Climate, Grapevine Phenology, Wine Production and Prices: Bordeaux (1800-2009)

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Climate conditions play an important role in explaining all sorts of agricultural outcomes. Temperatures and precipitations during the growing season, wind directions and intensities, the strength of solar radiation, and other climate variables, influence the phenological growth stages of crops. The precise onsets and durations of growth stages in turn influence the yields, qualities and prices. Ultimately, climate thus affects the revenues and profits of farmers, and consumer prices of agricultural products. To predict future values of these variables requires accurate and reliable models on the relationship between climate and agriculture. Recent concerns over global warming and its possible consequences also motivate a good understanding of this relationship.

The wine and viticulture sectors are particularly sensitive to climate variations. Gregory Jones and Robert Davis (2001) have shown that onsets of grapevine growth stages vary significantly with rainfall, hours of insolation, and the number of very hot days. They have argued that the increased temperatures observed in

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Bordeaux are largely responsible for the recent trend in earlier starts of phenological events. Climate also exerts a strong influence on wine prices. Orley Ashenfelter (2008) regresses prices on vintage indicators and weather conditions (cumulated rainfall during the winter, average temperature during the growing season, and total rainfall in the months just before the harvest), and shows that these alone explain more than 80 percent of the price variation in his sample of Bordeaux wines. Victor Ginsburgh et al. (1994) have a sample of Bordeaux wines from Médoc and fit a price equation using monthly data on rainfall and temperature, and the number of days with hail in April. They show that these variables (together with production techniques and soil characteristics) account for about two thirds of the price variation. Jones and Karl Storchmann (2001) study the indirect impact of weather conditions (via their influence on acid and sugar levels of grapes). They include in their price equation–for each phenological stage in the growing season and for the dormant period–the estimated potential evapotranspiration, total rainfall, and the number of days with temperatures more than 25 and 30°C. Once vintage indicators and expert-assessed quality grades are added, their model explains about 97 percent of the price variation. Although these price/climate studies sometimes have somewhat different implications, the overall picture that emerges is that high prices are associated with wet winters and warm and dry growing seasons. Weather variables are also key elements in explaining production yields. John Gladstones (1992) finds that, once technology factors are controlled for, climate is the main determinant of grapevine yields. Jones and Davis (2001) show that amounts of rainfall during certain phenological growth stages have significant effects.

This paper contributes to the above literature by studying two centuries of data that come from the archives of one of the most prestigious Bordeaux châteaux. These archives contain detailed information on several climate variables (daily min-max temperatures and daily rainfalls), yearly starting dates of three phenological growth stages of grapevine, and yearly production yields. We also have a series of wine prices obtained from several Bordeaux wine brokers. A unique aspect of our data is that they cover such a long period. Our empirical analysis is essentially descriptive. We discuss how the different variables of interest have evolved over the two past centuries and investigate how 19th and 20th century climate patterns have influenced phenological growth stages, yields, and prices.

1 Data

The data analyzed in this paper concern essentially one single Bordeaux château. It is located in Pauillac, a district situated some 50 kilometers (30 miles) north-west of the city of Bordeaux. The vineyards are near the Gironde estuary and cover 72 hectares (178 acres). The vines are planted on a sandy-gravelly soil, with no less than 90 percent made up of Cabernet Sauvignon (the grape varieties Cabernet Franc, Merlot and Petit Verdot account for the remaining 10 percent). The unusually high percentage of Cabernet-Sauvignon results in slowly maturing and full-bodied wines. The yearly average production during the period 1920-1978 was around 120 tonneaux of red wine (Cyril Ray 1980).[1] The château is classified as a first growth wine according to the famous 1855 classification[2] and its clarets are widely regarded as among the finest in Bordeaux.

We were kindly given access to the historical archives of the château. From these archives we constructed time series of several variables. We have yearly starting dates of three grapevine growth stages: flowering (when the pollination and fertilization of the grapevine takes place, resulting in the development of grape berries; in Bordeaux this event usually begins in May or June), veraison (when

[1] A tonneau is a frequently used measure of Bordeaux wine production, and consists of approximately 1,200 standard-size bottles.

