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Wine market prices and investment under uncertainty: an econometric model for Bordeaux Crus Classés

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Abstract

This paper describes an econometric assessment of wine market prices for 21 of the Crus Classés châteaux in the Bordeaux region of France. The model developed in the analysis attempts to define the relationship between factors that influence wine quality and those that influence wine prices. Characteristics of the models are: (1) climate influences on grape composition (acid and sugar levels), (2) grape composition influences on market prices, (3) subjective quality evaluations (Parker-points) on market prices, and (4) the effects of age of the wine on market prices.

The results indicate that composition levels of Merlot-dominated wines are more climate sensitive than those from Cabernet Sauvignon-dominated wines. Overall, warm, dry summers result in high sugar and low acid levels at harvest which in turn lead to higher quality wines.

Wine market price sensitivity to Parker-point ratings indicates that properties with high Cabernet Sauvignon-dominated wines are highly dependent on the external ratings while Merlot-dominated wines have a decreased rating sensitivity. Smaller properties tend to gain over proportionally from high ratings indicating great jumps in price from year to year. Additionally, châteaux that have experienced high ratings for past vintages exhibit great sensitivity to point steps in ratings for current vintages.

Aging has a positive effect on Bordeaux wine pricing. This is due to the increasing maturity as well as the increasing absolute scarcity. Absolute scarcity of product is expressed by the size of the property, with small properties producing less per vintage and therefore having less in the market. Additionally, Merlot-dominated wines exhibit more maturing potential and profit more from aging than Cabernet Sauvignon-dominated wines.

Average per château real annual profit ranges from 1 to 10%. High levels of grape ripeness, absolute scarcity, and smaller properties that are dominated by Merlot in their blend lead to the highest profits. Forecasts for a vintage not yet on the market indicates that 1995 is better than 1994 for both Cabernet Sauvignon and Merlot-dominated wines, but that 1996 and 1997 are not as good as 1995, especially for Merlot-dominated wines. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

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Wine aficionados' and collectors' interests have been raised by the sensational prices which old

wines sometimes achieve in auctions. Since many of the famous red wines like Châteaux Margaux, Mouton-Rothschild, Lafite-Rothschild or Petrus, which the average wine consumer has probably not experienced, but certainly heard of — this occurs especially to Bordeaux wines. The interest of professional investors in Bordeaux wines has increased dramatically in the last few decades because the profit yielded per year can be tremendous. According to a ranking of the best investment-wines of 1996, yields of 500% and more are routinely achieved (Blättel and Stainless, 1997). Therefore, the economic literature has begun to examine this theme with the goal to recommend appropriate investment strategies and portfolios (i.e., Schubert, 1996). In general, these recommendations are based on experiences of the potential for the development of certain wines and on intuitive knowledge of the product. Even with this increasing interest in wine investment, empirical studies on wine pricing are still rare. This lack of economic assessment is in fact amazing, first, because of the wide spread variance of the prices of single châteaux, and secondly, in respect to the variance within single vintages. For example a bottle of Château Cheval Blanc from the 1972 vintage is available for less than 20US-\$, while the 1982 vintage from the same château costs about 500US-\$.

Two of the rare empirical investigations on this topic are those of Combris et al. (1997) and Ashenfelter et al. (1995). After estimating a hedonic price function for many Bordeaux wines, Combris et al. (1997) come to the conclusion that wine prices are rarely caused by organoleptic (sensory) characteristics. Although it is true that experts, through many tastings, can build a complex quality profile for individual châteaux or vintages, the information is not overly useful for the average consumer since they would not want to repeat this procedure. Given that the average consumer only has general and sometimes imperfect information on quality, label notoriety seems to be much more important. Since Combris et al. (1997) investigated only young wines of all quality levels it is difficult to apply these results to top Bordeaux wines due to the enormous price variances of different vintages.

This empirical shortage is remedied by the econometric approach of Ashenfelter et al. (1995). The authors developed a panel equation, termed the "Bordeaux-equation", which defines the influence of

aging and different weather characteristics on a generalized Bordeaux index. Beside the evaluation of particular determinants, this approach also provides a relative prediction of prices for wines which are not yet on the market but have been sold as futures. It is obvious that the generalized Bordeaux-equation, as an average index, cannot explain the price of a single château's wines with the necessary exactness needed in an investment. This problem could be solved in general by estimating not a region-wide average index but single equations for each château. On one hand this approach could easily be adopted to help explain and forecast prices of single château wines. On the other hand, the blend of each château cannot be neglected since the top wines of Bordeaux are cuvées made from different varieties that are expected to react in a different way to climatic factors. Therefore, it is probable that the quality and prices could also be different according to the particular blend. This should be taken into account allowing the "objective quality" of the single varieties to be estimated separately. However, according to Combris et al. (1997), the impact of the wine quality on the price is not compelling since the quality information is not available or obvious to the average consumer. This information shortage has been remedied by the development of numerous subjective quality point systems and rankings in the specialized literature (e.g., Broadbent, 1981; Penning-Roswell, 1989; Parker, 1985). Since the hedonic approach assumes that most wine consumers consider these rankings in their buying decisions, their inclusion in an economic model is warranted.

Accordingly, the following paper introduces a recursive econometric multi-equation model on Bordeaux wine pricing. First, the model quantifies the dependence of Crus Classés prices on climatic influences, grape composition, Parker-points, and aging. Second, the model allows one to forecast wine prices in order to compare achievable market prices and actual future prices. In the first section the general structure of the model and the database used to construct it is explained. Next, the climatic influences on wine composition are described for the Bordeaux region. Then the recursive model blocks "composition" and "price" and the corresponding equation specifications from which the adaptability of a simultaneous solution is shown. The final section presents model simulations and sensitivity results.

Table 1
Prices of selected Bordeaux wines in US-\$ per bottle, 1996/1997^a

Château	Vintage														
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Beychevelle	13	21	65	29	22	37	39	14	29	39	31	18	21	17	20
Cheval Blanc	32	79	485	165	31	165	114	51	89	127	302	0	35	52	0
Cos d'Estournel	14	28	124	36	20	71	68	20	43	44	64	28	19	24	34
Ducru Beaucaillou	19	35	92	40	21	51	51	20	35	42	43	0	15	0	34
Grand Puy Lacoste	16	24	76	27	10	34	32	11	22	30	42	16	14	19	22
Gruaud Larose	15	30	92	40	13	47	58	21	31	32	31	16	19	25	21
Haut Brion	34	55	216	70	35	98	100	43	76	317	167	34	63	55	77
Lafite Rothschild	45	79	349	91	43	107	179	78	100	132	176	43	45	56	77
Latour	38	62	384	73	39	101	105	42	87	119	362	51	46	56	97
Leoville Barton	0	27	68	32	13	46	42	22	31	40	51	21	18	24	33
Leoville Las Cases	17	38	203	45	17	64	94	19	48	70	94	34	33	39	45
Lynch Bages	17	42	101	45	17	79	57	21	46	77	64	19	15	26	32
Margaux	49	92	359	175	43	149	192	46	100	136	342	59	38	73	76
La Mission-Haut-Brion	29	48	165	54	22	73	66	39	56	252	114	27	24	30	0
Montrose	14	21	55	26	21	33	42	16	31	60	176	24	18	21	31
Mouton Rothschild	54	69	468	91	51	150	334	62	100	128	146	49	48	73	79
Palmer	27	44	70	121	21	61	51	31	48	84	64	31	24	29	31
Petrus	155	491	1078	252	139	388	331	191	334	769	849	0	206	228	417
Pichon Comtesse	17	46	199	71	19	66	90	29	46	67	63	24	26	29	39
Talbot	11	24	72	38	12	38	49	15	28	33	27	0	15	15	26
Troplong Mondot	13	16	22	24	12	22	27	0	28	65	95	17	23	28	36

^a Data from Blättel and Stainless (1997). A value of zero means the wine was not available at auction.

