Weather Variables Predicting Wine Price in Bordeaux. Evidence from Web Data

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Abstract

◦*Purpose – Understanding the effects of weather on wine price in Bordeaux wine region. Testing the annual return of the hypothetical portfolio constituted by the examined wines.*

◦*Design/methodology/approach - Understanding the effects of weather on wine price in Bordeaux wine region. Testing the annual return of the hypothetical portfolio constituted by the examined wines.*

◦*Findings – Temperatures and rainfalls are the most important determinants of wine prices. Bordeaux wine region presents mixed results between being a winner or a loser in the past 70 years. From a climatic perspective it is a loser, from quality and price it is a winner. Therefore, adaptation measures are able to contrast and contain climate change in Bordeaux wine region*

◦*Practical implications – Check the status of the climate change problem in Bordeaux wine region.*

Key words: -

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1. INTRODUCTION

Wine economics is a vast and well established subfield of economics that aims to study the production, distribution, consumption, and trading of wine. One of its subfields focuses on the relationship between wine price and its determinants. Determinants on the price of wines reserved to the retail market are manifold and their research represents a big part of the literature. Wine producers set the price of their products before releasing them into the market. Year by year, price can increase mainly due to market demand and to ageing potential. At the beginning, when price is set by producers, this can depend a lot on the vintage quality, which is mainly given by weather conditions throughout the year. On top of that, other important factors often examined in the literature are the producer's prestige and history, the viticultural area from whence the wine comes, the terroir, and the sets of techniques that are used in the overall wine-making process. Ultimately, however, the weather can have a significant impact on the quality of the vintage and, therefore, on its price. A wrong timing in which rainfalls occur, or too much drought in August, or a severe frost in the growing season are just some of the factors which can have a detrimental effect on grape quality; all of these elements will be reflected on the price. On the other hand, a perfect vintage can push the wine price up to as much as double from year to year. Ashenfelter (2008) finds that the difference in price from year to year can be of a 20 times factor. As an example, in the case of Château Petrus in my dataset, it is around 7 times.

Different techniques are used to explain the variability in wine price. Hedonic price theory is one of the most used techniques. It normally involves a two-step procedure, in which a hedonic function is estimated in the first stage, normally through a regression; next, in the second stage, the implicit price of a specific factor is derived as the partial derivative of the hedonic equation with respect to that specific factor. Normally the equation also is run with the constraints of a buyer's set of preferences and income. Hedonic price theory is extensively used in several different markets and for a large number of goods. It has also been used in fine wine market to gauge the impact of different factors into wine price. Outreville and Le Fur (2020) present a detailed review of the different categories of variables used within the hedonic framework. The different hedonic price functions and wine price determinants can be manifold. Wine quality, normally assessed through a rating system, ranging from 0 to 100, from 0 to 5 or from 0 to 20, is one of the main factors in determining wine price. Wine quality is given by the weather throughout the year and by the ability of the producer to manage the overall wine-making process. The use of wine quality directly in the equations to estimate wine price could present a possible endogeneity problem. Indeed, wine quality can be endogenous to wine price with a reverse causality problem, the rating being higher for high price wines; or with an omitted variable problem, the price of the wine being explained by other factors than quality, which are not present in the model and thus not easily measurable, but that are correlated with the rating. The producer ability can be one of them. To avoid a possible endogeneity problem using wine quality directly to predict wine price, I use a mix of weather variables, mainly temperatures and rainfall, occurred at different times of the year. These variables are exogenous to wine price, and they are a good proxy for wine quality. I also use a variable, called Age, which represents an index for the age of the vintage, and that it can be seen as the real rate of return for storing the hypothetical portfolio constituted by the wines examined. Climate data are retrieved from the European Climate Assessment and Dataset (ECA&D) which is a gridded climate dataset containing information about temperature, rainfall, humidity, solar radiation and other variables. It covers the area: 25N-71.5N x 25W-45E. Cornes et al. (2018) build this dataset using gridded fields at a spacing of 0.25° × 0.25° according to the latitude and longitude coordinates. Wine prices are taken from Wine-Searcher and are readily available online on the website.

