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Abstract

This paper studies the relationship between the quality of the Argentinean Malbec and the weather in the Mendoza region. The wine data cover the 1995-2020 period and consists of 3,787 observations: Wine Spectator (WS) ratings, suggested retail prices, and wineries. The weather data, unlike previous studies that rely only on temperature and rainfall, also include humidity and cloudiness. Notwithstanding the fact that many weather-related variables are significant, we find that in general the weather variables offer only limited explicatory power for both WS ratings (adj-R^2=0.09) and prices (adj-R^2=0.01). Winery effects prove to be much more relevant when explaining Malbec's quality (adj-R^2=0.20), and weather-and-winery effects combined result in a higher adj-R^2 (0.27). These observations are in agreement with findings from previous studies in regions such as California and Australia, which also like Mendoza, enjoy fairly stable weather patterns.

Keywords: Malbec; Argentinean red wine; wine and weather effects; wine ratings; South American wines; Mendoza red wines

Introduction and Background

This paper explores the relationship between the quality of the Argentinean Malbec and year-to-year weather variations in the Mendoza region. Malbec, Argentina's flagship grape, has its origin in the south-west of France. The grape arrived in the country in 1853 thanks to the French viticulturist Michel Aime Pouget, after an effort initiated by Domingo Sarmiento, a distinguished Argentinean intellectual and political figure (he eventually became president) who intuited the wine-making potential of the Mendoza province (Ministerio de Cultura, 2020).

The Argentinean wine industry has come a long way since its humble beginnings. According to Pablo Lacoste, it took roughly 150 years to produce “a decent wine for export” (Lacoste, 2022). A recent study by Dominique Lee shares this sentiment (Lee, 2018). This author emphasizes that until the1990s Argentinean winemakers privileged quantity over quality and focused on mass production and homogeneity, aiming at producing a cheap table wine for domestic consumption. That changed dramatically in the 1990s with the arrival of French, Italian and California investors. These foreign winemakers reoriented the Argentinean industry to look outwards, and the Mendoza province was a great beneficiary of this influx of capital and technology. Today, Argentina is the fifth wine producing country in the world and exports more than US$ 700 million a year, mostly to the U.S. The Mendoza province, which accounts for more than 70% of the grape production in the country, is almost 85%-dedicated to Malbec. And nowadays, more than 75% of the world’s Malbec comes from Argentina (Instituto Nacional de Vitivinicultura, 2021; Barnes, 2022).

The Mendoza province is located in the central part of the country and is bordered on the west by the Andes. The wine region is situated in the northern part of the province, not far from the capital city (also named Mendoza) whose latitude is 32.8895° S. Most wineries are to be found at elevations that range between 700 and 1,200 meters. In all, the province boasts of almost 40,000 hectares dedicated to the Malbec grape. Mendoza’s climate can be described as Tropical and Subtropical Desert climate (Bwk under the Köppen Climate classification scheme). The average temperature for the year in Mendoza is 17 °C. January is typically the warmest month (average temperatures around 25 ºC) and July is the coolest month (average temperatures around 8 ºC). Annual rainfall averages 224 mm and January is the month with the highest precipitation (World Weather, 2022; Worlddata, 2022).

The relationship between weather (primarily temperature and rainfall variations during the different stages of the grape cycle) and wine quality has been explored previously. It seems that Orley Ashenfelter was the first researcher to investigate this topic. He and his co-authors have found that the average temperature during the growing season, rainfall during summer, and precipitation during the months preceding the vintage could explain an important part of the price variation associated with different vintages (Ashenfelter, 2008). Subsequent studies have validated, albeit with minor differences and nuances, these findings. In general, and not surprisingly, it has been found that in places where the weather changes significantly from year to year (the Bordeaux region is a typical example) the weather has a major influence on the vintage quality. On the other hand, in regions where the weather is more stable (California and Australia, for example), the weather has less explicatory power when it comes to vintage quality.

A recent paper by Outreville and Le Fur summarizes well the literature relevant to wine price determinants (Outreville and Le Fur, 2020). A salient characteristic of these studies is that they have focused mainly on wines from the northern hemisphere with the exception of Australian red wines which have received some attention. However, South American wines have generally been neglected in most weather-quality studies, and indeed, in most studies addressing the link between agricultural and geographical considerations and wine quality.

Recently, however, this tendency –at least in the context of the Argentinean Malbec– has started to shift. A study by Buscema and Boulton, for example, concluded that the phenolic composition of the Mendoza Malbec –a factor that plays an important role in red wine quality– was quite different than that of the California version of this grape (Buscema and Boulton, 2014). Puga et al. investigated the price dynamics behind all Mendoza-grown grapes (not only Malbec), but they did not focus on the weather. They looked at other factors such as transactions volume, the relationship between grape variety and profitability, and the level of financial stress faced by producers in different regions of the province (Puga et al., 2019). Urvieta et al. also studied the phenolic compounds of the Malbec, based on different grapes produced by different parcels. They speculated that despite the vintage effects (different weather conditions) one could identify the parcel of origin based on the phenolic profile of the grape (Urvieta et al., 2021).