2. Data and methods

One of the more typical features of great Bordeaux wines is their extraordinary longevity. It is through maturity, achieved during long storage, that most Bordeaux wines develop their typical character. Many vintages have life expectancies of several decades and have been known to remain viable for over a century. Together, the longevity and the high profit yield expectancy, make Bordeaux wines not only a consumption good in great demand but also a desirable international speculative good. Hence, the wines of many of the châteaux from Bordeaux (many other top wines from other regions are represented as well) are traded all over the world in established wine auctions. This system guarantees, similar to a stock market, a comparatively high price transparency. Therefore, it can be assumed that auction prices indicate the relative (economic) scarcity and therefore the international esteem for those wines. For this analysis, the price database refers to all relevant wine auctions held worldwide within 1996/1997 and is calculated as

the weighted arithmetic average of all auction prices of one wine.¹ To obtain a complete set of data, only frequently traded wines are considered in this analysis. Therefore, the current investigation is restricted to the vintages 1980–1994 and to 21 châteaux (Table 1 gives the price data set used in the analysis). The model is conceived as a pure panel model (cross-sectional model) which attempts to explain the wine prices of different châteaux and vintages. All equations are specified linearly, logarithmically or semi-logarithmically, and are estimated with the ordinary least square (OLS) technique. The model is recursive and consists of two sections: a composition and climate section and a price section.

First it is assumed that climatic variables such as precipitation, insolation or temperature determine particular quality features of the grapes — the composition of the raw material. Here, the model distinguishes between the two main varieties grown in Bordeaux:

¹ All auction results are to be found in Blättel and Stainless (1997).

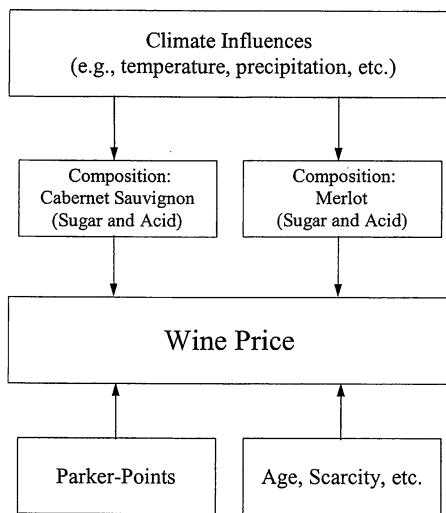


Fig. 1. Structure of the econometric model on wine pricing.

Cabernet Sauvignon and Merlot (which account for over 80% of grapes grown in the region) and explains their specific sugar and acid content at harvest (four separate equations). These endogenously determined variables are then used as explanatory variables in the price section of the model, which ultimately consists of 21 equations, (i.e., one for every château in the analysis). According to the average blend of the particular château, the specification of the equation involves more Cabernet Sauvignon or more Merlot compositional features. In addition to these exogenous wine quality variables, variables for the best known international quality rankings for each château, the so-called Parker-points (Parker, 1985), and the relative ages of the particular wines are included in the equations. The complete structure of the model is given in Fig. 1.

2.1. Climate, phenology, and composition effects on quality

Grapevines are a geographically expressive crop, being grown in distinct climate regimes worldwide that provide the ideal situations to produce high quality grapes. This is nowhere more evident than in Bordeaux, a region that is synonymous with some of the best wines in the world. While the interactions between the local climate, soil, and site location (termed the “*terroir*” by the French) play a varied

role in the growth and output of the grapevines, the general effect of the climate is well known. Mild to cool and wet winters followed by warm springs, then hot summers with little precipitation produce the best wines (see Jones (1997) for a review). Therefore, there is an optimum climate regime that contributes greatly to the overall quality of a given vintage.

Occurring as a direct effect of climate, the grapevine's growth can be described by its phenological events. Phenology is the study of individual physiological events or growth stages of plants or animals that recur seasonally in response to climate. Understanding the phenology of a given plant system is important in determining the ability of a region to produce a crop within the confines of its climatic regime. From a husbandry viewpoint, knowledge of a plant's growth stages is advantageous as cultural and chemical practices can be applied at optimum times in a plant's annual growth cycle. Additionally, information regarding growth stages can be useful in estimating crop yields. *Vitis vinifera* grapevines (“wine-bearing vines”) are a phenologically distinct crop with the most important developmental stages being débourrement (bud break), floraison (flowering), véraison (color change and maturation nascent), and harvest (grape maturity).² The timing of these developmental stages is also related to the ability of the vine to yield fruit, with early and fully expressed (unhindered by extremes of heat or cold, storms, etc.) phenological events usually resulting in larger yields (Jones, 1997; Mullins et al., 1992). Additionally, the phenological timing has been related to vintage quality with early harvests generally resulting in higher quality vintages (Ribereau-Gayon and Guimberteau, 1996).

Many studies looking at the relationship between climate and quality have employed monthly averages in temperature and precipitation as the independent variables (for a good review see Gladstones, 1992). Given that plants do not respond to a calendar division of climate data, and that phenological timing and quality are related (Jones, 1997), each vintage in the Bordeaux region is divided according to the

² For the main red varieties grown in Bordeaux, bud break occurs in late March or early April, floraison occurs in early June, véraison occurs from mid to late August, and harvest usually commences at the end of September or in early October (Jones, 1997).

major phenological events of bud break, floraison, véraison, and harvest, thereby creating four stages³ based upon the grapevine's annual response to the prevailing climate (Jones and Davis, 2000a). This allows for a comprehensive analysis of the climatic influences on the quality using a physiological approach. Climate variables of precipitation, estimated potential evapotranspiration (PET),⁴ and the number of days with temperatures more than 25 and 30°C are summed by day and phenological stage to produce up to four independent climate variables per stage that could ultimately play a role in quality levels.

Nearing harvest time, key vintage characteristics are the chemical composition of the grapes. Two of the chief determinants of crop ripeness are the relative amounts of sugar and acid found in the berries leading up to harvest (Mullins et al., 1992). Sugar represents a measure of the potential alcohol content of the wine and total acidity is a measure of the fixed and volatile acids present in the berries and has a direct influence on wine color, the growth of yeast and bacteria, and its pleasing balance with sugars on flavor qualities. During maturation, the levels of these two measures generally proceed in opposite directions: sugar levels increase and acid levels decline (Amerine et al., 1980). Optimum ripeness levels of sugar and acid vary by variety and region but should range between 165–230 g/l of sugar and 3–9 g/l of total acidity (Winkler et al., 1974). In general, relatively high sugar levels produce better quality while high acid levels produce lower quality (Ribereau-Gayon and Guimberteau, 1996; Jones and Davis, 2000b). Ideally, there exists a ratio of sugar to acid that determines proper ripeness and quality potential.

Daily climate data of maximum temperature, minimum temperature, and precipitation for the Bordeaux station for 1949–1997 are obtained from METEO-France (1998). The climate data are divided

by the mean phenology of the grapevines⁵ from reference vineyards observed by Ribereau-Gayon and Guimberteau (1996, pers. commun.). Composition values (acid and sugar levels) for Cabernet Sauvignon and Merlot grapes for 1970–1997 are also supplied by Ribereau-Gayon and Guimberteau (1996). Acid and sugar levels are measured at the reference vineyards prior to harvest and are averaged to obtain a single value for each vintage and variety. Table 2 shows the values for the significant climate variables in the analysis and grape composition for the years used in the analysis.

The estimated equations for the climate effects on Cabernet Sauvignon and Merlot grape composition are shown in Table 3. Cabernet Sauvignon sugar levels are influenced by precipitation throughout the growing season. Too much early season precipitation (BPREC) has a negative effect by delaying growth and late season precipitation (FPREC and VPREC), especially during the ripening period, has a negative impact by possibly diluting the berries and producing lower relative sugar levels. Also many days of warm temperatures during floraison would mean that the grapes ripen rapidly and to a higher degree. Increased precipitation over the growing season increases the Cabernet Sauvignon acid levels and results in unripe grapes. On the other hand, warm and dry conditions, especially from flowering to harvest, allow the acid levels to decline and the grapes to become ripe. A similar set of climate influences on Merlot grape composition is seen with warm and dry periods of growth providing higher sugar levels while wetter periods coincide with higher acid levels.