2. LITERATURE REVIEW AND PROBLEM STUDIED

The literature review starts with the aim of categorizing the vast set of wine price determinants normally used in the literature to explain price differences. To the best of my knowledge, the most comprehensive and up to date review of all the wine price determinants is offered by Outreville and Le Fur (2020) who have identified a list of 117 papers written in the period 1993-2018. They carry out a detailed review of the different categories of variables used within the hedonic framework and they divided the wine price determinants in 3 main sections: geographical and agricultural factors, temporal factors, and public information.

Hedonic price theory is recently attributed to Lancaster (1966) and Rosen (1974), but it traces back to at least Court (1939). According to Outreville and Le Fur (2020), research on wine price determinants, through the use of hedonic price modelling, is attributed to Ashenfelter (1986) who launched a newsletter called Liquid Assets - The International Guide to Fine Wines, with the aim of applying quantitative methods to fine wine. Since the Ashenfelter paper in 1986, more than a hundred papers are published on wine price determinants, most of them underpinning the hedonic framework. Hedonic price theory normally involves a two-step procedure, in which a hedonic function is estimated in the first stage, normally through a regression; next, in the second stage, the implicit price of a specific factor is derived as the partial derivative of the hedonic equation with respect to that specific factor.

Regarding the financial aspect of the wine, Le Fur and Outreville (2019) offer one of the most recent and up to date review in the context of fine wine investment. The fine wine return is analysed in more than 40 papers, and the authors make a review of fine wine investments in a mixed-asset based portfolio or in a wine-only portfolio. In both cases, returns are always positive. Fogarty (2006) applies hedonic regression to wine price using the Australian auction house Langton data, to shed light on the Australian market. The study is conducted over a period of ten years, from 1990 to 2000, and the data are quarterly. On average, returns per quarter amount to 2.35% with a standard deviation that is equal to 4.42%. The result says that the finest wines are the one with less risk compared to the one that are less expensive. Although the study shows that there is always some value in putting wines into mixed asset portfolio, Fogarty and Jones (2011) points out that caution must be taken when investing in wines to diversify the portfolio. The potential diversification benefit can vary a lot depending on the way the index prices are built, and the diversification method used. A classification and comparison of different wine returns estimation techniques can be found in Fogarty and Sadler (2014). The authors exploit the same dataset used in Fogarty (2006) for Australian wines with two additional years, so from 1988 to 2000. The dataset consists in 14’102 sale observations from the auction house Langton. On this dataset, the authors apply 6 methods to estimate the wine price returns, 4 of them which are regression based and 2 of them that are non-regression based. The four regression models are: hedonic regression, the repeat sales model, the hybrid model. The 2 non-regression models are the Average Adjacent Period Return Model and the Commercial Index Model. The best trade-off between complexity and accuracy of the model is expressed by the pooled model.

Wine is an agricultural good, therefore it is subject to the conditions of the weather throughout the year. The impact that the weather can manifest on the final quantity and quality of the berry, and so on the final wine, is especially important during the growing season; and there are some moments, like veraison and harvest, that is crucial. As it is well known, according to Jones et al. (2005), there can be winners and losers from any climate change. Storchmann (2005) uses a unique dataset containing data on the Schloss Johannisberg winery in Rhine Valley over more than 300 years, from 1700 to 2003. The authors convert the verbal quality assessment into 5 quality ranks using an ordered probit model. A 1% increase in temperature in the growing season is able to produce an increase of 20 to more than 50% in the probability of being ranked number 1 into the 5 ranks system. The conclusion is that the global warming is able to ameliorate the wine quality in the Rhine valley. Ashenfelter and Storchmann (2010) use a hedonic solar radiation model to assess the effect that climate change has on the quality of vineyards in the Mosel Valley in Germany. The structural model of solar radiation is able to measure the amount of energy collected by a vineyard. Then, an econometric relation between energy and vineyard quality is established. The hedonic equations is equipped with heat and energy variables, and it allows for an assessment of the temperature impact on the quality and price of the wine. Therefore, temperature and solar radiation relationship can be used to forecast the effect that climate change has on crop and price of the vineyard. The authors also use time series variation of the temperature to study the impact of the temperature on land and crop prices. Both methods reveal that highest temperatures will increase the value of the land. The increase in temperature will make the grapes riper. The augmented ripeness in the case of Mosel Valley is more than proportionally linked with wine revenues growth. Under a stress scenario of a 3°C increase in temperature, the study finds out that the vineyard would almost double its value; on the other hand, under a scenario of 1°C increase in temperature, the vineyard value will increase by more than 25%. Therefore, according to the theory of the winners and losers by Jones et a. (2005), Mosel and Rhine valley are both potential winners in the climate fight. Chevet et al. (2011) use a unique dataset covering 209 years, from 1800 to 2019, to study the effect of climate on a single Chateaux in Pauillac. Finally, Ashenfelter (2017) applies hedonic regression to the value of the land to find out which land become more or less suitable after the impact of climate change. After establishing the econometric relationship between climate and quality, these equations can be applied to other area. The relationship is first established for Burgundy Bordeaux, Rioja, and the Piedmont, and then applied in Czech Republic.

