AMERICAN ASSOCIATION OF WINE ECONOMISTS

AAWE WORKING PAPER
No. 2

Editor
Victor Ginsburgh

NATURAL ENDOWMENTS, PRODUCTION TECHNOLOGIES AND THE QUALITY OF WINES IN BORDEAUX. IS IT POSSIBLE TO PRODUCE WINE ON PAVED ROADS?

Olivier Gergaud
Victor Ginsburgh

April 2007

www.wine-economics.org

AAWE
Working Paper No. 2

Natural endowments, production technologies and the quality of wines in Bordeaux. Is it possible to produce wine on paved roads?*

Olivier Gergaud
OMI, Université de Reims Champagne-Ardenne and
TEAM, Université de Paris I

Victor Ginsburgh
ECARES, Université Libre de Bruxelles and
CORE, Université catholique de Louvain

August 2005

Abstract

We study whether quality assessments made by wine experts and by consumers (based on prices obtained at auction between 1980 and 1992), can be explained by variables describing endowments (land characteristics, exposures of vineyards) and technologies (from grape varieties and picking, to bottled wines). However, since technological choices are likely to depend on endowments, the effects can only be identified using an instrumental variables approach. We show that technological choices affect quality much more than natural endowments, the effect of which is negligible.

We are grateful to Orley Ashenfelter for his suggestion to rework on the Ginsburgh, Monzak and Monzak (1994) paper, as well as to Christophe Croux, Marcelo Fernandez, Abdul Noury, Loic Sadoulet, Peter Spencer, Etienne Wasmer and especially Catherine Dehon, for fruitful discussions on instrumental and less instrumental variables and for comments on a previous version.

1. Introduction

Winemaking cannot be envisaged unless very specific weather conditions prevail. But this is obviously not sufficient, since winemaking also involves a complex technology that needs natural endowments which can hardly be modified (land, slopes' exposure, other endowments, summarized by what is often called "terroir"), inputs that take 20 to 30 years before producing good quality outputs (vines), manual operations (picking), mechanical operations (crushing, racking), chemical processes (during fermentation) and specific storage conditions once the wine is bottled. There is little that can be done to correct an error in one of the various and delicate steps which extend over several years for every vintage, though nowadays it is said that a good chemist can make miracles. Wine is also the subject of many legends and production secrets. Wine tasting adds to this aura of mystery with its esoteric vocabulary describing perfumes and the harmony of a wine.

The influence of weather has been the subject of several studies, which consistently show that rain is needed during the winter season, while dry weather is good during the growing season and when grapes are picked. Warm weather has also a positive effect during the whole growing season.[1] An important question is whether good climatic conditions and specific choices of vines are sufficient to produce quality wines or whether, as the French have often claimed and still do, there is no good substitute for terroir. Thus goes Madame Denise Capbern Gasqueton, owner of Château Calon-Ségur, a third growth Saint-Estèphe, is typical:

> "I drink [foreign] wines. Very good wines are produced in Chile, for example, but they lack terroir, and terroir is what makes everything. A wine that is well-produced is a good wine, but lacks complexity and other elements to which we are used."

At best, this looks highly exaggerated. At worst, terroir has no influence, and the right combination of weather, vines, technology and chemistry are sufficient. This was already the opinion of Johan Joseph Krug (1800-1866), a famous champagne producer, who pointed out that

> "a good wine comes from a good grape, good vats, a good cellar and a gentleman who is able to coordinate the various ingredients."

And indeed, highly appreciated wines are now produced in California, South Africa, Australia, South America, as well as in some regions, such as Languedoc-Roussillon

---

[1] See among others Ashenfelter et al. (1993) or Di Vittorio and Ginsburgh (1996).

in Southern France that were thought, 20 or 30 years ago, to be good enough for "table wines" only.

Wine can be considered as a commodity endowed with characteristics that make it both vertically and horizontally differentiated. Though wines from a given region differ, good weather benefits equally to all of them.[2] Weather seems to generate vertical differentiation--all the wines produced in a region benefit to the same extent from good weather conditions, and experts as well as experienced consumers can recognize this--, while it may be terroir and technological choices that make for horizontal differentiation--some consumers prefer Château Mouton, a wine from the Pauillac region, others prefer Château Laffitte, also a Pauillac. At least this is suggested by looking at the opinions of wine experts who agree more on classifying vintages than on classifying châteaux. The (Spearman rank) correlation coefficient between rankings by Michael Broadbent (Christie's well-known wine expert) and Robert Parker is equal to 0.75 for the 30 Haut-Médoc vintages from 1961 to 1990, while it is equal to 0.47 only when they come to rank 48 châteaux of the same region, over the same years.