2.2. Wine prices

The price of a wine is determined by many different factors. One of the more important factors is an assumption that the value of a wine is greater the older it is. For the majority of wines this generalized assumption is actually not correct. Only outstanding wines, to which it can be argued that all of the wines

³ For the remainder of this analysis, each of the four stages will be represented by D = the dormant stage (harvest of one year to bud break of the next), B = the bud break stage (bud break to floraison), F = the floraison stage (flowering to véraison), and V = the véraison stage (véraison to harvest).

⁴ The PET variable is equal to the sum of the average temperatures $\sum (T_{\max} - T_{\min})/2$ minus precipitation. It is a derived temperature-related variable that has been used to study the climate/viticulture relationship. It is referred to as the Ribereau-Gayon and Peyraud Index.

⁵ The dates of floraison, véraison, and harvest are supplied by Ribereau-Gayon and Guimberteau (1996, pers. commun.) and the dates of bud break are estimated from climate data with bud growth considered to occur when the mean daily temperature is above 10°C for five consecutive days (Mullins et al., 1992; Jones, 1997).

Table 2
Significant phenological stage climate variables and grape composition: 1980-1995^a

	DPET	BPET	BPREC	FPET	FPREC	FTEMP25	VPET	VPREC	VTEMP25	VTEMP30	CABACID	CABSUG	MERACID	MERSUG
1980	1008	780	216	1198	120	30	577	128	14	2	5.9	179	5.3	196
1981	760	1062	204	1283	81	27	752	116	23	3	5.1	186	4.5	196
1982	1096	732	129	1168	159	33	814	55	25	6	4.6	200	4.3	212
1983	1345	707	220	1306	114	45	681	92	18	3	5.2	195	4.2	206
1984	967	724	195	1199	75	38	544	261	11	2	6.0	185	5.6	195
1985	892	786	230	1089	123	26	871	14	29	11	4.6	200	4.3	220
1986	1022	757	103	1220	31	41	651	146	18	3	4.3	199	4.1	208
1987	984	899	111	1112	117	24	932	153	28	14	4.9	176	4.1	196
1988	1028	963	237	1211	118	34	842	53	18	5	4.6	191	4.0	211
1989	1732	732	198	1331	79	49	824	60	29	3	4.7	205	3.3	232
1990	863	1201	128	1364	98	36	951	74	36	11	3.8	199	3.2	220
1991	741	1116	222	1254	115	41	792	179	33	12	4.8	183	4.3	195
1992	896	1005	258	1078	324	34	697	167	19	4	6.9	168	5.7	176
1993	1060	945	218	1099	170	36	675	242	19	6	5.6	175	5.0	186
1994	1190	989	312	1243	111	43	730	166	21	6	5.0	193	3.7	207
1995	1082	1076	276	1376	80	48	692	117	19	9	4.0	194	3.5	223

^a Where DPET: potential evapotranspiration for the Dormant stage in millimeter, BPET: potential evapotranspiration for the Bud break stage in millimeter, BPREC: precipitation for the Bud break stage in millimeter, FPET: potential evapotranspiration for the Floraaison stage in millimeter, FPREC: precipitation for the Floraaison stage in millimeter, FTEMP25: the number of days with temperatures greater than 25°C during the Floraaison stage, VPET: potential evapotranspiration for the Véraison stage in millimeter, VPREC: precipitation for the Véraison stage in millimeter, VTEMP25: the number of days with temperatures greater than 25°C during the Véraison stage, FTEMP30: the number of days with temperatures greater than 30°C during the Floraaison stage, CABACID: acid levels for Cabernet Sauvignon in g/l, CABSUG: sugar levels for Cabernet Sauvignon in g/l, MERACID: acid levels for Merlot in g/l, MERSUG: sugar levels for Merlot in g/l (for brevity, only those climate variables that are statistically significant in the composition models are shown).

Table 3

Climate and phenology influences on sugar, and acid for Cabernet Sauvignon and Merlot: equations and statistical tests^a

Independent variables	Dependent variables (g/l)			
	CABSUG	CABACID	MERSUG	MERACID
DPET	–	–	19.64 log(x) (3.11)	1265.2(1/ x) (6.97)
BPET	–	1014.0(1/ x) (3.78)	–	–
BPREC	1260.4(1/ x) (2.61)	0.81 log(x) (6.84)	–	–
FPET	–	–	–	5115.9(1/ x) (8.13)
FPREC	–0.06 x (4.32)	0.007 x (8.99)	–0.09 x (5.76)	0.48 log(x) (4.35)
FTEMP25	–926.2(1/ x) (6.07)	–1.08 log(x) (4.91)	–442.53(1/ x) (2.03)	–
VPET	–	–	–	–2.01 log(x) (5.98)
VPREC	–11.0 log(x) (9.84)	0.48 log(x) (7.26)	–11.15 log(x) (6.48)	–
VTEMP25	–	–	0.52 x (3.10)	–
VTEMP30	–	1.82 (1/ x) (4.69)	–	2.07(1/ x) (5.31)
CONSTANT	267.8 (34.22)	–	132.0 (2.49)	9.35 (3.87)
<i>Test statistics</i>				
S.E.	3.30	0.154	3.92	0.130
R ²	0.931	0.974	0.952	0.980

^a Model calculations: time 1980–1994, *T*-ratios in parentheses, and variables as described in Table 2.

investigated in this study certainly belong, are able to profit from increased aging. The reasons for this are:

- On one hand, the aging potential is caused by the slow development to maturity for many of the top wines from Bordeaux. In its youth Bordeaux wines are characterized by an extremely high content of tannins. In this state these wines are astringent and not yet ready for drinking. But with increasing storage, generally 10 years or more, the tannins and astringency are reduced and the wine becomes more pleasing to the palate. This optimum drinking condition can last several decades before the quality begins to decline.
- On the other hand, the available stock of a particular wine will decrease over time as it ages (i.e., the product is consumed and the absolute scarcity increases). Therefore, in the price equations a variable T (trend) is included that could be interpreted

as a constant linear retirement function of a certain (distinct) initial stock. It is true that data of absolute production could give useful additional information, but these data are not publicly available in the necessary detail.

- Additionally, the aging of a wine expresses storage costs and opportunity costs (costs of tying down capital as well as borrowing on credit).

Given the decline in available product, a continuously linear increasing variable T (trend) is incorporated into the model. The trend variable starts with 1994 = 1 and ends with 1970 = 25, allowing for the evaluation of the effect of aging and scarcity on wine prices. Generally, the wine price of a respective château (P_i) would be expected to be correlated positively with T_i , for example:

$$P_i = \beta_1 T_i + \varepsilon_i \quad (1)$$

where ε_i denotes the stochastic error term. Here it is especially emphasized that T_i is not to be interpreted as an element of a time series model, but that it only expresses different features of the wines (i.e., the state of aging).

Furthermore, it is assumed that the wine price is correlated positively with the relative composition of the grapes. The price equation is referenced to the calculated sugar and acid equations given in the prior section. According to the results, it can be assumed that high sugar values have positive effects on wine prices and that high acid values have a negative influence on the wine prices.⁶ Hence the specification has the following form:

$$P_i = \beta_1 T_i + \beta_2 \text{SUG}_i - \beta_3 \text{ACID}_i + \varepsilon_i \quad (2)$$

Except some wines from the Pomerol region, Bordeaux Cru Classés⁷ are blends of different varieties. Overall, Cabernet Sauvignon and Merlot are the main varieties grown in the region but other varieties such as Cabernet Franc, Petit Verdot, and Malbec are planted to varying degrees throughout the region. Although the shares of the single varieties used in the wines vary from vintage to vintage, the varietal priorities of the individual châteaux can be seen in the area devoted to growing the different varieties (Table 4). Hence, châteaux with Cabernet Sauvignon- and Merlot-dominated wines can be distinguished from one another and are considered in the specification of the price equations.

The international wine press regularly publishes quality ratings and continually updates them as long as the wine remains available on the open market. Although these ratings are influenced by personal subjective preferences (wine styles and varietal composition), and do not lay claim to measurable objectivity,

⁶ On the influence of taste and chemical attributes of wine and their impact on consumption see Nerlove (1995) and Schneider (1996).