Nevertheless, notwithstanding the merits of these studies, the fact remains that when it comes to Mendoza's Malbec the relationship between weather and quality (assessed either via prices or wine ratings) has not been explored. Given the increasing importance that Argentinean wine exports have been gaining in recent years, this topic warrants attention.

Data and Sources

This study considered all the vintages from the 1995-2020 period, 26 vintages in all. The weather data was provided by the Information Center of the Argentinean Meteorological Service (a unit of the Defense Ministry) and it was recorded at the Mendoza airport (Plumerillo) station (32.8331° S, 68.7715° W; elevation, 704 meters).

Table 1 summarizes the key weather statistics. Figure 1 shows that the average temperatures during each of the three stages of the grape lifecycle (winter, growing season and harvest) are fairly stable. Figure 2 shows the cumulative rainfall as a function of the vintage. As it is often the case, rainfall metrics exhibit much more variability than temperature metrics. Weather data also included humidity and cloudiness. (Note: cloudiness is expressed in oktas; level 0, denotes a clear sky; level 8, denotes a completely covered sky).

Information regarding the vintages was obtained from the Wine Spectator (WS) database. In all, we had 3,787 observations corresponding to Malbec and Malbec blends. Each datapoint recorded the wine rating (a score between 50 and 100, with 100 being best); the suggested retail price for the standard 750 cc bottle at the time of release (this figure was later adjusted with the U.S. CPI index to 2020 dollars); and the winery. Table 2 summarizes these data. Figure 3 shows that the Argentinean Malbec, judged based on either ratings or prices, has improved steadily over the years. (The sharp drop at the right end of the curve probably reflects a pandemic-driven anomaly.) Figure 4 displays the ratings histogram. Note that the average rating is 87.2 and 72.2% of the observations exceed 85. These two facts support the good reputation earned by the Argentinean Malbec. In fact, according to the Wine Spectator's opinion wines with a rating of 85 or higher are considered very good wines (Wine Spectator, 2022).

Modeling Approach

In principle, there are two valid proxies to assess wine quality: ratings and prices (Haeger and Storchmann, 2006). However, in the case of the Argentinean Malbec we are inclined to believe that ratings are more reliable than prices as quality indicators. Wine Spectator ratings are established by experienced judges in blind tests, and they are not aware of the suggested retail price. The suggested retail price, nevertheless (as the name indicates), is not really the result of a free supply-demand interaction, but the result of an educated guess based on previous experience and market knowledge. This price is typically suggested by either the producer or the importer. Thus, we have taken in our modeling the rating as a quality indicator.

More precisely, the structure of the model is as follows:

$$R_{p,q} = I + \sum_i \alpha_i \, W_{i,q} + \sum_j \beta_j \, G_{j,q} + \sum_k \gamma_k \, H_{k,q} + \sum_s \omega_s \, \Omega_{p,s} + \varepsilon_p \qquad (1)$$

where R denotes the WS rating assigned to the p observation; p = 1, …, 3,787; q designates the vintage associated with the p observation; I is the intercept; the indices i, j and k refer to the different weather-related variables associated with each stage of the grape lifecycle, that is, *W*(inter), *G*(rowing) and *H*(arvest); α, β and γ are the regression coefficients associated with weather effects; *s* is the index that identifies the specific winery; ω and Ω denote, respectively, the winery coefficient and a dummy (1, 0) that links the *p* observation to the corresponding winery; and ε_p is the error term.

The data included a total of 420 wineries. However, for our model, we only individualized the top 38 wineries (in terms of the number of observations). The aggregate of the wineries we identified in the model with a specific index accounted for 53.82% of the total 3,787 observations.

Results and Discussion

Table 3 describes the relevant variables and the results (heteroscedasticity consistent) obtained with three models, based on the structure specified by Eq.(1): Model 1, includes only weather variables; Model 2 contains only the wineries as independent variables; and Model 3 incorporates both, weather and winery effects.