As was pointed out before, the relation between climate and wine quality is reasonably well documented. There is much less evidence on whether and how terroir and production technologies influence quality.[3] We are interested in trying to quantify the impact of each of the many inputs and steps used in producing wine in one of the most renowned wine producing regions of France, Haut-Médoc with its celebrated châteaux, such as Mouton-Rothschild, Latour, Lafite-Rothschild and Margaux.

We use a database on terroir characteristics and techniques in some 100 vineyards in 1990, to describe and quantify the wine processing technology and to separate its effects on quality from legend on the one hand, and from reputation effects on the other.

The paper is organized as follows. Section 2 clarifies what we call "terroir" in this paper. Section 3 is devoted to the description of the database (land characteristics and technologies). In Section 4 we try to disentangle the effects that terroir and technologies are supposed to have on the quality of wines, proxied by classifications made by three wine experts (Parker, Bettane and Desseauve, and Broadbent) and indirectly, by consumers, through the prices that they are ready to pay at auction. Section 5 draws some conclusions.

---

[2] See Ashenfelter et al. (1993).

[3] See however Ashenfelter and Storchmann (2001), Ginsburgh, Monzak and Monzak (1994).

2. Terroir and technology: General considerations

Terroir is a French word that recovers many interpretations. Here is what Robert Tinlot (2001, p. 9) a former Director General of OIV writes in a paper entitled Terroir: A concept that wins over the world:

> "There is no wine region in our world that does not try to value its vineyards and their output without reference to the character that they inherit from the place where the wine is produced. Consumers who visit producers are particularly sensitive to the beauty of the landscape, to the architecture of the villages and to any other element that belongs to the region of production."

Thus terroir includes event the landscape, as if it affected the quality and the taste of the wine. Tinlot becomes a bit more reasonable in the next pages, suggesting that an objevtive definition of terroir should be restricted to "natural endowments of a region, such as soil, subsoil, slopes and exposure of the vineyards, climate." (p. 10) But he adds that more recently, there is a

> "tendency to extend the notion to human factors, such as savoir-faire and local traditions of the local population, that are influenced by the natural, social, political and, why not, religious conditions that prevail in the region…which leads quite naturally to the French notion of *appellation d'origine contrôlée*." (p. 10)

This is essentially the same as what is decribed by Wilson (1998, p. 55):[4]

> "Terroir has become a buzz word in English wine literature. The lighthearted use disregards reverence for the land which is a critical, invisible element of the term. The true concept is not easily grasped but includes nphysical elements of the vinehard habitat—the vine, subsoil, siting, drainage, and microclimate. Beyond the measurable ecosystem, there is an additional dimension—the spiritual aspect that recognizes the joys, the heartbreaks, the pride, the sweat, and the frustrations of its history."

In this paper, we restrict the notion of terroir to natural endowments which are non-transferable, and which are likely to really influence in a measurable way both the quality and the taste of a wine: soil, subsoil, slopes and exposure of vineyards. All the other elements are either not quantifiable (the influence of social relations, for example) or can be reproduced elsewhere, taking into account adjustments due to local conditions. Clearly, not all grapes grow in every region because of soil, slopes

[4] Quoted in Barham (2003, p. 131).

and climate, but enough experimentation exists and winemakes know how this should be handled. All the remainder, including the choice of grapes, is technological.

3. Terroir and technology in the Haut-Médoc region

Data on the Haut-Médoc region were collected during the winter and spring of 1990-1991 by Andras and Muriel Monzak[5] who conducted interviews in 102 châteaux. Each château was visited, and a questionnaire was handed out with some thirty questions on types of soil, exposure of the vineyards, grape varieties, age of vines, picking techniques, wine-making and "élevage." The questions were set up to make quantification easy. Some answers are represented by continuous variables, such as the proportions of grape varieties, but most are categorical (and represented by dummy variables), since they describe the types of production techniques used.