⁷ For the western part of the Bordeaux area, the Médoc, a five-stage classification was introduced in 1855, which has mainly remained the same. The list of Crus Classés includes 61 Châteaux. The five Premier Cru Classés are Châteaux Haut Brion, Lafite-Rothschild, Latour, Margaux and, since 1973, Mouton-Rothschild. In the second half of this century, classifications for the regions of Graves and St. Emilion have been introduced. A new classification according to the ancient method was undertaken by Ashenfelter (1997).

they are, however, able to deliver information regarding the current state and the development potential of single wines. Of the many wine writers, the most well known and influential is Robert M. Parker. His ratings, based on a 100-point system, are widely used within the industry as a gauge of relative quality. It must be emphasized that once a vintage is given a point rating, it is not permanently fixed, but is regularly checked for quality changes at new tastings and, if necessary, corrected.⁸ However, since Parker-points are orientated at the future potential of a wine, normal aging does not affect the rating. Hence, Parker-points do not cover the influence of the trend variable T .

To obtain a single value for each vintage and for each château, the following calculations are based on the current Parker-point ratings from 1994/1995 as given in Table 5. The high influence of Parker-points on purchasing patterns and wine prices is undisputed (e.g., see Kühler and Kühler, 1995; Ashenfelter and Jones, 2000), and can be recognized by the “shooting stars” châteaux which were “discovered” by Parker. Therefore, the price function can be extended by a variable called PT (Parker-points)

$$P_i = \beta_1 T_i + \beta_2 \text{SUG}_i - \beta_3 \text{ACID}_i + \beta_4 \text{PT}_i + \varepsilon_i \quad (3)$$

In the case where wines of particular vintages were not traded (e.g., the Cheval Blanc of 1991), a dummy variable is included in the equation. Dummy variables can also reveal erratic items like a change of an owner or cellarmaster, modernization of production facilities, etc., whose influence could not be described sufficiently by the introduced variables. This occurs especially to the vintage 1982. The extreme high auction prices cannot be explained for all châteaux sufficiently by age, sugar and acid values, and Parker-points. Therefore, for this year a dummy variable is introduced under the assumption that only a small amount of product is available on the open market. Additionally, determinants which are time-invariant, such as slope, aspect, soil (i.e., Pomerol, 1989) or Cru-classification, etc. generally do not cause annual quality variations, but mainly determine the price level and are included in the equation by a constant.

⁸ Spectacular devaluations occur often in the re-evaluation of the vintages. For instance the Château Mouton-Rothschild and Château Latour from 1979 suffered a downgrading from 85 to 72 and from 90 to 85 points, respectively. See Kühler and Kühler (1995).

Table 4
Shares of varieties for selected châteaux (%) of planted area^a

Château	Region	Area (ha)	Cabernet Sauvignon	Merlot	Cabernet Franc	Petit Verdot	Malbec
Beychevelle	St.-Julien	71	72	25	2	1	0
Cheval Blanc	St.-Emilion	35	0	33	66	0	1
Cos d'Estournel	St.-Estèphe	64	50	40	10	0	0
Ducru Beaucaillou	St.-Julien	49	65	25	5	5	0
Grand-Puy-Lacoste	Pauillac	44	70	25	0	5	0
Gruaud-Larose	St.-Julien	81	63	25	9	3	0
Haut Brion	Pessac-Léognan	45	55	25	20	0	0
Lafite Rothschild	Pauillac	89	70	20	5	5	0
Latour	Pauillac	59	80	10	5	5	0
Léoville Barton	St.-Julien	40	70	15	7	8	0
Léoville Las Cases	St.-Julien	84	65	17	13	5	0
Lynch Bages	Pauillac	75	70	15	10	5	0
Margaux	Margaux	84	75	20	5	0	0
La Mission Haut Brion	Pessac-Léognan	20	60	35	5	0	0
Montrose	St.-Estèphe	67	65	30	5	0	0
Mouton Rothschild	Pauillac	74	85	5	10	0	0
Palmer	Margaux	44	45	40	5	10	0
Petrus	Pomerol	11.5	0	95	5	0	0
Pichon Comtesse	Pauillac	60	45	35	12	8	0
Talbot	St.-Julien	99	70	20	5	5	0
Troplong Mondot	St.-Emilion	30	10	65	15	0	10

^a According to Parker (1985).

Table 5
Parker-points of selected Bordeaux wines (1995)^a

Château	Vintage														
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Beychevelle	0	83	92	85	79	87	92	78	84	91	85	85	81	77.5	83.5
Cheval Blanc	80	90	100	94	0	90	93	85	87	88	95	0	77	86	88
Cos d'Estournel	83	83	97	85	84	95	95	83	87	89	90	87	88	89	90.5
Ducru Beaucaillou	74	90	94	87	79	91	94	83	88	90	89	86	87	91	92
Grand-Puy-Lacoste	0	80	92	86	75	88	90	76	85	89	90	87	86	88.5	89
Gruaud-Larose	80	88	97	90	83	90	97	84	89	88	88	85	86	89.5	86.5
Haut Brion	0	85	93	87	0	91	92	87	91	100	94	86	90	92	93
Lafite Rothschild	83	93	100	92	84	87	99	87	94	92	94	86	89	91.5	88
Latour	83	88	98	87	84	87	91	86	89	90	98	89	88	91	94
Léoville Barton	83	84	93	86	84	92	92	85	88	88	95	87	87	89	89
Léoville Las Cases	75	88	100	90	84	92	97	87	92	95	94	87	90	92	93.5
Lynch Bages	78	85	93	89	84	92	92	82	90	96	93	86	86	87	89
Margaux	89	90	99	96	87	91	96	86	88	90	100	88	89	92	91.5
La Mission Haut Brion	72	90	95	90	82	92	90	87	90	99	92	87	89	91	93
Montrose	72	84	88	81	77	85	91	0	83	95	100	85	87	87.5	92.5
Mouton Rothschild	74	84	100	91	85	92	100	89	89	89	87	86	88	91	91
Palmer	72	81	88	97	82	87	89	86	87	96	87	87	84	87.5	88
Petrus	85	87	97	88	87	89	89	87	94	98	100	0	90	93	92
Pichon Comtesse	84	89	99.5	94	86	90	96	87	90	92	87	89	79	89	92.5
Talbot	82	85	94	90	82	89	96	85	89	88	85	72	86	86.5	86
Troplong Mondot	0	79	81	0	73	87	89	0	89	91	94	85	89	91	93.5

^a According to Kühler and Kühler (1995). A value of zero represents a non-traded wine.

All estimated price equations for the 21 selected châteaux are given in Table 6. The results reveal that wine prices react with great sensitivity to variations in the sugar/acid ratio as well as Parker-points. Therefore, both variables are included in a polynomial form in the function and cause above average elasticities regarding changes of the independent variable. Hence, the effects of an increase of Parker-points from 94 to 95 are clearly much higher than those caused by an increase from 84 to 85. The same can be seen for the sugar/acid ratio (which is often used to evaluate ripeness). Additionally, wine prices tend to increase with aging and, except for Chateau Petrus and Talbot, the trend variable (T) was introduced in a linear form in the equations. Finally, all equations contain one or two dummy variables which indicate either corrections for the previously mentioned very high 1982 prices, missing data of single vintages, or some other change with which data are not available.

2.3. Model validation

To evaluate the quality of an econometric model the properties of the model and its explanatory power should be checked by several statistical tests. Important indications can be gained from a comparison between the actual data and a simultaneous “ex-post”-solution of the model. From the numerous test statistics available, those employed in this research are:

- the mean error, $MEAN = \frac{1}{n} \sum_{i=1}^n (\bar{y}_i - y_i)$,
- the mean absolute error, $MAE = \frac{1}{n} \sum_{i=1}^n |\bar{y}_i - y_i|$,
- the root mean square error,

$$RMSE = \frac{1}{n} \sqrt{\sum_{i=1}^n (\bar{y}_i - y_i)^2}$$
,
- the mean absolute percentage error,

$$MAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{\bar{y}_i - y_i}{y_i} \right|$$
.