[2] In 1855 the Bordeaux Chamber of Wine-Brokers was invited to present a classification of Bordeaux wines. They came up with a highly selective list of only 62 estates (out of thousands of domains), grouped into 5 classes. The château studied in this paper is today classified as a first growth wine (together with four others).

grape berries start to soften and change color, signalling the beginning of their ripening process; July or August), and harvest (grapes are harvested when they are fully mature; September or October).[3] We also constructed time series of several temperature variables (monthly average temperatures, average temperatures of growing season, etc.), and a time series of monthly total rainfalls. Finally we compiled a series of yearly yields, defined as hectoliters of wine per hectare.[4] The data from the château records were supplemented with a series of yearly prices obtained from several wine brokers in Bordeaux. These are so-called en primeur prices paid by brokers to the château owner a couple of months after harvest, typically in spring, when wine is still maturating in casks and not yet bottled. Prices are per tonneau and are converted into 2009 euros using cost-of-living indices (19th century indices from Maurice Lévy-Leboyer and François Bourguignon 1985; 20th century indices from the French Institute of Statistics, INSEE). All time series at our disposal end in 2009 but start at different instants: harvest dates are first observed in 1800, onsets of flowering and veraison in 1830, climate variables in 1896, wine prices in 1839, and yields in 1847.[5]

2 Findings

Figure 1 displays the series of average temperatures between April and September, and cumulated rainfalls between October and September. The months between April and September correspond to the growing season months of grapevine, and it

[3] We do not know to which grape variety the onsets of the three phenological stages refer.

[4] The climate series come partly from the archives of a château adjacent to the one we are studying and from the main Bordeaux weather station located in Mérignac. This is unlikely to pose problems as Sébastien Lecocq and Michael Visser (2006) have shown that local weather data do not add much in explaining wine prices (relatively to using data from Mérignac). The yield data are from the château under study for the period 1924-2009, and from the adjacent château for the period 1847-1923. The correlation between the two yields is 0.86 (calculated over the period where they are observed for both châteaux: 1924-2009).

[5] Each time series has a few missing observations (except the series of yields which is complete).

is essentially during this period that temperatures matter. Rain not only matters during the growing season but also during the dormant period, i.e., the period right after harvest (October until March). As Figure 1 indicates, the overall mean growing season temperature during 1896-2009 was 17.4°C. The coldest growing season was in 1925, with average temperature barely above 15°C, while the hottest season was in 2003 (average temperature slightly above 20°C). That year was marked by exceedingly high August temperatures. 1898 was the driest year: between October 1897 and September 1898 only 472mm of rainfall was measured in Bordeaux. In 1977, the wettest year, there was almost three times more rainfall (between October 1976 and September 1977 cumulated rainfall amounted to 1,360.5mm). Figure 1 also shows that cumulated rainfall fluctuates quite evenly about the overall mean (865.8mm). Regressing rainfall on year, we do indeed not find a significant trend over the observation period. In the temperature data there appear, however, to be some clear trends. Temperatures decline from the beginning of the observation period until roughly 1925, and there is an upward trend starting around 1985 until the end of the period. In the temperature regression the coefficient on year is significantly positive, indicating that, over the whole period, temperatures have increased (this impact becomes more pronounced when regressions are ran on recent periods).