A first observation is that the weather effects detected by Models 1 and 3 are fairly consistent in terms of the signs and the values of the coefficients, which supports the robustness of the results. A few coefficients are straightforward to interpret. For example, temperatures below freezing during the growing season are known to have detrimental effects on grapes. The negative coefficient associated with this effect reveals that. The fact that during winter the average coefficient for the temperature (T) is positive but that of T^2 is negative suggests that there is an optimal temperature (inverted parabola). Again, a situation which is in agreement with viniculture experience. Previous studies have also found that rainfall during harvest is detrimental (Oczkowski, 2016a; Outreville, 2018). Even though the amount of cumulative rainfall in this case did not reach significance, another variable highly correlated with rainfall, the average humidity, is significant and is associated with a negative coefficient. Also, the negative coefficient linked to the variable Highest T minus 30 °C during the growing season makes sense as temperatures in January and February in Mendoza can easily exceed 30 °C. And excessive heat can either impair grape growth or impede sugar accumulation (Greer and Weston, 2010).

Other coefficients lack a clear interpretation, a situation that has been detected in previous studies. For example, Ashenfelter reported in his study of Bordeaux that the average temperature during the growing season, a proxy for quality, had a positive effect on the price (Ashenfelter, 2008). In our case such coefficient is negative. In general, it is difficult to derive sweeping conclusions from the sign of these values since these coefficients are probably affected (if not totally determined) by the discrepancy between the average observed value and the optimal value based on wine-making considerations and interactions with the other weather variables. Hence, a clear interpretation is not apparent.

Furthermore, these three models reveal the weak relative importance of the weather in terms of explaining the overall quality of the vintages. The modest explicatory power of Model 1 (adj-R^2 = 0.09) is in agreement with the findings of previous authors who have concluded that in regions with stable weather, the weather lacks the explicatory power that it has in regions with important year-to-year weather variations. For instance, Ramirez found in his study of Napa Valley (California) reds, that a weather-only regression resulted in an also modest adj-R^2 (0.03), (Ramirez, 2008). Oczkowski, in a study devoted to Australian reds, also concluded that a weather-only model resulted in a very low adj-R^2 (0.03), (Oczkowski, 2016b). This finding is in contrast, of course, with the much higher explicatory power achieved by weather-only models in regions where the weather exhibits more variability, a phenomenon that has been mentioned by previous researchers. For example, Ashenfelter has reported adj-R^2's around 80% in his Bordeaux study; Outreville, in a similar study of Bordeaux, reported a lower adj-R^2 (0.48) but still much higher than the adj-R^2's reported in the already-mentioned weather-only models (Ashenfelter, 2008; Outreville, 2018).

Model 2 (see Table 3), a winery-only model, clearly indicates the importance of these variables (adj-R^2 = 0.20), specially vis-à-vis the weather-related variables. Thus, and not surprisingly, Model 3, which includes both, wineries and weather, results in a much-improved adj-R^2 (0.27). Again, this situation is very much in agreement with the findings reported by Ramirez and Oczkowski, who saw the respective adj-R^2's of their models to improve from 0.03 to 0.29 and 0.34 respectively, when they added the wineries to their regressions, (Ramirez, 2008; Oczkowski, 2016b).

Versions of Models 1, 2, and 3 (based on the same independent variables, not the same coefficients and not shown in this paper) but using the logarithm of the price as dependent variable, validated the relative importance of the wineries versus the weather. The adj-R^2's were: 0.01, 0.25, and 0.26 respectively.

In summary, the quality of Mendoza's Malbec, is much more influenced by winery effects rather than weather (vintage) effects.

Concluding Remarks

The most important conclusion from these analyses is that in the case of Mendoza's Malbec –even though many weather-related variables are significant– all in all, the explicatory power of the weather when it comes to quality is modest. This finding is not surprising given the stability of the weather in the region. For example, the average temperature during the growing season, an important variable due to its effect on the grapes' development, in the case of Mendoza exhibited a coefficient of variation equal to 0.02 (see Table 1). In contrast, in the Bordeaux region the same metric exhibited a coefficient of variation equal to 0.03, that is, 50% higher (calculation performed by the authors based on weather data downloaded from https://www.ncdc.noaa.gov/cdo-web). More specifically, this conclusion is very much in tune with those derived from studies based on Californian and Australian wines, both of which are also the product of regions with a stable weather.

The high explicatory power of the winery variables vis-à-vis weather variables calls for some reflection. (Recall that the adj-R^2 of the weather-only model was 0.09 while that of the winery-only model was 0.20.) A winery variable is both challenging and interesting because it captures the combined effects and interactions of three possible factors. First, there is the specific chemical composition of the soil where the winery is located. Urvieta et al. in their study of Mendoza wineries concluded that different parcels had a distinctive and unique phenolic profile. Moreover, they were able to identify the parcel of origin of many grapes, regardless of the vintage, based solely on an analysis of the phenolic compounds (Urvieta et al., 2021). Second, different wineries also differ on their level of technological know-how and expertise. And third, their winemaking processes are obviously similar but not identical. For example, a few wineries hand-harvest their grapes while others rely on machine-based harvesting. Also, the type of barrel employed (oak versus steel) makes a huge difference. Note that if one were to rely on the price as a proxy for quality there is a fourth element to consider: marketing and branding.