The statistics above are examined to evaluate the quality of the complete wine price model. The test results, as assembled in Table 7, show a satisfactory improvement over the observed data, especially in respect to the sugar and acid values, while the MAPE for the wine prices is much higher. This is especially true for Château Cheval Blanc, which has a 26% mean absolute percentage error. This large MAPE can mainly be attributed to the high share of Cabernet Franc in its blend. Since Cabernet Franc data were not available

for this study, the Cheval Blanc equation was specified as a Merlot equation. However, for the overall results, the MAPE-values in the range 7–26% are to be judged against the background of the extremely high volatility of the dependent variables. Hence the percentage deviations are naturally high when the explained variable, the wine price, fluctuates near zero, although the adjustment of the equation is quite satisfactory. In those cases the explanatory power of the MAE and the RMSE is higher and, compared to the dimension of the dependent variable, these tests are more moderate. The MEAN ratio indicates that the variables scarcely are under- or over-estimated. An underestimation of 5 US-\$/bottle in the case of Château Mouton Rothschild would appear, against the background of the dimension of its prices, to be negligible.

In Fig. 2 the adjustments of the model for sugar and acid values as well as for the wine prices for a sample

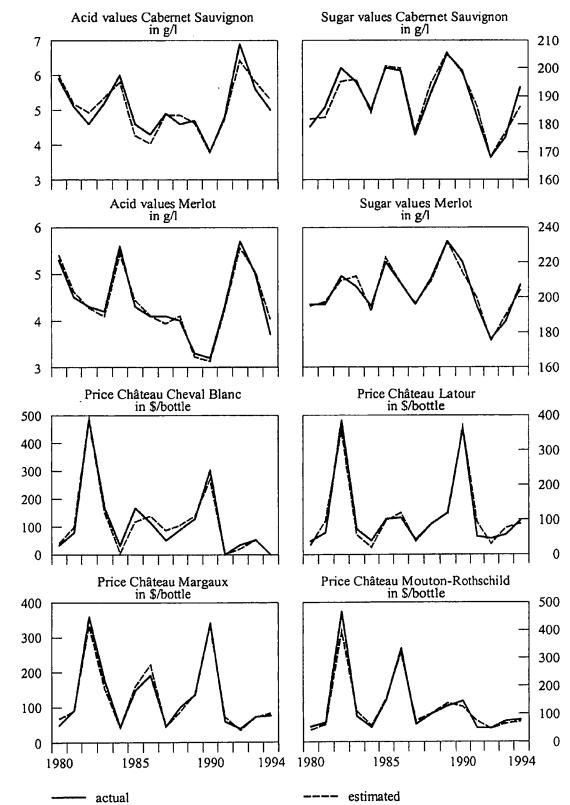


Fig. 2. A graphical analysis of a simultaneous ex-post solutions for 1980–1994. A comparison between actual and estimated values for selected variables.

Table 6
Wine prices and its determinants — equations and test statistics^a

	CABSUG	CABACID	MERSUG	MERACID	PT	T	Dummy	Dummy	Constant	S.E.	R ²
PXBARTON	$6.1(10^{-18})x^8$ (8.32)	$-2.11x$ (10.57)			$2.27x$ (201.18)	$0.0002x^4$ (3.17)	17.15 D82 (4.91)		-170.47 (128.57)	3.09	0.978
PXBECHE	$0.0001x^2$ (13.34)				$0.0001x^2$ (2.68)	$0.0129x$ (1.43)	0.53 D82 (3.89)	0.52 D92 (4.11)		0.12	0.946
PXCHEVAL			$1.2(10^{-7})(SUG/ACID)^5$ (6.94)		$1.7(10^{-12})x^7$ (6.32)	$-31.3(1/x)$ (0.97)	283.95 D82 (8.15)	-145.88 D89 (5.83)		26.1	0.974
PXCOMTES		$-68.4 \log(x)$ (8.51)	$0.001x^2$ (3.54)		$1.5(10^{-7})x^4$ (7.11)	$1.71x$ (3.89)	88.05 D82 (8.77)	61.71 D92 (5.85)		6.89	0.984
PXCOSDES		$0.018(SUG/ACID)^2$ (8.64)			$-23842(1/x)$ (9.34)	$1.4x$ (6.79)	45.9 D82 (9.62)		272.04 (9.00)	3.56	0.987
log(PXDUCRU)	$2.0(10^{-7})x^3$ (4.14)	$-0.0068x^2$ (1.72)			$0.0003x^2$ (5.50)	$0.038x$ (4.62)	-3.12 D91 (22.37)	-3.07 D93 (18.58)		0.13	0.993
PXGRUAUD	$5.3(10^{-16})x^7$ (1.47)	$-13.7 \log(x)$ (5.94)			$7.8(10^{-9})x^5$ (9.08)	$0.68x$ (2.84)	29.99 D82 (11.46)			3.86	0.975
PXHBRION		$1.6(10^{-12})(SUG/ACID)^8$ (7.86)			$1.2(10^{-16})x^9$ (10.94)	$1.79x$ (4.79)	110.2 D82 (9.96)	165.5 D89 (14.72)		9.62	0.987
PXLACOST		$1.0(10^{-9})(SUG/ACID)^6$ (5.48)			$3.6(10^{-13})x^7$ (8.71)	$0.87x$ (6.96)	38.0 D82 (11.64)			3.01	0.974
PXLAFITE		$1.7(10^{-5})(SUG/ACID)^4$ (7.54)			$9.4(10^{-17})x^9$ (5.16)	$0.91x$ (1.45)	181.8 D82 (12.18)			12.6	0.981
PXLASCAS		$2.47(SUG/ACID)^9$ (6.87)			$7.7(10^{-17})x^9$ (11.38)	$0.49x$ (1.95)	103.25 D82 (14.99)			5.72	0.989
PXLATOUR		$2.3(10^{-10})(SUG/ACID)^7$ (14.36)			$1.5(10^{-16})x^9$ (4.98)	$1.3x$ (1.93)	194.14 D82 (12.41)	-56.34 D86 (5.93)	-2.18 XL (1.37)	8.56	0.996
PXLYNCH		$0.0077(SUG/ACID)^2$ (2.20)			$1.1(10^{-14})x^8$ (8.26)	$1.47x$ (5.26)	32.0 D82 (6.52)	19.41 D85 (3.79)		4.49	0.981
PXMARGAU		$5.1(10^{-7})(SUG/ACID)^5$ (9.96)			$9.49x$ (7.61)	$2.09x$ (2.65)	134.81 D82 (8.12)		-821.7 (7.51)	13.6	0.986
Log(PXMBRION)		$1.4(10^{-7})(SUG/ACID)^4$ (6.59)			$2.8(10^{-18})x^9$ (12.91)	$0.06x$ (6.47)	-0.33 D81 (2.3)		1.95	0.13	0.993
PXMONTRO		$5.2(10^{-6})(SUG/ACID)^4$ (3.28)			$4.8(10^{-17})x^9$ (4.54)	$0.67x$ (2.81)	85.16 D90 (9.89)		(14.44)	5.82	0.982
Log(PXMOUTON)	$6.0(10^{-17})x^7$ (4.15)	$4.49(1/x)$ (21.74)			$1.5(10^{-16})x^8$ (3.50)	$-0.29(1/x)$ (1.37)	0.46 D82 (1.93)			0.18	0.955
PXPALMER			$0.0001(SUG/ACID)^3$ (4.54)		$5.0(10^{-15})x^8$ (4.06)	$1.47x$ (4.39)	18.80 D82 (2.53)	50.40 D83 (10.82)		7.49	0.947
PXPETRUS			$0.0015(SUG/ACID)^3$ (6.20)		$4.9(10^{-8})x^5$ (5.25)	$2.4(10^{-4})x^6$ (3.97)	533.26 D82 (7.82)		-173.68 (3.33)	64.1	0.967
PXTALBOT	$5.7(10^{-19})x^8$ (4.76)	$-11.9 \log(x)$ (7.32)			$6.7(10^{-9})x^5$ (10.04)	$0.0014x^3$ (1.81)	23.76 D82 (6.94)			2.83	0.982
PXTROPLO			$3.3(10^{-10})(SUG/ACID)^6$ (7.53)		$4.7(10^{-17})x^9$ (8.64)	$0.81x$ (5.52)	-10.38 D87 (2.22)	29.41 D90 (5.56)		4.30	0.976

^a Model calculations: 1980–1984, T-ratio in parentheses.