3. RESEARCH OBJECTIVES

Weather plays an important role in determining the potential quality of future wine and its price. The first aim of this paper is to test whether wine price in the Bordeaux region can be predicted by a combination of weather variables. If it can, these variables can be used to predict wine price as soon as the growing season is terminated. The second goal of this paper is to measure whether the Bordeaux wine region is an overall winner or a loser in the fight against climate change in the past years, according to the theory of winners and losers by Jones et al. (2005). It is very interesting and difficult to understand if it is a matter of climate change by itself, or if the producer ability has somehow increased over the years with the help of new technologies or with an increased use of adaption measures. It is interesting to note that from 1990 to 2019, the average quality of vintages is steadily above 80 points, with an average of 90 points as it is shown in the Figure 1 below. From 1960 to 1999, so over the same time frame of 30 years, but in the previous period, the average is 78 points. Therefore, what is causing the 12-point difference? Is it just due to climate change, and if so, Bordeaux is momentarily a winner, or is it driven by something else, such as increased producer ability, new technologies adopted, or, maybe, by a relaxation of the vintage score criteria? The vintage score is an average given by most influential wine critic journals around the globe, like Wine Advocate by Robert Parker or Wine Enthusiast, or Wine Spectator, whose opinions are highly recognised and valued. One thing is clear, that the variability after 1993 is diminishing significantly. Of course, high scores are present before 1993, too, as the notable 1959, 1961, 1982, and 1990 vintages show, but they are far less compared to recent years and there are a lot of bad vintages as well: there are 10 vintages below 65 points which is considered a very bad vintage score. After 1993 there is not one single vintage below 80 points. The variability is clearly decreasing significantly, so what is happening after 1993? After 1993 there is a period without vintages scoring below 82 points. The average over the entire period, from 1952 to 2019, is 83.