In short, a winery variable is difficult to interpret because it encompasses several effects at the same time. Understanding the relative weights of each of the factors mentioned, however fascinating, is obviously a topic that goes beyond the scope of this project. Anyhow, it seems clear that future efforts aimed at understanding the drivers behind the quality of Mendoza's Malbec, should focus less on the weather and more on disentangling the nuances of what is behind the "winery effect." We leave that challenge to future researchers.

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Table 1 Weather variables, descriptive statistics

Weather variables	Mean	Std. Dev.	C.V. (σ/μ)	Min.	Max.
WINTER (Jun-Aug)					
Avg. (T), °C	9.21	0.94	0.10	6.90	10.73
Avg. Max (T), °C	16.64	1.00	0.06	14.73	18.02
Avg. Min (T), °C	3.05	1.08	0.36	0.45	4.58
Avg. Monthly Highest (T), °C	25.27	1.77	0.07	21.70	28.87
Avg. Monthly Lowest (T), °C	−2.45	1.39	−0.57	−4.93	−0.03
Avg. Humidity, %	59.00	6.72	0.11	48.47	72.91
Cumulative Rain, mm	16.93	12.90	0.76	0.00	63.00
Cumulative Cloudiness, oktas	273.12	42.69	0.16	225.00	392.00
GROWING SEASON (Sept-Feb)					
Avg. (T), °C	21.96	0.45	0.02	20.66	22.60
Avg. Max (T), °C	28.83	0.68	0.02	27.07	29.96
Avg. Min (T), °C	15.23	0.33	0.02	14.56	16.02
Avg. Monthly Highest (T), °C	36.16	0.85	0.02	34.37	37.72
Avg. Monthly Lowest (T), °C	8.65	0.88	0.10	6.93	10.25
Highest T over the entire period minus 30 °C, °C	10.17	1.60	0.16	7.50	14.40
Lowest T over the entire period, °C	0.86	1.45	1.67	−2.00	3.10
Avg. Humidity, %	45.83	3.90	0.08	40.73	57.17
Cumulative Rain, mm	160.35	58.36	0.36	66.20	303.80
Cumulative Cloudiness, oktas	564.85	52.39	0.09	495.00	742.00
HARVEST (Mar-Apr)					
Avg. (T), °C	19.16	1.08	0.06	16.97	21.52
Avg. Max (T), °C	25.73	1.43	0.06	23.03	29.06
Avg. Min (T), °C	13.31	1.01	0.08	10.90	15.71
Avg. Monthly Highest (T), °C	31.90	1.80	0.06	28.10	34.85
Avg. Monthly Lowest (T), °C	6.44	1.51	0.23	3.80	10.45
Avg. Humidity, %	60.34	5.85	0.10	51.58	74.37
Cumulative Rain, mm	47.35	35.63	0.75	3.80	144.20
Cumulative Cloudiness, oktas	187.00	44.40	0.24	105.00	305.00

Table 2 Summary statistics: Malbec vintages (1995-2020) in the study

Variables	Statistic
Number of Observations	3,787
Number of Vintages (1995-2020)	26
Number of Wineries	420
Average WS Rating	87.23
Standard Deviation of WS Rating	3.82
Minimum WS Rating	55
Maximum WS Rating	96
Average Price (in 2020 US$); 750 cc bottle	37.98
Standard Deviation of Price (in 2020 US$)	39.17
Minimum Price (in 2020 US$)	7.00
Maximum Price (in 2020 US$)	500.00

Table 3 Weather and wineries effects on WS ratings (N=3,787)

		Model 1 (Weather Only)		Model 2 (Wineries Only)		Model 3 (Weather and Wineries)	
		Par. Est.	Std. Err.	Par. Est.	Std. Err.	Par. Est.	Std. Err.
	WINTER (Jun-Aug)						
α_1	Avg Max (T)	−3.11***	0.525			−3.10***	0.485
α_2	Avg Min (T)	−2.03**	0.663			−2.24***	0.622
α_3	Avg (T)	11.06***	3.047			9.55***	2.794
α_4	Avg $(T)^2$	−0.37**	0.139			−0.27*	0.127
α_5	Avg Monthly Highest (T)	−0.61***	0.109			−0.55***	0.099
α_6	Avg Monthly Lowest (T)	1.95***	0.303			1.72***	0.279
α_7	Avg Humidity	−0.28***	0.039			−0.24***	0.036
	GROWING SEASON (Sept-Feb)						
β_1	Avg (T)	−0.94†	0.488			−0.77†	0.443
β_2	Avg Monthly Highest (T)	2.20***	0.273			1.97***	0.253
β_3	Highest T over the entire period minus 30 °C	−0.24**	0.073			−0.22***	0.066
β_4	Number of days with T < 0	−1.65***	0.231			−1.44***	0.212
β_5	Cumulative Cloudiness	0.01***	0.003			0.01**	0.002
β_6	Cumulative Rain	0.03***	0.005			0.03***	0.005
	HARVEST (Mar-Apr)						
γ_1	Avg Min (T)	−1.06**	0.398			−1.04**	0.364
γ_2	Avg Monthly Highest (T)	−0.88***	0.128			−0.78***	0.116
γ_3	Avg Monthly Lowest (T)	−0.65***	0.127			−0.57***	0.117
γ_4	Avg Humidity	−0.95***	0.161			−0.89***	0.149
γ_5	Avg Humidity × Avg (T)	0.05***	0.010			0.04***	0.009