Table 7

Test statistics of a simultaneous solution of the wine price model^a

Model	Variable	MEAN	MAE	RMSE	MAPE
CABACID	Acid values — Cabernet Sauvignon	0.00	0.10	0.12	1.98
CABSUG	Sugar values — Cabernet Sauvignon	-0.10	2.19	2.80	1.16
MERACID	Acid values — Merlot	0.00	0.08	0.11	1.91
MERSUG	Sugar values — Merlot	0.00	2.46	3.03	1.21
PXBARTON	Léoville Barton	-0.10	2.54	2.96	10.29
PXBEYCHE	Beychevelle	-0.60	1.92	2.77	7.08
PXCHEVAL	Cheval Blanc	-1.71	19.28	22.90	26.35
PXCOMTES	Pich. Longueville Comtesse de Lalande	0.02	4.05	5.97	10.98
PXCOSDES	Cos d'Estournel	0.28	2.74	3.53	9.38
PXDUCRU	Ducru Beaucaillou	-1.09	4.46	9.03	8.80
PXGRUAUD	Gruaud-Larose	0.01	2.45	3.12	10.01
PXHBRION	Haut Brion	0.66	7.82	9.12	15.04
PXLACOST	Grand-Puy-Lacoste	0.20	2.30	2.74	13.25
PXLAFITE	Lafite Rothschild	-0.17	8.65	11.27	11.29
PXLASCAS	Léoville Las Cases	0.59	3.49	4.69	11.15
PXLATOUR	Latour	0.47	10.47	13.51	13.08
PXLYNCH	Lynch Bages	0.17	2.96	3.92	11.55
PXMARGAU	Margaux	0.14	10.27	13.88	9.44
PXMBRION	La Mission Haut Brion	2.09	9.17	14.26	10.69
PXMONTRO	Montrose	0.05	4.13	6.02	12.87
PXMOUTON	Mouton Rothschild	-5.10	14.71	22.42	13.74
PXPALMER	Palmer	-0.01	5.16	6.32	14.28
PXPETRUS	Petrus	-2.73	51.84	61.22	17.95
PXTALBOT	Talbot	-0.06	2.77	3.03	11.93
PXTROPLO	Troplong Mondot	-0.72	2.77	3.65	10.75

^a Model calculations: PX stands for wine price and is followed by an abbreviation of the château in the model.

of four châteaux are shown. Overall the model is able to reflect the actual data very well. Even for problematic cases, like Château Cheval Blanc, the explanatory power of the model falls within an acceptable range.

3. Sensitivity analysis

In the model introduced in this analysis, the influence of single determinants on the wine price can be isolated and evaluated. One of the advantages of an econometric model, in contrast to intuitive methods, is that in the scope of sensitivity analysis a variation of one of these determinants can be simulated as well as the impacts quantified. Since the model is cross-sectional, only the average effect of these factors on the wines of different vintages for single châteaux can be calculated. Therefore, with the model, it is not possible to predict the development of prices of one single wine, for instance the Château Cheval Blanc

1982. For this purpose a time series model would be necessary, which explains the development of the price of one single wine over a long period of time, not only by the characteristics of the wine itself, but also by economic benchmark data and their inter-temporal variations. However, in the scope of the model introduced in this analysis, it is possible to quantify the impact on average prices for all wines of a given year (here 1996/1997) and for single châteaux, by the variation of one or several exogenous variables. Hence, the influence of climatic determinants, Parker ratings, and the impact of aging can be quantified.

3.1. Climate sensitivity

As described earlier, the main varieties of the Bordeaux wines are characterized by different climatic influences. Accordingly, one purpose of blending wines is to balance the disadvantages resulting from weather conditions of a particular vintage which in turn affect

Table 8

Climate sensitivity of Cabernet Sauvignon and Merlot — impact of a cooler and moister ripening period^a

	Change (g/l)	Change (%)
Cabernet Sauvignon — sugar	−2.46	−1.31
Merlot — sugar	−5.47	−2.68
Cabernet Sauvignon — acid	0.25	4.99
Merlot — acid	0.75	17.29

^a Model simulation calculations. VPET, VTEMP25, and VTEMP30 are each reduced by 25%. VPREC is increased by 25%.

the ripeness of the different varieties (Kühler and Kühler, 1995). Since the weather during the ripening period plays an important role in the grape quality, a model simulation of the influence of a cooler, wetter period from véraison to harvest on sugar, acid, and price is evaluated. In this scenario the exogenous variables VPET (a measure of overall heat and dryness), VTEMP25, and VTEMP30 were reduced by 25% (which could easily occur within the normal climate variability), while VPREC was assumed to be 25% higher (see Table 2 for abbreviations). The results of this simulation reveal that sugar and acid values of Merlot are much more sensitive in respect to variations in véraison stage climate as is Cabernet Sauvignon (Table 8). Due to the simulated poorer véraison stage climate conditions, the sugar values for Cabernet Sauvignon decrease by 2.46 g/l (1.3%), while those for Merlot decrease by 5.47 g/l (2.7%). In respect to the simulated acid values, the differences are even more significant: the acid values for Cabernet Sauvignon increase by 5% and increase by 17% for Merlot. From the prior climate analysis and the simulations, it is confirmed that the Merlot variety is much more sensitive in respect to climate influences during the ripening period than Cabernet Sauvignon.

Overall, one can proceed on the assumption that Merlot-dominated wines, in respect to quality as well as price, are generally more influenced by weather characteristics during the critical ripening stage than Cabernet Sauvignon-dominated wines. Table 9 displays the climate impacts on the wine prices. From the given scenario of a wetter, cooler ripening stage, all prices decrease, but it should be noted that this occurs to a higher degree with non-Cabernet Sauvignon wines like Cheval Blanc (−31.3%), Petrus (−21.1%), and Troplong Mondot (−14.1%).

In comparison, price decreases for typical Cabernet Sauvignon-dominated wines like Haut Brion (−5.3%) or Mouton-Rothschild (−8.6%) are noticeably less. Although Merlot-dominated wines are clearly under-represented among the investigated wines, Fig. 3 shows that with increasing Cabernet Sauvignon shares planted (Table 4), the compensating character of that variety becomes obvious and therefore the price sensitivity decreases.

3.2. Parker-point sensitivity

The extremely high influence of quality ratings on wine prices has often been mentioned, and sometimes deplored, in the trade press. In the specification of the equations, this influence is expressed by including Parker-points in a polynomial form. It is obvious that Parker-points are oriented by “objective chemical quality measures”, by which there often appears a close correlation to the above mentioned climate determinants. However, since the test statistics are highly significant, the problem of multicollinearity can be neglected.⁹ The wine pricing reactions caused by a one-point increase in the Parker rating is shown in Table 9. From the results it is clear that there are great differences between particular châteaux in respect to Parker-point elasticities of the prices. While the price from this simulation for Châteaux Beychevelle or Palmer has risen less than 4%, properties like Châteaux Margaux, La Mission Haut Brion or Pichon Comtesse de Lalande show price increases over 10%. As shown in the following equation, these differences are due to many of factors.

$$\log(\text{SENSPT}) = 54480 \frac{\text{CAB/MER}}{\text{HA}^3} + 0.096(\text{PTAVG}) - 6.61 \quad (4)$$

(not including Château Beychevelle in the model), where S.E.: 0.661, R^2 : 0.662, T -ratios in parentheses, with: SENSPT: Parker-point sensitivity in % according to Table 9, CAB: share of Cabernet Sauvignon in % area planted, MER: share of Merlot in % area planted,

⁹ In each of the estimated equations the squared correlation coefficient of two regressors is not nearly as great as the unadjusted R^2 (see Studenmund, 1996, or Intriligator, 1978).