In this section, we discuss the various elements which are usually thought to produce a good wine. These can be classified as follows: soil, exposure of the slopes, grape varieties, age of vines, and wine-making. Clearly, weather conditions, and age of the wine are also important characteristics, but since we are only interested in differentiating between châteaux, and not vintages, this should not concern us here.

Soil

In the Haut-Médoc region, soil ranges from heavy clay to light gravels. One usually distinguishes four types of soil, present in various proportions: clay-chalky, gravely, gravel-sandy and sandy. Some soils are better than others and deep gravel beds (like in Pauillac) seem to be the best, though there are outstanding wines produced in the much poorer gravel-sandy region of Margaux. Subtle differences in soil may lead to very different styles. However, "(soil) is not, as the Bordelais would have one believe, the only element necessary to make a great wine." (Parker, 1985, p. 505).

In addition to soil density, chemical composition is also thought to play an important role. The database singles out five (nonexclusive) chemical components: nitrogen, phosphoric acid, potassium, lime and magnesia. Though fertilizer is kept to a minimum, it is used to maintain the complex mineral and chemical equilibrium.

These various characteristics are measured by four dummy soil variables (clay-chalk, gravel, gravel-sand and sand, which take the value 1 if the type is present, 0 otherwise), and five dummy chemical components variables (nitrogen, phosphoric acid, lime, potassium and magnesia).

[5] See Ginsburgh, Monzak and Monzak (1994).

Slope exposure

Slopes exposed to the East and the Southeast are protected from western winds, dominant in the region. The rising sun quickly dries the dew, and reduces the risk for grapes to go rotten. Western slopes are usually closer to the river Garonne, and are more likely to have a gravely soil; they also benefit from some light reflection thanks to the river. These characteristics are represented by five dummy variables (Eastern, Southeastern, Southern, Southwestern and Western exposures), which take the value 1 if the château possesses slopes with a given exposure.[6] Slopes can be of low or higher altitude. A dummy is included and takes the value 1 if the château grows vines on higher altitude lots.

Grape varieties

Haut-Médoc wines result from a combination of five varieties of grapes used in varying proportions: Cabernet Sauvignon (40 to 85%), Merlot (5 to 45%), Cabernet Franc (0 to 30%), Petit Verdot (3 to 8%) and Malbec, in small proportions (less than 2%). These varieties ripen and are harvested at different times and weather conditions at certain moments may thus influence some vineyards more than others, in accordance with the grape varieties used. Each variety has its own influence on the characteristics of wines. Cabernet Sauvignon is poor in sugar, rich in tannin, and allows wines to age. Merlot is the first to ripen, is less tannic and richer in sugar than Cabernet Sauvignon. This makes the association of both varieties very attractive. Cabernet Franc ripens earlier than Cabernet Sauvignon, adds bouquet and tends to produce lighter wines. Petit Verdot ripens late (and is therefore used only in small proportions), is very tannic and rich in sugar, adding alcohol to the wine. Malbec is being replaced more and more by Merlot, with which it shares the same qualities. It is worth noting that grape varieties may lead to different outcomes according to the type of soil on which they are grown. Grape varieties are represented by four variables which represent the proportions used by every château.

Age of vines

Old vines produce less, but a wine of better quality. Mouton-Rothschild vines for instance are, on average, 43 years old. So are the vines at Lafite-Rothschild, another Pauillac First-Growth. Age, however, does not seem to be necessary. Pichon Lalande,

[6] For a given château, several of the variables may be equal to 1, if vines are grown on different types of slopes. Since the final product results from blending, this definition looks reasonable.

classified as a First-Growth by Parker, has vines the average age of which is 22 years only. Vines are classified into three age categories, represented by three dummy varaibles.[7,8]

Wine-making

We now follow the production process through the eight steps distinguished by Parker (1985), and on which the questionnaire was based: (1) picking (and selecting), (2) de-stemming and crushing, (3) pumping into fermentation tanks, (4) fermenting of grape sugar into alcohol, (5) macerating or keeping the grape skins and pips in contact with the grape juice for additional extract and color, (6) pressing and racking or transferring the wine to small barrels (or tanks) for the secondary (malolactic) fermentation to be completed, (7) putting the wine in oak barrels and letting it age and (8) bottling the wine.

(1) Picking and selecting

Harvesting usually starts after September 15 and may take as long as three weeks. Manual picking is disappearing, since it costs more and may take too much time. Automatic picking is faster, allowing thus to harvest at the right maturity, but may damage grapes and mix more stems than needed. In most cases, both methods are used, but some châteaux still resort to manual picking exclusively. A dummy variable is defined which takes the value 1 if only manual picking is used.