Table 3 Weather and wineries effects on WS ratings (N=3,787) Continued

		Model 1 (Weather Only)		Model 2 (Wineries Only)		Model 3 (Weather and Wineries)	
		Par. Est.	**Std. Err.**	**Par. Est.**	**Std. Err.**	**Par. Est.**	**Std. Err.**
	WINERIES						
ω_1	Winery-1			5.45***	0.252	5.01***	0.251
ω_2	Winery-2			3.86***	0.354	3.90***	0.319
ω_3	Winery-3			5.42***	0.307	5.34***	0.309
ω_4	Winery-4			1.99***	0.445	2.00***	0.360
ω_5	Winery-5			1.27**	0.414	1.55***	0.363
ω_6	Winery-6			1.70***	0.405	1.79***	0.385
ω_7	Winery-7			2.70***	0.438	2.79***	0.448
ω_8	Winery-8			5.93***	0.279	5.90***	0.304
ω_9	Winery-9			0.73*	0.330	0.62†	0.341
ω_{10}	Winery-10			1.44***	0.385	0.98**	0.367
ω_{11}	Winery-11			2.29***	0.351	1.99***	0.348
ω_{12}	Winery-12			1.82***	0.320	1.83***	0.331
ω_{13}	Winery-13			3.65***	0.236	3.39***	0.264
ω_{14}	Winery-14			1.08***	0.248	0.94***	0.240
ω_{15}	Winery-15			2.41***	0.226	1.88***	0.226
ω_{16}	Winery-16			2.32***	0.295	1.99***	0.304
ω_{17}	Winery-17			2.08***	0.254	1.83***	0.262
ω_{18}	Winery-18			1.86***	0.326	1.78***	0.344
ω_{19}	Winery-19			1.34***	0.294	0.99***	0.288
ω_{20}	Winery-20			0.67**	0.251	0.19	0.250
ω_{21}	Winery-21			−0.29	0.306	−0.65*	0.300
ω_{22}	Winery-22			−3.14***	0.247	−3.10***	0.244
	Constant (I)	98.47***	12.034	86.01***	0.093	99.73***	10.821
	adj-R^2	0.091		0.196		0.273	