Table 9
Sensitivity analysis for selected Bordeaux wines^a

Château	Price change (%)		
	Climate sensitivity: price reaction to a cooler and wetter ripening period	Parker-point sensitivity: price reaction to an increase by one Parker-point	Annual yield sensitivity: price reaction to aging
Beychevelle	−6.59	0.97	1.30
Cheval Blanc	−31.32	5.69	2.48
Cos d'Estournel	−8.40	9.92	4.41
Ducru Beaucaillou	−6.88	4.66	3.91
Grand-Puy-Lacoste	−5.03	4.11	3.98
Gruaud-Larose	−4.03	8.78	2.63
Haut Brion	−5.29	5.80	2.82
Lafite Rothschild	−9.05	4.71	1.18
Latour	−13.85	7.46	1.92
Leoville Barton	−9.58	8.05	2.03
Leoville Las Cases	−5.92	6.91	1.24
Lynch Bages	−3.50	10.37	4.60
Margaux	−11.25	11.58	2.55
La Mission Haut Brion	−7.76	12.54	6.59
Montrose	−7.89	4.24	2.51
Mouton Rothschild	−8.55	6.21	1.87
Palmer	−13.43	3.61	3.67
Petrus	−21.05	4.95	9.61
Pichon Comtesse	−15.29	10.99	4.65
Talbot	−6.47	8.46	1.71
Troplong Mondot	−14.07	4.78	3.66

^a Model calculations.

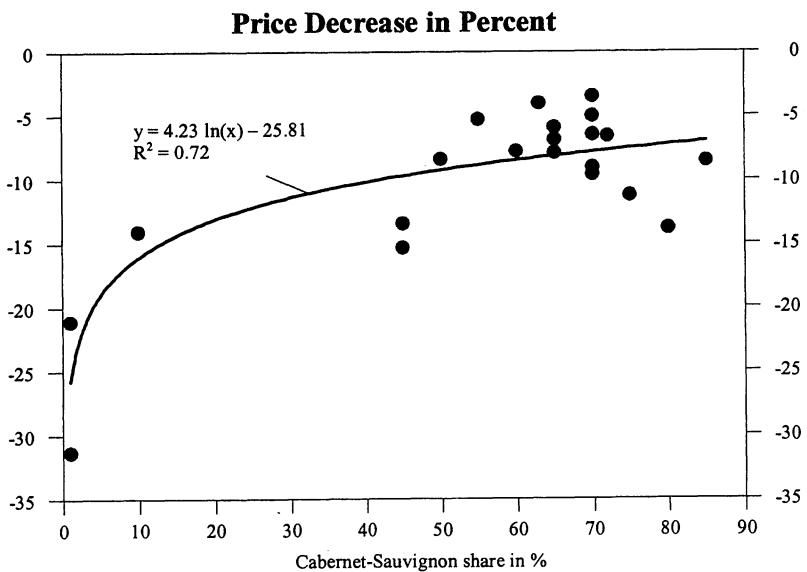


Fig. 3. Reflection of the relative percent of area planted in Cabernet Sauvignon grapes per château and the related climate-caused price decrease.

HA: area planted in hectares, PTAVG: Parker-points, average 1980–1994.

First, it is evident that the wine's blend in respect to the Parker-point sensitivity is very important. While high Cabernet Sauvignon shares have the tendency to increase the dependence on external ratings, the rating sensitivity will be decreased by higher shares of Merlot. Secondly, the dependence on Parker-points is higher for smaller properties. Therefore, smaller châteaux often gain over-proportionally from higher ratings. Third, those châteaux which were already rated relatively high in the past are characterized by a higher dependence in respect to Parker-points. Hence, as mentioned above, more attention is drawn to a point step from 94 to 95 than one from 84 to 85. Thus, if Parker-points are still unknown or unpublished, one would have to recommend to a risk-averse wine investor to buy a Merlot-dominated wine from a large property, with an average rating that has not been over-rated in the past. Given the possibility of an unfavorable rating later during the storage of the wine, the probable loss is within a reasonable limit. Otherwise a wine investor willing to take risks should buy a Cabernet Sauvignon-dominated wine from a small property that is given a high rating since the chance to yield a higher profit is much greater.

3.3. Aging sensitivity

In general the influence of aging on the Cru Classé wines of Bordeaux is positive — the older the wine, the more expensive the wine. But how strong is that influence, or in economic terms what is the expected annual return of capital? Methodologically, the influence of aging can be simulated by a variation of the trend variable T . Increasing T by one ($T + 1$) the model proceeds on the assumption that all wines are one year older and calculates the impacts on the prices. The amount of wine available at market is a reflection of the calculation and refers to an average value of one château — single vintages could vary from that value. Since the model is based on the prices achieved during 1996, the yields are calculated in real prices (i.e., in terms of 1996 prices). Table 9 reveals that the influence of aging differs among châteaux. Real average yields of less than 1.5% are seen for Châteaux Lafite-Rothschild, Leoville Las Cases and Beychevelle

in comparison to those of 6.6 and 9.6% for Châteaux La Mission Haut Brion and Petrus, respectively.

From an empirical point of view, the main influence on the annual increase in value seems to be the size of the producing château, since the absolute scarcity is expressed. The results indicate that, for the smaller producing properties, there will be less wine available in the future and in turn higher annual increases in value. Furthermore, it is shown that Merlot-dominated wines profit more from aging than do Cabernet-dominated wines.¹⁰ A simple regression over the 21 châteaux confirms this connection

$$\text{SENSAGE} = 0.4 \log(\text{MER}) + 85.8 \frac{1}{\text{HA}} \quad (5)$$

(3.14) (5.44)

where S.E.: 1.06, R^2 : 0.732, T -ratios in parentheses, with: SENSAGE: aging sensitivity (annual yield) in % according to Table 9, MER: share of Merlot in % area planted, HA: area planted in hectares.

From these results, the best recommendation to wine investors who want to maximize their annual yields is to buy mainly Merlot-dominated wines from small properties such as Petrus. A wine investor of this kind is comparable to a conservative shareholder with risk aversion who aims for dividends only. If, however, a short-term yield is desired, shareholders as well as wine investors should turn to the new issues. In this case, these are sold as subscriptions or futures. The wine is normally purchased one year after the harvest for a fixed price and once it is put on the market two years later, a scarcity-oriented price increase could appear. Thus, the "rentability" of wine subscriptions should always be assessed against the background of the uncertain market price in the future. Therefore, a forecast of future values for already harvested, but not yet traded wines, could be useful to examine whether a subscription or futures purchase would be lucrative or not.

4. Forecast

In addition to the prediction of prices for wines which are already introduced on the market by varying

¹⁰ However, it needs to be pointed out that there is a multicollinear relation between both variables: smaller châteaux tend to concentrate on Merlot.

Table 10

Climate determinants and chemical wine quality^a

	Actual 1994 and forecast 1995–1997			
	1994	1995	1996	1997
<i>Exogenous climatic determinants with positive influence</i>				
DPET	1190	1082	1352	951
BPET	989	1076	832	1015
FTEMP25	43	48	45	32
FPET	1243	1376	1271	1175
VTEMP25	21	19	14	27
VTEMP30	6	9	3	14
VPET	730	692	668	689
<i>Exogenous climatic determinants with negative influence</i>				
BPREC	312	276	167	175
FPREC	111	80	148	202
VPREC	166	117	132	106
	Actual	Predicted		
<i>Endogenous wine qualities</i>				
CABSUG (g/l)	193	195.4	191.4	181.7
MERSUG (g/l)	207	209.3	202.7	196.0
CABACID (g/l)	5.0	4.3	5.2	5.2
MERACID (g/l)	3.7	3.5	4.4	4.6

^a Model calculations.

the aging variable T (see Section 3.3), the model is also able to predict market prices of wines which are still in the barrel and were tasted only by a few individuals. As input for the model, the knowledge of climate variables as well as Parker-points is sufficient to come to a reliable estimation of wine prices — both are available to the public before the wines enter the market. However, since the model is cross-sectional, and not a time series model, the influence of time-variable factors, which could have a global structural effect on wine buying behavior, cannot be considered in the calculations. This temporal effect could be attributed to a worldwide economic depression as well as an economically-caused wine boom, as has occurred during the latest stock market crisis in Asia.¹¹ Therefore, the model cannot answer whether the extent of the higher prices of the latest vintages is caused by changes in the buying behavior or by the better quality of those vintages. However, as shown in Table 10, it is obvious that due to the exogenous climate vari-

¹¹ Some impacts of the Asia crisis on wine prices are described by Robinson (1997) in the Financial Times.