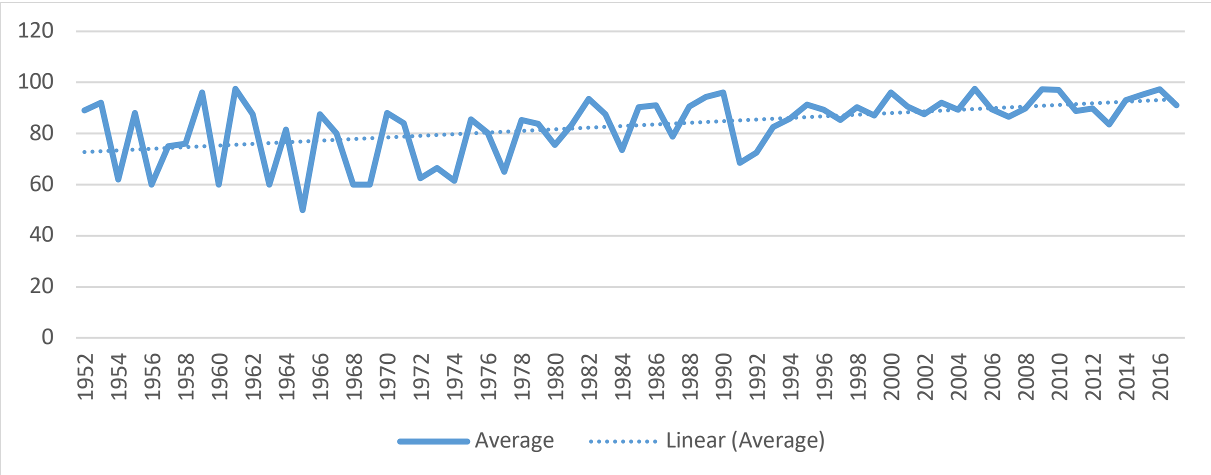

Figure 1: Vintage score from 1952 to 2018 in Bordeaux Wine Region

Finally, the third aim of the paper is to test how much is the annual return of the hypothetical portfolio of the 23 Chateaux taken from Wine-Searcher. This will be benchmarked with previous results.

4. RESEARCH METHODOLOGY

The model is specified in 4 regressions of an index representing Wine Price as dependent variable and weather variables and Age as predictors:

$$WP_i = \alpha + \beta TG_i + \mu Age_i + \varepsilon_t \quad \text{(eq.1)}$$

$$WP_i = \alpha + \beta TG_i + \gamma SM_i + \delta TX_i + \mu Age_i + \varepsilon_i \quad \text{(eq.2)}$$

$$WP_i = \alpha + \beta TG_i + \gamma SM_i + \delta WR_i + \delta TN_i + \mu Age_i + \varepsilon_i \quad \text{(eq.3)}$$

$$WP_i = \alpha + \beta Age_i + \delta TA_i + \mu TA_i^2 + \vartheta TX_i + \pi TX_i^2 + \varepsilon_i \quad \text{(eq.4)}$$

Where WP is the wine price index built regressing the price logarithm of the Châteaux on dummy variables for vintage, year, and Château. TG represents the average temperature from May to September. The higher the temperature, the better it is, as grapes in growing season need a lot of sun to produce sugar that will become alcohol after fermentation. Sun in the Bordeaux wine region is essential as it can be wet and cloudy due to the Atlantic exposure from the West; and, in general, the production of red wines requires a lot of sun, therefore I would expect a positive impact by this variable. SM represents the rainfall occurred in August and September, during the late part of the growing and harvesting seasons. In this period rainfall has a double sword effect. Too much or too little can be detrimental: too much is going to dilute the grapes juice yielding a diluted wine, too little can cause severe drought and can results in an unbalanced and flabby wine. A right amount of rainfall in the right moment can be the difference between a normal or a very good vintage: normally if producers could choose a scenario, they would go for the one where there are not so many precipitations and the sun hits and matures the grapes, therefore the less it rains in this period, the better it is for the price. Although, if the weather is too hot, and without rainfalls, it can be equally detrimental for the grape and have the opposite effect. Therefore, I would expect a negative relationship but not with a high magnitude. TX and TN represent average maximum and minimum temperatures in August and September. They are drawn from a slightly different dataset than TG; indeed, while TG is drawn from the daily mean temperature dataset, TN is drawn from the daily minimum temperature dataset, and TX from the daily maximum temperature dataset. In the case of the maximum temperature, I would expect a positive sign, as a high amount of sun is needed in this period. However, it can have a negative sign as the amount of sun is important, but too much heat can be dangerous, confirming that balance is key when producing wine. In the case of the minimum temperature dataset, the lower the temperature, the better it is for the wine, as acids inside the grapes are able to increase with cool temperatures overnight, thus establishing again the optimal sugar-acid level. Therefore, I would expect a negative sign, as this dataset contains the information of the minimum temperature registered in the day; the higher the temperature, the worst it is for the wine and therefore for its price as it does not reach a lower temperature to cool the grapes and establish the correct sugar-acid level. WR represents the rainfall occurred from October to March, during the pre-growing season. Normally, a good vintage is produced when this season is wet, but not excessively, therefore I would expect a positive sign and not a heavy impact. Age represents the age of the vintage, and it can be seen as the real rate of return to holding the wine portfolio. T represents the average temperature over the entire year, the magnitude of the increase is 1.39℃. The sign of this variable is expected to be positive as well. Finally, TA represents the average temperature in August and September, and I would expect a positive sign as more heat is needed in this period. The second aim of the paper, as already mentioned, is to check whether the Bordeaux wine region is a potential winner or loser in the climate change contest. The first graphs below is representing average temperatures throughout the year; the second is about the total rainfall occurred in a year. The first time series shows that temperatures are increasing over the years. The average temperature in the first 22 years, from 1952 to 1973 is 12.5°C, in the subsequent 22 years is 13.08°C, and in the last 22 years, is 13.9°C. The average temperature has increased almost 1.4°C in the past 66 years, from the first step to the third.