Whether the picking is manual or not, grapes must be selected: damaged, unripe or rotten berries must be eliminated, before crushing starts. Most châteaux instruct their pickers to eliminate unhealthy grapes and some châteaux still sort grapes by hand, after the picking. In such cases, a dummy variable (manual sorting) takes the value 1.

(2) De-stemming and crushing

In most châteaux, crushing the berries and de-stemming[9] is done simultaneously. Some vineyards still use the older technique of crushing before de-stemming. A dummy variable (crushing) takes the value 1 when this is the case.

---

[7] Age1=1 for 5 to 20 years old vines; Age2=1 for 20 to 40 years old vines; Age3=1 for vines older than 40 years. In general, there will thus be several variables equal to 1 for a château.

[8] An alternative would have been to compute an average age of vines for every château; our questionnaire was not put up under that form, and Parker (1985) does not provide this information for all the châteaux.

[9] De-stemming may be total or partial, since stems and pips add tannin. Most châteaux de-stem fully.

(3) Pumping into fermentation vats

The partially crushed berries are then pumped into vats and fermentation can start. Several chemical decisions have to be made at this point. These consist in: adding sulfite (which has many complex effects and is practised by all châteaux); chaptalizing (adding sugar, increases the alcohol content and is used by most châteaux, when needed); acidifying or de-acidifying are not practised, and only seldom allowed; adding yeast is used to start fermentation unless the process starts spontaneously; used by all châteaux). Since all vineyards proceed similarly, it is not possible to capture the possible effects of these chemical steps.

(4) Fermenting of grape sugar into alcohol

Several types of vats are used: oak, cement and stainless steel. During fermentation, temperature has to stay within tight bounds, usually between 25° and 30° C. Fermentation does not start if the temperature is too low, while acetic bacteria may grow and natural yeasts will be destroyed (and stop fermentation) if temperature increases too much. This severe monitoring is easier to achieve in stainless steel tanks, by running cool water over the outside of the tanks. In the two other cases (oak and concrete tanks), wine must be run through cooling tubes. Oak vats, on the other hand, are more natural and allow wood components to mix with the wine. Since most châteaux use stainless steel, we did not include the possible choices in our regressions.

The crushed grapes are in some cases mixed with heated must. This step, represented by a dummy, which takes the value 1 if heating is used, is supposed to free coloring and some other components.

During fermentation, skins, stems and pips rise to the top of the tank and form a solid cap (the "chapeau"), which must be kept moist by pumping the wine juice over it (remontage). Three techniques are available to achieve this: open tank with floating marc; closed tank; open tank with submerged marc. The first technique allows a contact with air. This may oxidize (and infect) the wine, and needs a remontage. Both these drawbacks are avoided in the third technique. Oxidation is also avoided in the second technique, but since temperature may increase too much, a remontage (and thus, a contact with air) may be needed. The techniques are represented by three dummies.

(5) Maceration

After the alcoholic fermentation is completed, the wine is macerated with the skins during one to two weeks. The length of this period is crucial for the wine, but since most châteaux proceed in the same way, we included no control variable.

(6) Pressing

After steps (4) and (5) which constitute the *cuvaison*, the wine is separated from its lees. The free-run juice is the wine of better quality, while the remainder is pressed one or several times, resulting in press-wine which is more pigmented and tannic than the free-run juice. Some press-wine (the proportion depends on the year and the château) is then blended with the free-juice to adjust for color and tannin. Several types of presses exist, but are said to have no influence on quality, which may, however, be negatively influenced by the number of pressings.

(7) Ageing in barrels and racking

The wine is then transferred to 225 litre barrels (where the alcoholic fermentation may be pursued) and the secondary (or malolactic) fermentation, which adds roundness and character, starts and lasts for three to five months. Most châteaux use (a mix of old and new[10]) oak barrels. Some Crus Bourgeois use both oak barrels and tanks. A dummy variable takes the value 1 if oak barrels are used, in isolation or in conjunction with other.