Figure 2 shows the time series of yearly starting dates of our three phenological growth stages. The trajectories have quite similar patterns. They move upwards and downwards in parallel ways and their peaks and dips tend to coincide. The starting dates are indeed strongly correlated among each other (correlation coefficients vary between 0.65 and 0.79 and are significant at the 1 percent level). The overall mean occurrence date for flowering, veraison, and harvest is May 28th (148 Julian days), July 23rd (204), and September 24th (267) respectively. For each phenological stage the earliest observed onset occurred in 1893. In that year, flowering started on April 28th, veraison on June 22nd, and grape-harvest on August 22nd. Although there are no precise and reliable data on the climate conditions that prevailed in 1893, it is known to have been a bakingly hot year. The latest observed onsets did not occur in the same year for each growth stage. The latest occurrence of flowering was in 1879. That year was marked by very low temperatures in winter and spring, and consequently the first signs of flowering appeared only on June 16th. The latest occurrence of veraison was in 1845, a year where the first signs of repining only showed up on August 12th. The latest harvest was in 1816. Historians have called it the "year without summer" and grape-picking began as late as October 28th. Both 1816 and 1845 belong to the Little Ice Age, a period extending from roughly the early 16th century to 1860. The years around 1816 were marked by violent eruptions of several volcanoes (notably the 1815 eruption of the Tambora in Indonesia). These volcanoes expelled huge quantities of dust and ash in the atmosphere which diminished the strength of solar radiation. Consequently average yearly temperature dropped by 0.4-0.7°C in those years (Emmanuel Le Roy Ladurie, 2006). 1845 was a cold and humid year which drastically slowed down the growth process of grapevines in Bordeaux.

In none of the time series displayed in Figure 2 there appears to be a clear monotonous trend. This impression is confirmed for the data on flowering and veraison, but not for those on harvest. Indeed, when starting dates are regressed on year, a significant time-effect (5 percent level) is found only in the harvest regression. The effect is positive but modest since our estimate implies that, between 1800 and 2009, grape-picking has been delayed by only 0.03 days per year. When our harvest regression is performed exclusively on more recent data (observations from the last six or seven decades only), the time-coefficient turns significantly negative (implying that since the 1940s or 1950s harvests have been advanced by about 0.2 days per year). These observed trends in grape-picking dates are interesting in light of a literature that uses historical data on grape-harvests to reconstruct spring-summer temperatures. The process-based phenology models developed in this literature predict high growing season temperatures when harvest is early and inversely (see for example Isabelle Chuine et al., 2004).

Following this literature, our findings suggest that average spring-summer temperatures have augmented if the analysis is focussed on recent time periods (last six or seven decades)–confirming the conclusion obtained from Figure 1–but have instead slightly decreased according to a more long-run statistical analysis (last two centuries).

Figure 3 displays the series of yearly yields and prices. The average yield over the observation period 1847-2009 was 23.58 hectoliters per hectare. The lowest yield was observed in 1854 (2.82hl/ha) and the highest in 1973 (62.34hl/ha). Between 1853 and 1856 many vineyards in Pauillac were infected by powdery mildew (also called oidium), a disease caused by fungus-like organisms. The disease, caused by low levels of sunlight and high humidity, dramatically reduced productivity levels in those years. 1973 was marked by heavy rainfall during the weeks preceding the onset of veraison (July 23rd).[6] Rain between the end of floraison and start of veraison favors berry growth, which in turn augments yields. Years with early phenological onsets were often productive (a result also found by Jones and Davis 2000). A good example is 1893, the record-breaking year in terms of phenological starting dates (see Figure 2), when one of the highest 19th century productivity levels was reached (26.92hl/ha). In the second half of the 19th century and beginning of the 20th, vineyards were plagued by many diseases. They explain some patterns in Figure 3. The drop in productivity during 1876-1885 can be explained by the presence of phylloxera (insects that feed themselves on the roots and leaves of grapevines) which destroyed many vineyards. The dip around 1890-1892 was caused by two new types of grapevine moth, while the dips in 1910 and 1915 were, again, due to the presence of powdery mildew. Between 1920 and 1960 productivity levels remained relatively stable. They increased substantially thereafter mainly because more and more effective and efficient pesticides are employed. Since around 1990, yields have deliberately been set at lower levels (for example

[6]Rainfall in July 1973 amounted to 128mm, more than twice the average precipitation in that month (49mm).

through “green harvesting” which amounts to picking and eliminating part of the grapes in July) in order to obtain higher wine quality.