†*p<0.10; *p* < 0.05; ***p* < 0.01; ****p* < 0.001

Figure 1. Average temperatures by vintage

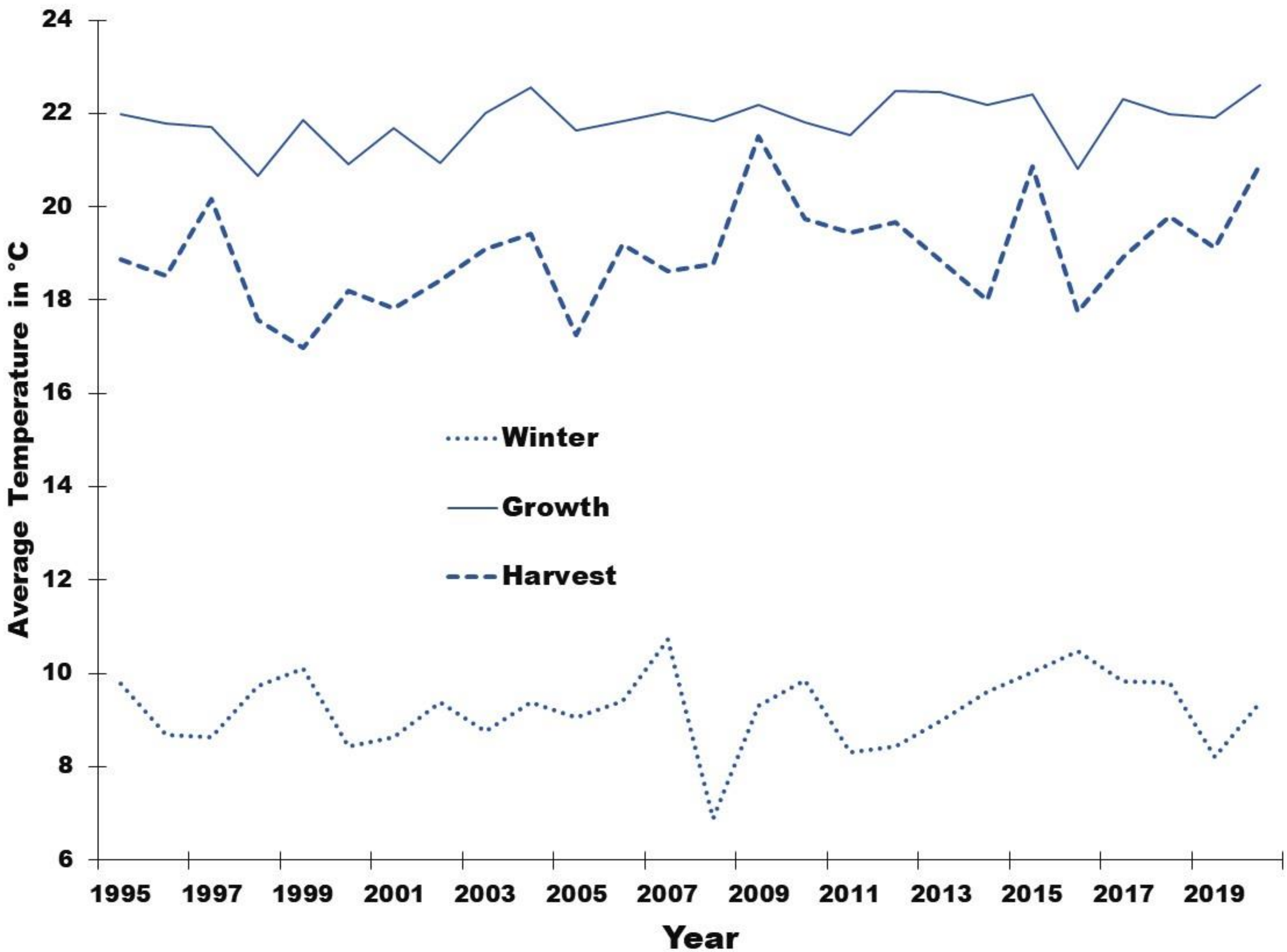