The ageing in barrels varies between 12 and 24 months (depending on the vintage), during which a number of steps have to be taken. First, the wine evaporates and produces carbon dioxide; this empties the casks, which have to be refilled every week; all châteaux carry out this step. Secondly, the wine is racked several times during the first year, to separate the clear wine from the lees which have fallen to the bottom of the cask. We introduced a variable representing the number of rackings. Thirdly, all châteaux carry out a procedure which cleans the wine from suspended matter. This is the fining of the wine, achieved with egg whites, fresh or not. A variable which takes the value 1 if fresh egg whites are used, captures the influence.[11]

[10] Whether the barrels have to be new or old is a hotly debated issue; we had little information on this and could not take it into account in our regressions.

[11] Fining can also be achieved with bentonite or gelatine. This was the case only once or twice in our sample.

(8) Bottling the wine

In January following the vintage, most châteaux select the wine which is going to be bottled under the château's name, while the remainder will be sold under secondary labels, or in other ways. At the same time, wines resulting from different vines are blended. Since these two steps are impossible to quantify and are used in most places, they are not included in our analysis.

Before bottling takes place, wines are filtered,[12] in order to remove solid matters. There are two filtering techniques which proceed mechanically (one uses kieselguhr, the other cellulosic-asbestos filtering components); a third process is adsorption. The particularity is that adsorption needs one of the two other processes, while each of the mechanical processes can be used on its own. To represent this technology, we introduce three dummy variables which take the value 1 if the technique is used, 0 otherwise.[13]

4. Disentangling the effects of natural endowments and technology

The simplest idea which comes to mind is to regress "quality" (represented by the three alternative classifications produced by wine experts, or by prices obtained at auction) on the variables defined in Section 3 which measure natural endowments and technologies. The problem is that correlation between technological variables and quality does not necessarily mean that the former have an effect on the latter, since production choices may have been influenced by natural endowment characteristics, to correct for their possibly negative effects. We are thus faced with a simultaneous equations model in which quality depends on endowments and technological choices, and technological choices depend on endowments. To determine the effect of technologies, instrumental variables which affect production technologies, but have no (or hopefully little) effect on endowments[14] should be used. The model can be written:

(1) $$Q = E\alpha + T\beta + u$$

(2) $$T = E\gamma + W\delta + v,$$

where Q represents quality, E is a vector of endowments, T a vector of technological variables, and W a vector of instruments; α, β, γ and δ are vectors of parameters, and

[12] Note that some châteaux start to filter in earlier stages.

[13] Note that First-Growths never filter their wine, and only 3 Second-Growths do so; other Growth-wines use asbestos filtering, with or without adsorption; Crus Bourgeois use kieselguhr filters exclusively.

[14] Endowments can be changed to some extent, by adding chemicals, dropping unfavorable slopes, etc. But this remains marginal.

u and v are error terms. Note that (1) represents a single equation, while (2) contains one equation for each technological variable.

The instruments W are the 1855 classification (First to Fifth Growth wines,[15] and Other), and the cultivated area expressed in hectares - as a proxy for the wealth of the vineyard- and its square. The 1855 classification seems a reasonable instrument. It is likely to be correlated with today's technologies (a vineyard classified in 1855 should have had incentives to make good technological choices in order to fulfil the promise made on the label).

Quality is represented by three recent ratings, and by auction prices obtained at Christie's London. The first rating is due to Robert Parker (1985), who classifies wines into nine categories: First- to Fifth Growth, Cru Grand Bourgeois Exceptionnel, Cru Grand Bourgeois, Cru Bourgeois and Other. We grouped all wines from Cru Grand Bourgeois Exceptionnel to Other into a single category, which leaves us with six categories. The second rating is due to Bettane and Desseauve (2000), editors of the *Revue du Vin de France*, who classify wines into five groups (3, 2, 1 and 0 stars, and unclassified). The third rating is obtained on calculations based on Michael Broadbent (1991), Christie's well known wine expert. Broadbent gives zero to five stars to wines but does not taste systematically all the châteaux. As a result, while some of them are tasted and graded more than 20 times over the period 1961-1990, others do not appear in the tasting list. We decided to compute average ratings for the 63 wines that Broadbent assessed at least three times.

For prices, we use the coefficients associated with château dummies obtained in a hedonic price regression ran by Di Vittorio and Ginsburgh (1996). This regression is based on some 30,000 lots (that include vintages from 1949 to 1989 for 51 Haut-Médoc vineyards) sold by Christie's London between 1980 and 1992.