Table 11

Parker-points and pricing forecasts for 1998 for selected Bordeaux wines of the vintages 1995 and 1996 (in US-\$ per bottle and in 1996 prices)

Château	Parker-points			Prices	
	1994	1995	1996	Actual (1994)	Predicted
				1995	1996
Beychevelle	83.5	85	85.5	20	27
Cheval Blanc	88	92	92	0	175
Cos d'Estournel	90.5	95	95	34	60
Ducru Beaucaillou	92	94	95.5	34	41
Grand Puy Lacoste	89	88.5	89	22	25
Gruaud Larose	86.5	89	89.5	21	31
Haut Brion	93	96	95.5	77	113
Lafite Rothschild	88	95	95	77	131
Latour	94	96	95.5	97	173
Leoville Barton	89	91	92.5	33	40
Leoville Las Cases	93.5	92	93.5	45	58
Lynch Bages	89	90	91.5	32	40
Margaux	91.5	95	99	76	178
La Mission-Haut-Brion	93	91	90.5	0	49
Montrose	92.5	93	91.5	31	48
Mouton Rothschild	91	95	95	79	151
Palmer	88	90	89.5	31	50
Petrus	92	96	92	417	559
Pichon Comtesse	92.5	96	95	39	76
Talbot	86	88	88	26	30
Troplong Mondot	93.5	92	89	36	40

ables the 1995 vintage is to be judged better than the 1994 vintage especially in relation to those items having an adverse (negative coefficient) effect on quality. The weather during the 1996 and 1997 vintages was not as good, with mixed growing season conditions leading to less than ideal quality and the need to apply selective harvesting. The chemical measures were predicted accordingly: for 1995, the sugar content is the highest for both varieties and the acid values are the lowest; however, for the 1996 and 1997 vintages the acid levels increase while the sugar levels drop indicating less than ideal ripeness.

In Table 11, the predicted market prices (for 1998) of the 1995 and 1996 vintages are given. To provide a better comparison, the prices of the 1994 vintage¹² (as given in Table 1), as well as the

¹² Since these are the prices of 1996 the comparison is restricted. Due to aging, the values of these wines will likely be higher in 1998.

development of the Parker-points, are added. The 1995 vintage yields higher predicted prices than the 1994 vintage for each of the châteaux in the analysis. This is especially evident with Premier Crus like Châteaux Latour, Lafite-Rothschild or Margaux, whose prices are more than double those of 1994. This is also evident whether the wines are Cabernet Sauvignon-dominated or Merlot-dominated (e.g., the 1995 vintage of Château Petrus).

The predicted prices for the 1996 vintage do not follow the increases predicted for 1995. This can be traced back to the fact that the compositional measures indicate that the 1996 vintage is not likely to be as good as the 1995 vintage, especially for Merlot-dominated wines. This is also reflected in the nature of the Parker-point ratings for both years: while the ratings for the 1996 Cabernet Sauvignon-dominated wines generally remain on par with the 1995 ratings, the Merlot-dominated wine ratings decrease significantly. Therefore, the typical Merlot-dominated wines like Châteaux Petrus or Troplong Mondot achieve only 92 and 89 Parker-points, respectively for the 1996 vintage, compared with 96 and 92, respectively for the 1995 vintage. The result is extended to the prices: while most of the Cru Classés remain close to the 1995 level,¹³ for Merlot-dominated wines a distinct price drop is expected. For example, the 1996 vintage of Château Petrus will cost 302 US-\$ per bottle, compared to roughly 560 US-\$ for the 1995 vintage.

5. Summary

Because exquisite wines are expensive and can yield remarkable investment appreciation, many people consider wine not only a semi-luxury drink but also a profitable capital investment. Since there are numerous illustrious properties like Châteaux Mouton-Rothschild, Latour, Petrus, and many others, this is especially evident with Bordeaux wines. Recommendations regarding the potential development or possible profit yield, however, are usually based on the experience or intuition of a few experts, and empirical investigations into the topic are few. This research presents an econometric model that introduces how the prices of wines,

which are already harvested but not yet traded, can be forecast and how wine price sensitivity, in respect to different parameters, can be evaluated.

First, the model proceeds by considering that Bordeaux wines are blends from different varieties, which reflect different climate sensitivity. The model develops the climate/grape ripeness relationship for the two main varieties grown in Bordeaux by examining the relative sugar and acid values of Cabernet Sauvignon and Merlot grapes. These exogenously-determined variables are then used as explanatory variables in the single price equations. From the results it is shown that Merlot-dominated wines are more climate sensitive than Cabernet Sauvignon-dominated wines. In climatically excellent years, outstanding quality and prices can be expected for both varieties, although Merlot-dominated wines tend to do the best. In climatically average or marginal years, Merlot-dominated wines yield below average prices. From these results, the 1996 and 1997 vintages for Merlot-dominated wines seem to be especially problematic.

Wine prices are also shown to be largely determined by the rating level they achieve. The model tracks this influence by examining the effect that the ratings given each vintage by the most prominent wine writer, Robert M. Parker, has on price fluctuations. Overall, the relative level of Parker-points, given by château and vintage, has a large price influence as seen by the polynomial form of the equations. This effect varies between châteaux and is mostly due to whether the property is Cabernet Sauvignon-dominated (increased dependence on ratings) or Merlot-dominated (decreased rating sensitivity). Additionally, the model shows that properties that have achieved high ratings in the past have greater sensitivity to single point jumps in ratings in subsequent vintages. Another aspect the model reveals is that smaller properties have a much higher dependence on Parker-points showing larger relative gains from higher ratings.

For most fine wines the prices they achieve are also partially determined by the age of the particular wine, which generally indicates its potential “drinkability”. This is very evident for Bordeaux wines, as they have long been regarded as wines to “lay down” for many years. The model examines this effect on the annual return of capital by simulating an increase in a trend variable. Since the model is cross-sectional, the calculation reflects the average return by château, with

¹³ Since they are one year younger than the 1995s, a lower price is expected.

individual vintages varying from the value. The results indicate that there is a large degree of within château variability, with 1–10% returns possible. This effect appears to be largely influenced by two factors: (1) absolute scarcity as reflected by the size of the property, and (2) Merlot-dominated wines profit more from aging, on the average, than do Cabernet Sauvignon-dominated wines.

Given that the subscription (futures) market of Bordeaux wines has grown tremendously, the model attempts to forecast the future values for harvested but not yet traded wines. This is done because the wine could be purchased one year after the harvest for a fixed price but once it is put on the market two years later, a scarcity-oriented price will appear. Thus, a forecast of future values would be useful to examine whether a subscription could yield a short-term profit or not. Using the background climate and Parker-point data, the model reveals that the 1995 vintage is better than the 1994, but that the 1996 and 1997 vintages are not as good due to lower sugar levels, higher acid levels, and the resultant change in Parker-point ratings. A prediction of prices for 1998 reveals that the 1995 vintage indeed yields higher predicted prices than does 1994 for each of the châteaux included in the analysis. This effect is evident for both Cabernet Sauvignon-dominated or Merlot-dominated wines of the 1995 vintage. For the 1996 vintage, predicted prices do not follow those of 1995. This is especially true for the more climate sensitive Merlot-dominated wines, which received lower Parker-point ratings and had a resultant price decrease.

Under the assumption that subscription prices of Cabernet Sauvignon and Merlot wines vary proportionally, the models provide these suggestions for investors looking to buy into the Bordeaux wine market: (1) in marginal climate years purchase wines from properties that generally have higher percentages of Cabernet Sauvignon, (2) for the short-term investor — when Parker-points are unknown, purchase Merlot-dominated wines from large properties to avoid risk and Cabernet Sauvignon-dominated wines from small properties to maximize profit potential, (3) for the long-term investor — purchase Merlot-dominated wines as they show much greater aging potential, and (4) in terms of absolute scarcity, one would want to purchase wines from small properties as the relative amount available to the market

diminishes rapidly. Predicted price forecasts indicate that, of the last three vintages (1994, 1995, and 1996), the 1995 vintage is the one to invest in as long the wine is not over-priced to begin with.

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