For expository reasons Figure 3 displays the logarithm of prices (in levels the graph is not informative since it is practically flat for 19th century prices). On average, a tonneau fetched 31,462 euros. The lowest price paid by brokers during the observation period was for the 1920 vintage (2,124 euros per tonneau) and highest for the 2009 vintage (540,000). Although weather conditions may partly explain these extreme prices, specific economic factors probably mattered more. In 1917, World War I seemed never to end, and in this period of uncertainty a number of well-known châteaux (including three first growths but not the château studied in this paper) contracted with a broker and fixed their prices for the four consecutive years at 2,650 old francs per tonneau. This constrained the prices of other comparable estates through competition effects and consequently, in 1920, the château under study could sell its wines at only 2,400 old francs (2,124 euros). The sky-high price paid for the 2009 vintage can in large part be attributed to increased wine demand from Asia (China in particular). Economic factors may explain other patterns in the price series as well. Between 1819 and 1860 export tariffs were reduced in France. This increased wine exports in particular to England and led to an increase of prices during the period. This effect was reinforced by the commercial trade treaty signed in 1862. The decline in prices between end of 19th century and beginning of 20th is not only due to the various diseases mentioned above, but also to reduced demand from England (more wines were imported from Australia than from France). The boom in prices in the 1940s resulted from widespread speculation during World War II. Prices rose sharply between 1955 and 1973, until the crash of 1974, a consequence of the fact that 1971-1973 vintages were heavily overpriced relatively to quality. But there are also many patterns in the price series that can essentially be explained in terms of climate variations. For instance, the second highest 19th century price was paid for the 1868 vintage (16,744 euros). Since harvesting started on September 8th (seventh earliest harvest date), spring-summer temperatures must have been particularly high in that year. Two of the most outstanding 20th century vintages, 1945 and 1961, were also produced under exceptional weather conditions: 1945 had a warm growing season (18.8°C, eight highest April-September temperature); 1961 had a particularly dry summer (cumulated August-September rainfall was 17.4mm, second lowest precipitation after 1985).

3 Concluding comments

This paper has analyzed 19th and 20th century data concerning a well-known château in Bordeaux. The dataset includes information on weather conditions, starting dates of three phenological stages of grapevine (flowering, veraison, harvest), prices, and yields. We find that phenological events are strongly related to climate in both centuries. In years with extreme weather conditions the phenological events started very early or very late. Yields are also linked to climate variations–in the 19th century often via the appearance of various grapevine diseases–but in the 20th century man-made decisions (fruit-thinning, use of pesticides) also tend to have an effect. Prices and weather conditions are strongly correlated but in both centuries economic factors played a crucial role as well (through commercial treatises, pricing policies, demand variations, speculation).

References

[1] **Ashenfelter, Orley**. 2008. "Predicting the Quality and Prices of Bordeaux Wine." *Economic Journal*, 118(529): F174-F184.

[2] **Chuine, Isabelle, Pascal Yiou, Nicolas Viovy, Bernard Seguin, Valérie Daux, and Emmanuel Le Roy Ladurie**. 2004. "Grape Ripening as a Past Climate Indicator." *Nature*, 432(7015): 289-290.

[3] **Ginsburgh, Victor, Muriel Monzak, and Andras Monzak**. 1994. "Red Wines of Médoc: What is Wine Tasting Worth." Verona: Vineyard Data Quantification Society.

[4] **Gladstones, John**. 1992. *Viticulture and Environment*. Adelaide: Winetitles.

[5] **Jones, Gregory, and Robert Davis**. 2000. "Climate Influences on Grapevine Phenology, Grape Composition, and Wine Production and Quality for Bordeaux, France." *American Journal of Enology and Viticulture*, 51(3): 249-261.

[6] **Jones, Gregory, and Karl Storchmann**. 2001. "Wine Market Prices and Investment Under Uncertainty: An Econometric Model for Bordeaux Crus Classés". *Agricultural Economics*, 26(2):115-133.

[7] **Lecocq, Sébastien, and Michael Visser**. 2006. "Spatial Variations in Weather Conditions and Wine Prices in Bordeaux." *Journal of Wine Economics*, 1(2): 114-124.