Figure 2. Cumulative rainfall by vintage

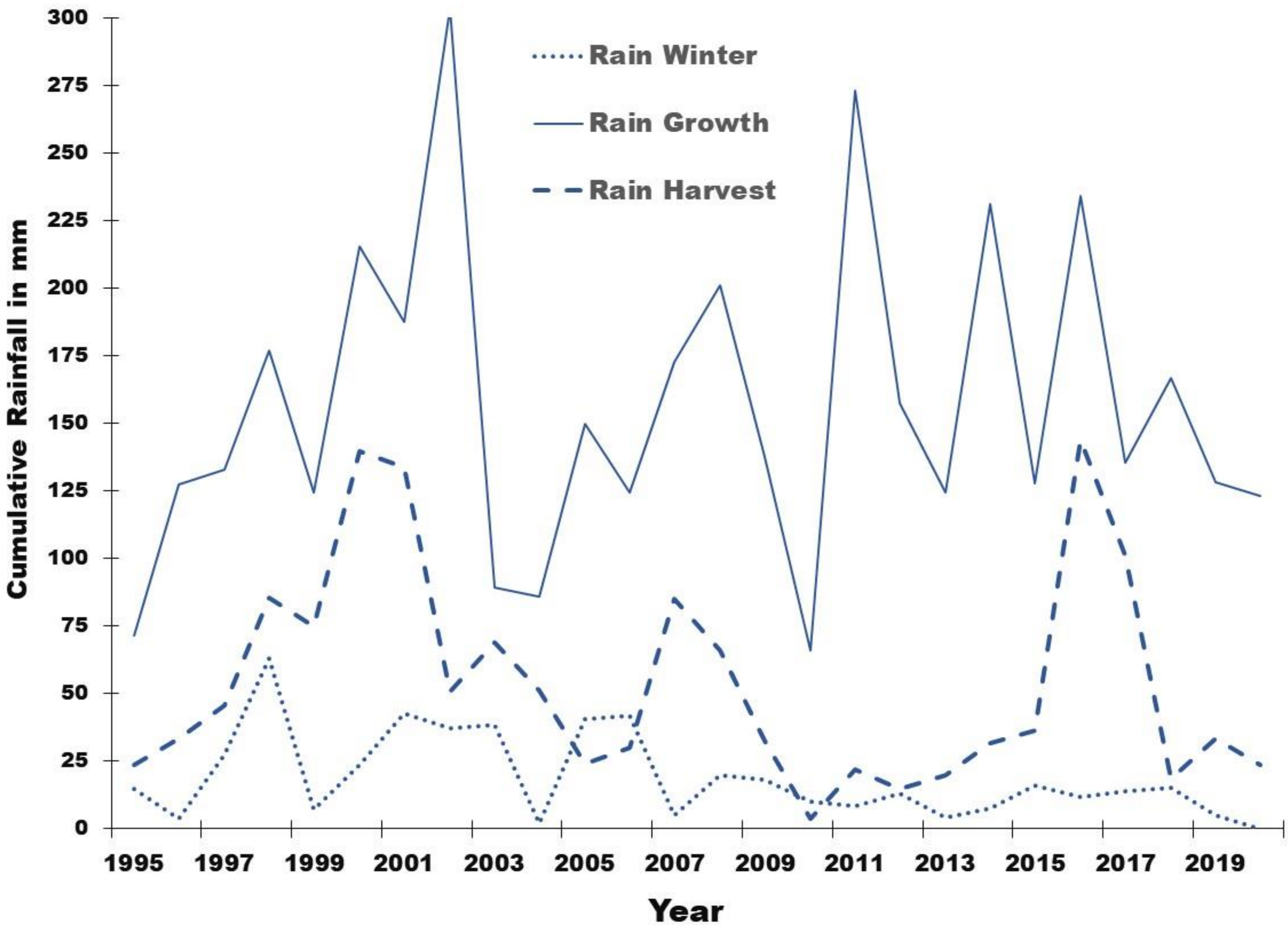


Figure 3. WS ratings and prices (in 2020 US$) by vintage

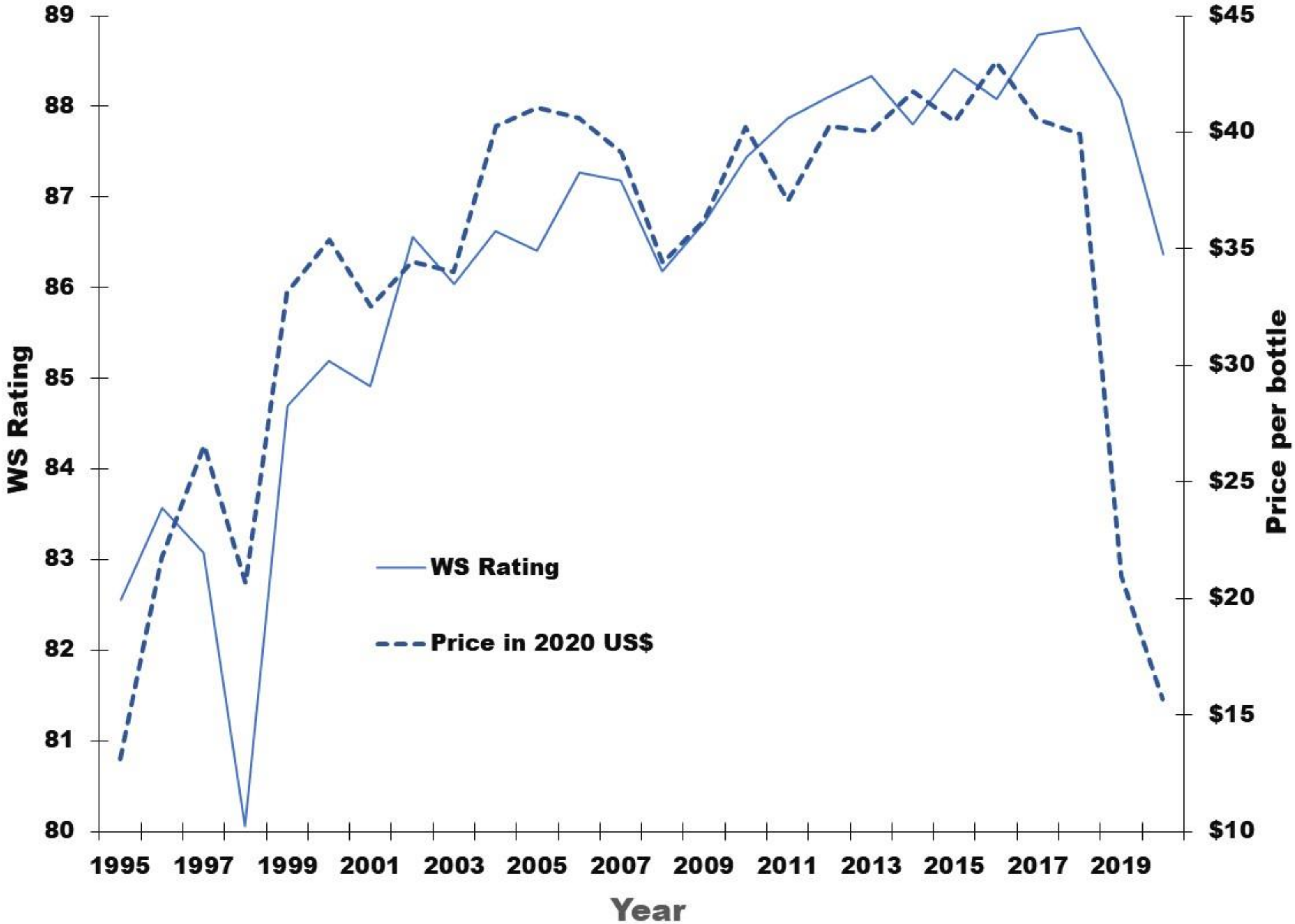