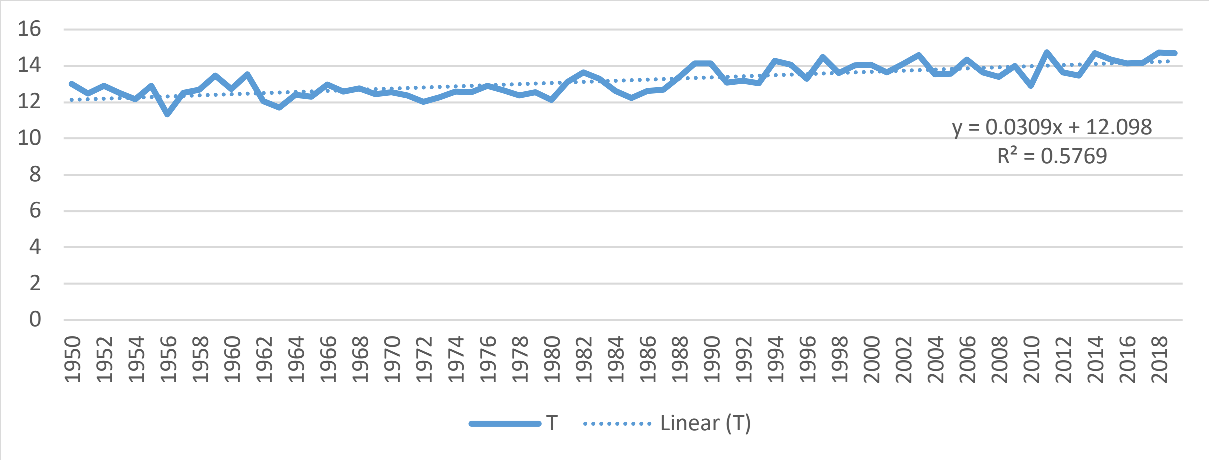

Figure 2: Average Temperature from 1952 to 2018 in Bordeaux Wine Region

In the figure below, rainfalls are plotted. The trend is descending over the entire period. It is interesting to note that, if I take the average in the same time frame as in the temperature case, I have 823, 854, and 768, respectively. Although in the second period there is an increase in the amount of rainfall, in the last 22 years, rainfall is steadily declining. Rainfalls are measured in mm., and they are retrieved from ECA&D.

