 m Euros, provided by the CMO. As seen in the coping mechanism section, vineyards are in need of financing and subsidies for the sake of research, education, agricultural changes

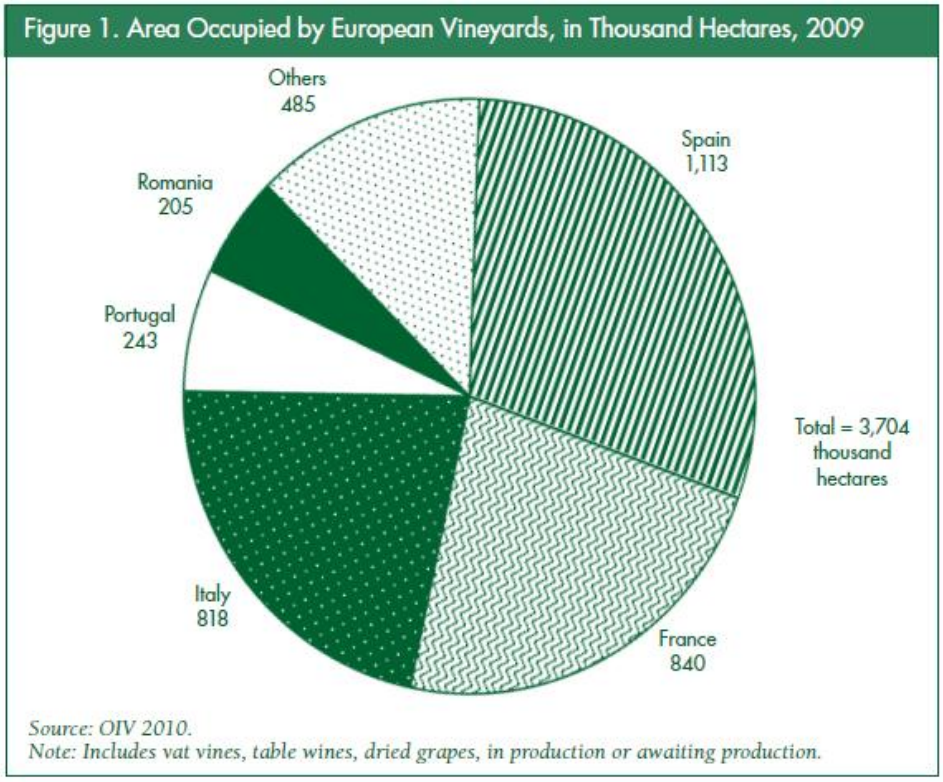
and varietal experimentation. Once again, because of their importance to the wine sector in Spain, higher quality wines should receive priority.

CONCLUSION

As the market for high quality wines grows outside of Europe, European producers must adaptive to remain competitive. Despite threats from climate change, the Spanish wine industry and the regulatory bodies that govern it can increase its preparedness for the changes ahead by investing in research and education, as well as irrigational infrastructure. Further research should investigate the usage and quality of irrigation systems in regions with high quality vineyards, as they are the most valuable to the industry and should get priority. Furthermore, regulatory bodies could amend their policies to give vineyards greater leeway in movement and research. CMO funding for vine pulling would be more effective in areas of research and education such as an issue of a Spanish 'Grapevine Management Guide". The vineyards themselves can stay adaptive by experimenting with different varieties of grapes and different agricultural techniques that will keep their grapes healthy. There is no doubt that climate change will affect this sector of agriculture by reducing rainfall and increasing temperatures. Should Spain's vineyards follow the necessary requirements for coping with climate change, and receive governmental help along the way, they may find themselves leading in the market for quality wines in the years to come.

APPENDIX

Table 1: Area Occupied by European Vineyards (2009)