[8] **Lévy-Leboyer, Maurice, and François Bourguignon**. 1985. *L'Économie Française au XIXè Siècle. Analyse Macroéconomique*. Paris: Éditions Economica.

[9] **Le Roy Ladurie, Emmanuel**. 2006. *Histoire Humaine et Comparée du Climat. Tome 2: Disettes et Révolutions 1740-1860*. Paris: Éditions Fayard.

[10] **Ray, Cyril**. 1980. *Mouton-Rothschild: The Wine, the Family, the Museum*. London: Christie's Wine Publications.

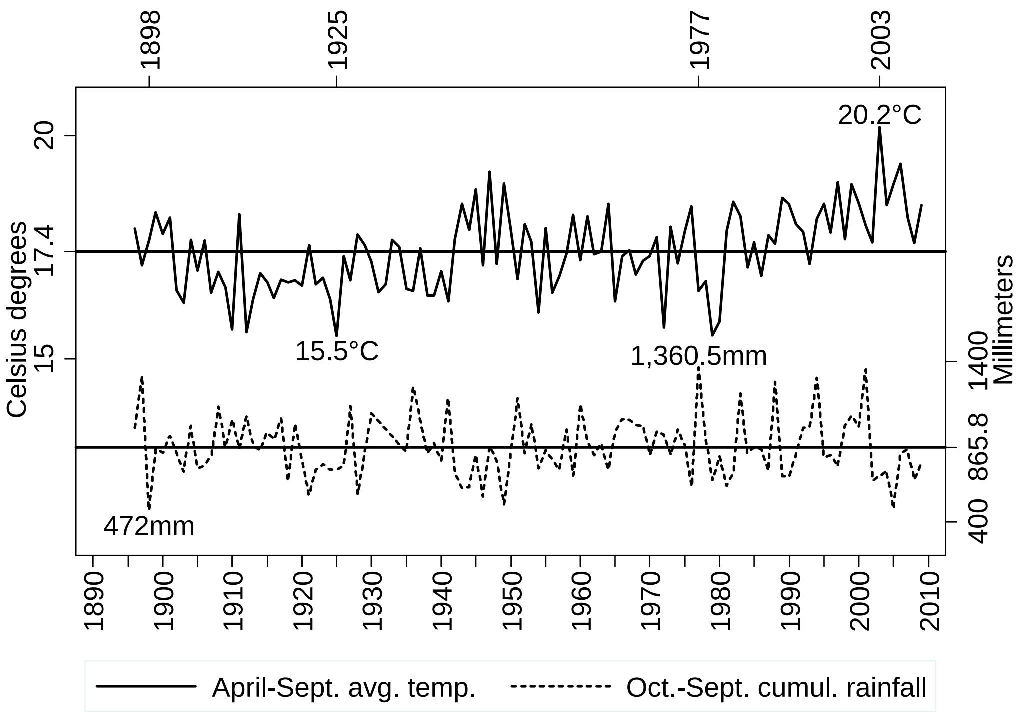

Figure 1: Temperature and rainfall.