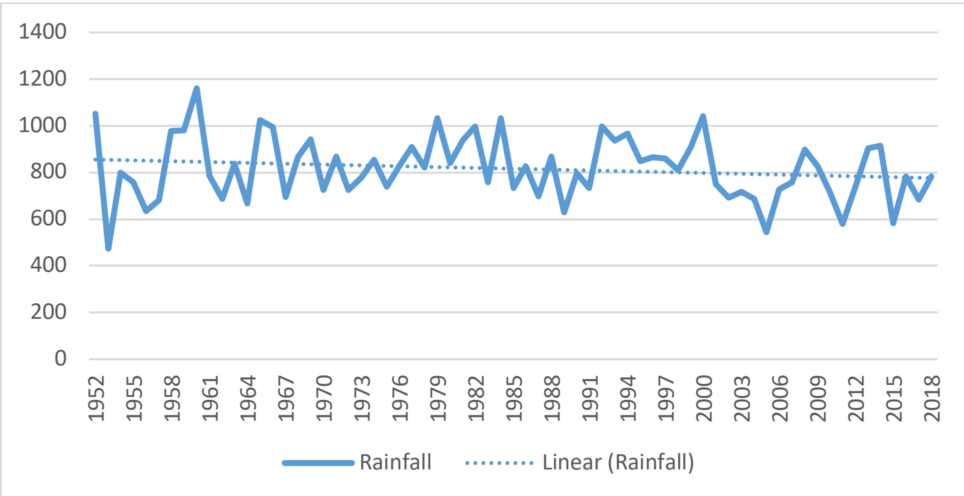

Figure 3: Rainfall occurred from 1952 to 2018 in Bordeaux Wine Region

These 2 variables show 2 effects that climate change is having on our planet on temperatures that are rising, and rainfall that are diminishing. These two factors combined can be detrimental to wine making process; however, winemakers today are able to compensate part of these effects with adaption measures

5. RESULTS

In Table 1, preliminary results are shown. The first, second, and fourth models have a longer time frame, from 1952 to 2014, while the second third (eq.3) is run from 1980 to 2014. The different time span is due to the fact that some of the vintages between 1952 and 1980, are now rarely sold and are not easy to find in the market. From 1980, there is much less variability in the frequency that it is found in Wine-Searcher. Model 1 is run with just 2 variables, Age and

TG both with positive sign. The coefficient on Age variable is positive and around 2%. TG coefficient is positive as well and with a magnitude of nearly 20%. The predictability of the model, given by R2 is around 38%. When the other 2 variables, SM and TX, are added into the model, the predictability grows up to 45.3%. Model 2 has a positive sign for TG, confirming the hypothesis that temperatures from May to September have had a positive effect on wine prices. At this time of the year, heat is preferrable to wet weather because grapes need the sun to burst and complete their growth. Model 2 has a negative sign for SM, which measures the rainfall from August to September; a wet weather in these months is not optimal for prices, as too much rain produces diluted wines. The sign of TX is negative: the average temperature in August and September. Here producers and wine experts sometimes disagree: some of them would expect a positive sign, in accordance with TG variable sign; others instead think of the sign as negative. In model 2 the sign is negative: the higher the maximum temperature, the worse it is for the price of wine. One can argue that too much heat can be bad for the grapes: so, heat is necessary though in reasonable quantity, while, when it is measured by the maximum temperature, it can be detrimental to wine quality and, therefore, to its price. It can cause severe drought whereby wine can have an unbalanced level of sugars and acids. Model 2 has a positive sign for Age. It is interesting to note that Age and TG appear in all of the 3 specifications of the model. In the shortest time frame model, the age coefficient is around 1% whereas in the other two longer time frame models the coefficient is around 2% which is in line with the other results as in Ashenfelter (2008) but less than Dimson et al. (2015). It is interesting to note that in the shorter model, the age coefficient is half compared to the models in the longer time period, meaning that the more you hold the wine, the better it is for your return. In the model with the coefficient of 1%, the return generated of holding the wine portfolio is around 1% per annum over the entire period, so from 1980 to 2014, while it is around 2% from 1952 to 2014. Model 3 estimation period is from 1980 to 2014, therefore with 35 data points. The R2 is almost 61% and it can be higher due to the shorter time frame calibration period. Age coefficient is around 1% per annum, therefore the shorter the time frame, the lower the return you can have from this specific wine portfolio. This makes sense from an investment point of view as older wines should give higher return; the more you keep a wine in the portfolio the higher should be the reward. This is true for Bordeaux wines that are prone to ageing but is also generally true for other red wines that age well. Every red wine has its own ageing curve and given the proper cellar conditions and sometimes a bit of luck, a red Bordeaux wine can age for at least 50 years and there is not really a limit. Some still exceptional old vintages are Château Petrus 1929 and 1945, Cheval Blanc 1947. Model 3 has a positive sign for TG and a negative one for SM in line with model 2. TX variable is not present in this specification but there is WR which measure the average rainfall occurred from October to March. WR here has a positive sign and a small magnitude. As already explained, the rainfall in the pre-growing season is necessary for the correct development of the grapes, although an excessive amount is not optimal, and this is confirmed from the low magnitude. The last variable is TN, which measures the average temperature in August and September and as for TX, this variable is not drawn from TG (daily average temperature), but it is drawn from the daily minimum temperature dataset. Therefore, it measures the minimum temperature occurred in that particular day. This variable is very interesting because it confirms the fact that grapes need to cool down during the night and re-establish the correct sugar-acid level, but again, not in an excessive way, as too much cold can cause acids to prevaricate on sugar therefore resulting in an un-balanced wine. In model 3 there is not TX which is present in model 2; however, the data show that the best meteorological conditions are often in the middle and nor at the extreme. Too little or too much sun, rainfall, and cool nights are often not optimal: what is optimal is a balance between the different combinations of factors. This poses a serious problem due to climate change as it is demonstrated that extreme events are now more frequent than in the past. Model 4 has a quadratic form in it for the variable TA. It confirms the importance and magnitude of variable Age, and it establishes a high relevance of variable T, which is the average temperature across all year. The magnitude is about 30%, confirming the importance of the temperature in the wine-making process: for a 1.0℃ increase, the price of the wine increases by 30%. This is just a hypothetical result, as temperature does not increase every year by 1℃. Regarding the quadratic form that models the variable TA, the maximum is reached at 18.74℃. Beyond this point, and according to the model, prices should start to decrease as excessive temperature can be detrimental to wine prices. However, according to vintage ratings and prices, this is not happening, as there are a lot of vintages, especially after 1993, where ratings and prices are higher. This may suggest that adaption measures are helping vintners in Bordeaux wine region to mitigate the bad effect of temperature increase. In Figure 1 above it is clear how much the vintage score has improved throughout the years. The variability after 1993 has clearly diminished. In and , average temperatures are raising and rainfall declining. The temperature trend is in line with climate change predictions about rising temperatures. As to rainfall, evidence in support of a decreasing trend is more controversial: and there is no consensus over the fact that a lower level of rainfall is detrimental to grapes. The Bordeaux wine region is an example of successful adaptation of local wine production techniques to decreased levels of rainfall. As a result, a number of exceptional vintages is on the rise for the past 30 years.