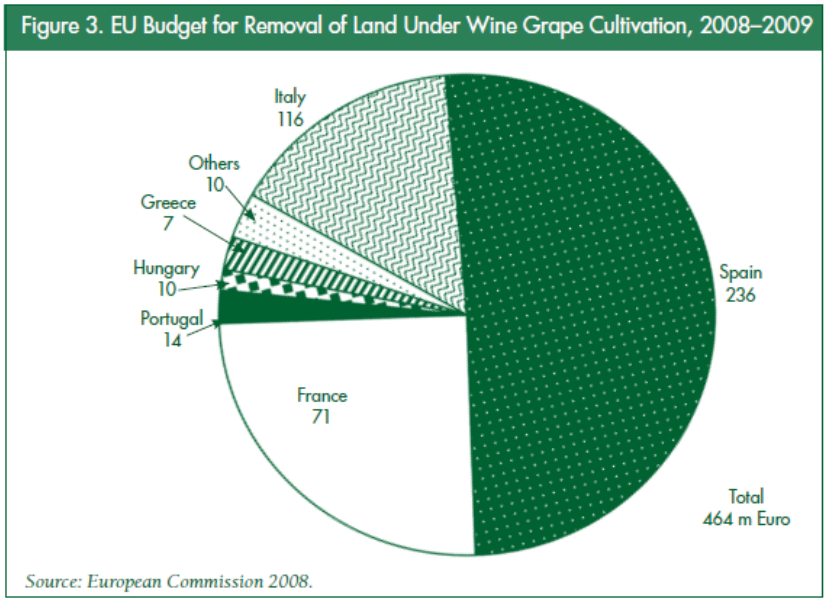


(Montaigne, 2010)

Table 2: European wine exports (1960-2008)

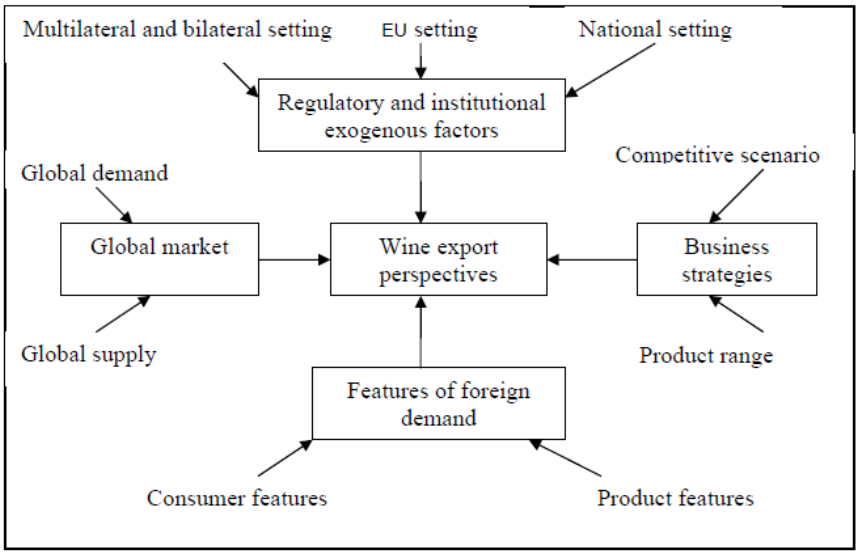
(Montaigne, 2010)

Table 3: EU budget for removal of land under wine grape cultivation (2008-2009)



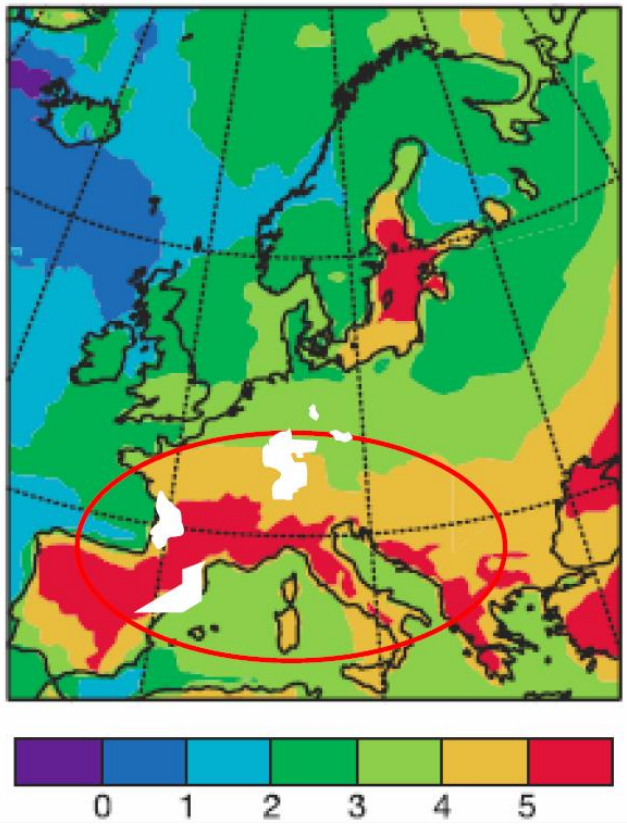
(Montaigne, 2010)