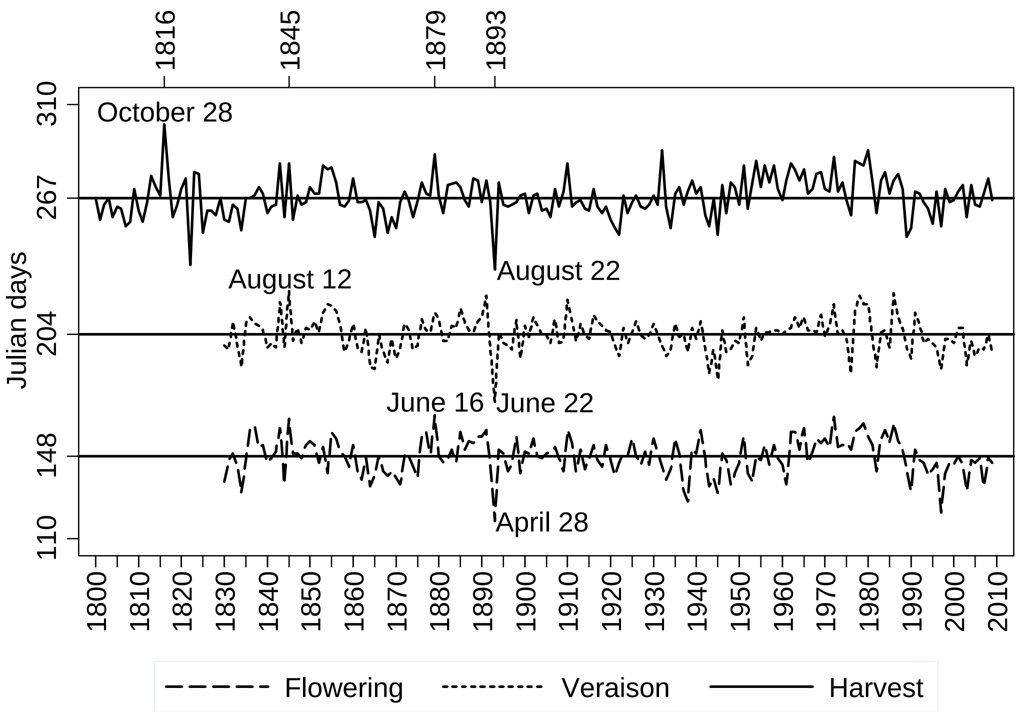

Figure 2: Start of phenological stages.

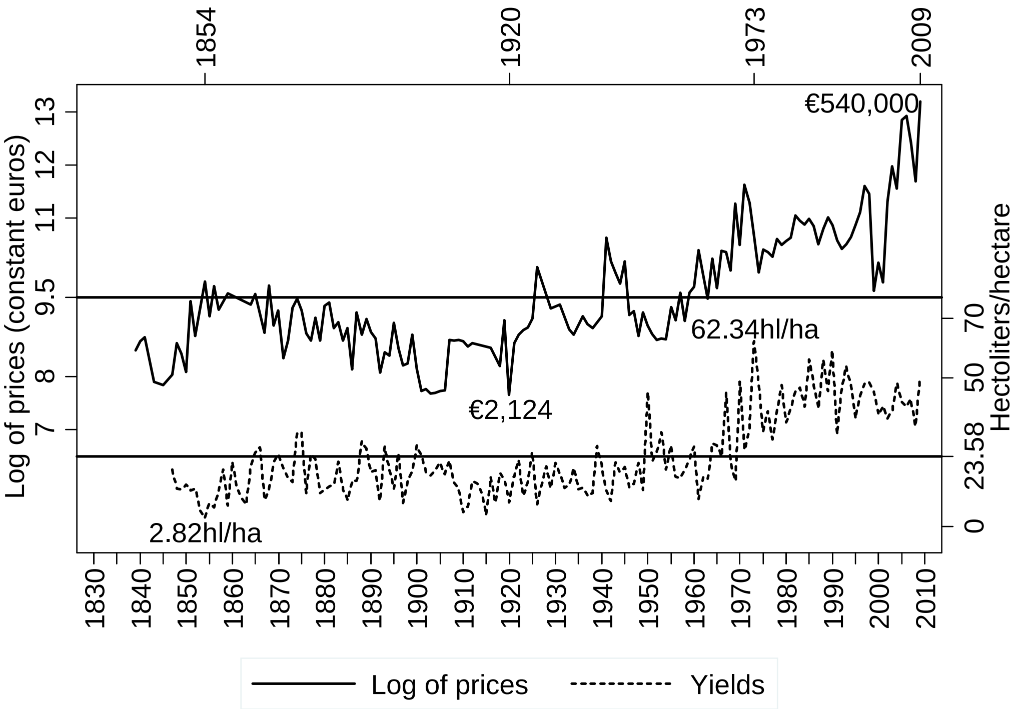

Figure 3: Yearly price and yield.