Table 1: Preliminary Results

Variable	(1)	(2)	(3)	(4)
Age: Age of the Vintage	0.020***	0.021***	0.010*	0.018***
TG: Average Temperature May - September	0.198**	0.349***	0.407***	
SM: Rainfall August - September		-0.003**	-0.002*	
TX: Average Temperature August - September		-0.150*		-8.879***
WR: Rainfall October - March			0.001**	
TN: Average Temperature August - September			-0.235***	
T: Average Temperature over the entire year				0.291**
TA: Average Temperature August - September				10.445***
TA^2: Average Temperature A - S squared				-0.279***
TX^2: Average Temperature A - S squared				0.185***
Constant	-4.675***	-3.413**	-4.760***	3.514
N	63	63	35	63
R-squared	0.400	0.489	0.667	0.554
Adj. R-squared	0.380	0.453	0.609	0.506

6. CONCLUSIONS AND MANAGERIAL IMPLICATIONS

This paper confirms the important effect of rainfall and temperature on wine price. Once the Bordeaux wine region model is perfected, it will be possible to expand its reach by applying it to other wine areas, such as the Barolo, Napa Valley or Chianti regions. The gridded climate dataset, used as an input, contains information about an area covering 25N-71.5N x 25W-45E coordinates, therefore covering most, if not all, the important viticultural areas around the globe. Therefore, an open future question would be to apply the model to other viticoltural area and check whether the same relationships apply. Regarding the climate change fight, the results suggests that Bordeaux is a potential winner in the fight against climate change in terms of adaption measures, but a loser from a climate change perspective. Returns made with the hypothetical portfolio are around 2% per annum in the longer framework, from 1952 to 2014, while it is around 1% from 1980 to 2014.

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