Table 4: External forces affecting wine exports



(Bardaji and Miri, 2009)

Table 5: Predicted temperature increases in degrees Celsius (2100)



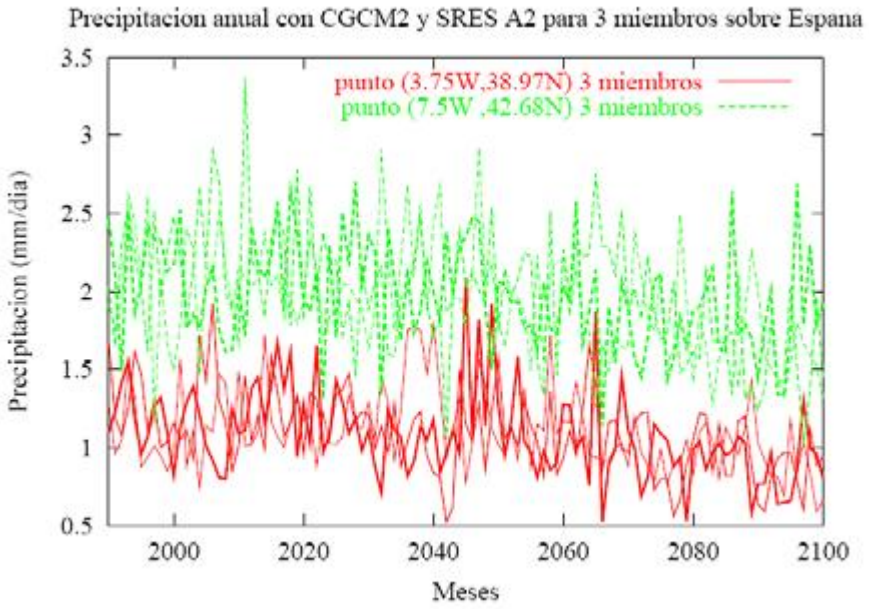
(Schar and Jendritzky, 2004)

Table 6: Wine growing regions in Spain

Source: espavino.com (Used of map allowed by the web site host)
http://www.espavino.com/spain_wine_region/spanish_wine_regions.php

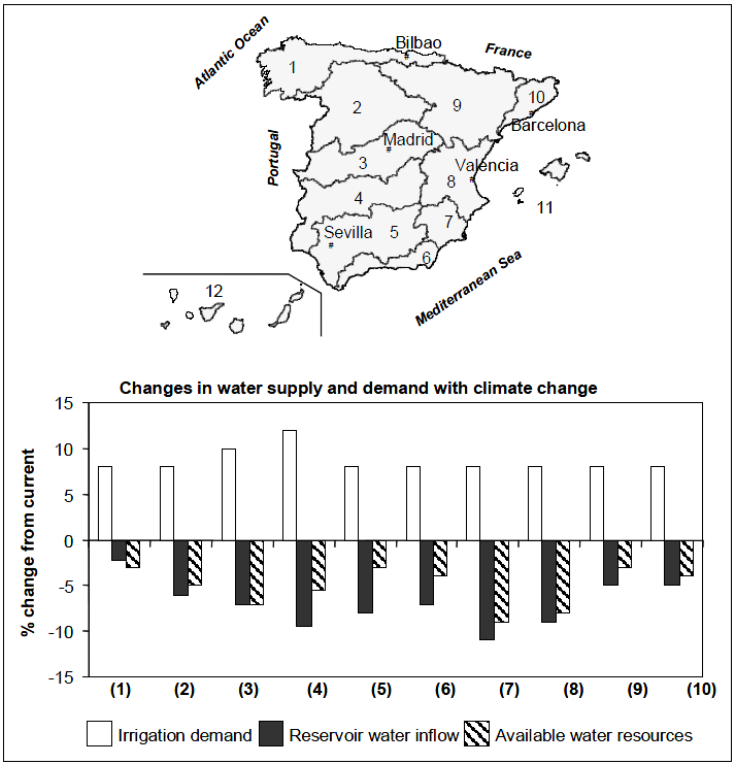
(Alonso and O'Neill, 2011)

Table 7: Projected precipitation levels in Spain (millimetres per day)



(Agrarian technological Institute, 2006)

Table 8: Changes in water supply and demand with climate change



(Iglesias, 2009)

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