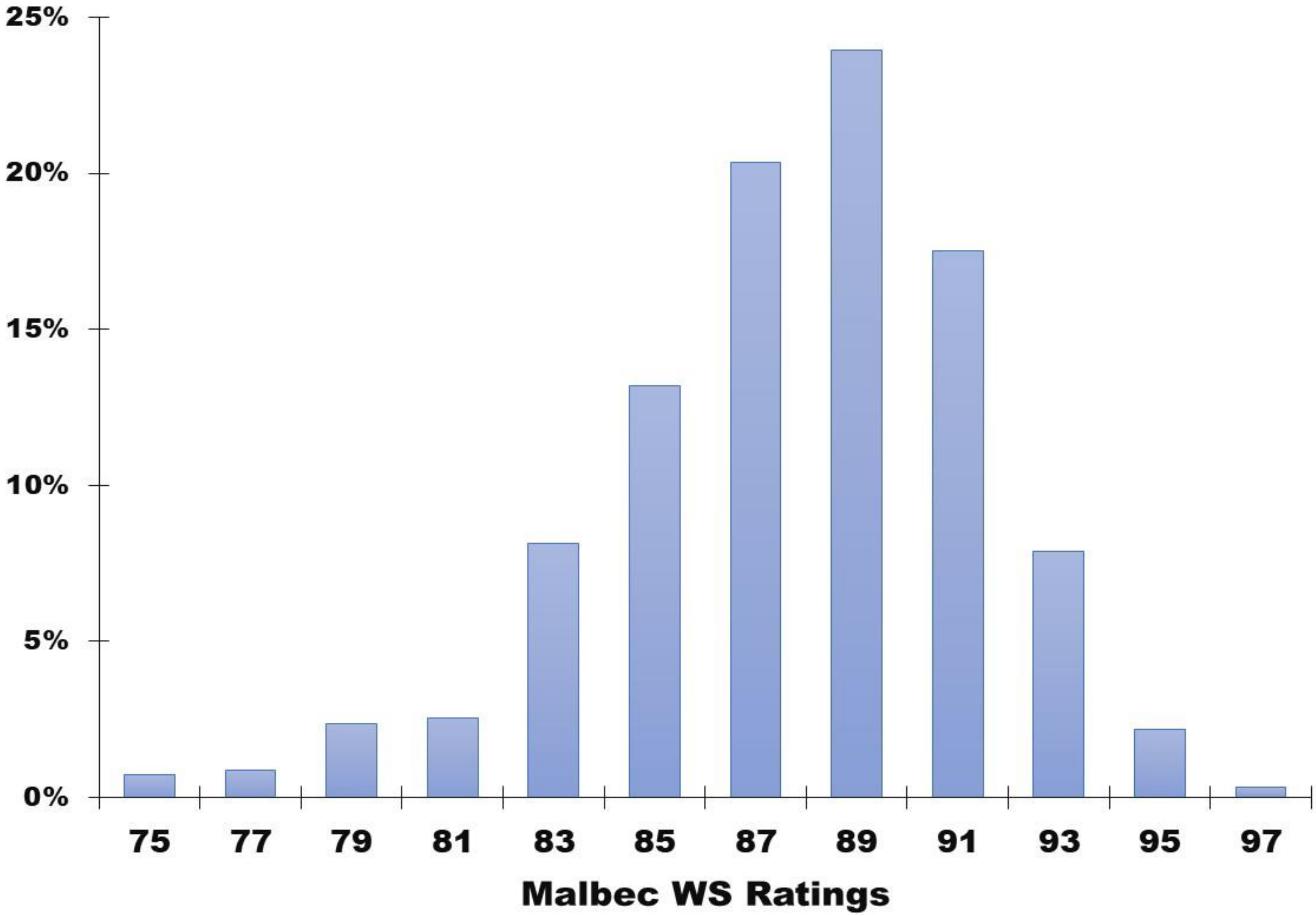


Figure 4. Histogram of the WS ratings in the study



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