Estimation results

Since there is little if any theory concerning the impact of endowments and of the various steps of the production process, we were led to select variables[16] using backward and forward stepwise procedures using OLS as a first step. More precisely, we ran two distinct stepwise procedures: one in which quality (or prices) is regressed

[15] In 1855, the wines of Médoc were classified. At that time, 60 châteaux were selected and classified as First to Fifth-Growth on the basis of their quality (actually, on the basis of their prices). The only change since 1855 was made in 1973, when Mouton-Rothschild was elevated to a First-Growth wine.

[16] Observed values for the varaibles representing endowments, and values predicted by an equation $T = E\gamma + W\delta$ for the variables representing technological choices, where γ and δ are estimated by OLS. Technologies are mainly represented by dummies and not by continuous variables, which may suggest using logit or probit regressions. See however Angrist and Krueger (2001, p. 80) who suggest using OLS instead. The correlation coefficients obtained in this step vary between 0.24 and 0.43. The distribution is as follows: $R^2 < 0.30$: 8 instances; R^2 between 0.30 and 0.40: 7 ; $R^2 > 0.40$: 2.

on endowments and another one where the regressors are technologies, to give each group of variables their chance to pass the statistical procedure. All the variables selected by either procedure were included.[17] Our first group of results, presented in Appendix Table 1, is obtained by two-stage least squares. These lead to the following three observations:

(a) Though the variables that enter the four quality equations (Parker, Bettane and Desseauve, Broadbent and Prices) were selected as contributing to explain quality (or prices) in the stepwise procedures, the number of coefficients that are significantly different from zero is small, particularly for endowments. We do not discuss individual coefficients, since the hypotheses that we want to test is whether endowments (as a group) or technologies (as a group) have an effect on quality.

(b) Durbin-Wu-Hausman tests are used to check whether technologies are exogenous and whether we could have run ordinary least squares to estimate our quality equations (1). Intuitively, this test calculates the "distance" between parameters obtained by OLS and by TSLS. If the distance (a χ^2 statistic) is small, there is no difference between OLS and TSLS, and technologies could be considered exogenous. The calculated values that appear in the upper part of Table 1 clearly indicate that OLS would lead to inconsistent estimates for the Parker and the Bettane and Dessauve equations: technologies are endogenous. OLS estimation is acceptable for the two other equations (Broadbent and auction prices).

(c) The results that are reproduced in the lower part of Table 1 deal with our main concern. What, if any, is the effect on quality of terroir and of technology. The hypotheses that are tested here are H_{0E}: endowments have no effect and H_{0T}: technologies have no effect. The results show that endowments do hardly matter in the Parker, the B&D and the Price equations:[18] removing endowment variables does not significantly change the results. This is far from being the case for technologies. Endowments do not seem to matter, whereas technologies do.

Recall that Parker and Bettane and Dessauve express their quality ratings by integers (1 to 5) or number of stars (1 to 4). Therefore, using ordered probit maximum likelihood methods to estimate equation (1) is more appropriate than the linear method used by TSLS. This generates two difficulties.

---

[17] The significance level considered for adding in the forward procedure (removing in the backward procedure) a variable to (from) the model is 5% (10%).

[18] This is not so in the Broadbent equation. Note, however, that there is only one (significant) endowment variable that appears in this equation (altitude).

First, given the number of endogenous variables and equations,[19] it is unlikely that a full information maximum likelihood simultaneous estimation of the system (1)-(2) is feasible.[20] This prompted us using a two step procedure, in which the first step consists in constructing instrumented technologies, the second consists in using endowments and instrumented technologies to estimate the quality (or price) equation by ordered probit.

This leads to the second difficulty, since the standard errors of the parameters estimated in the second step are biased.[21] To correct for this, we ran 200 bootstrap replications for each equation, and used these to estimate unbiased standard errors. Regression results appear in Appendix Table 2, and the more interesting results whether endowments and technologies have an effect can be found in Table 2. Usual tabulated significance levels would reject both H_{0E}: endowments have no effect (Parker) and H_{0T}: technologies have no effect (Parker and B&D), though H_{0T} is rejected at a much lower confidence level than H_{0E}. Simulated significance levels which have to be used here,[22] do not reject the hypothesis that endowments have no effect on quality, but reject this hypothesis for technologies.

5. Concluding comments

It may be tempting to conclude that the wine-making technology has become so sophisticated that it can completely shade the effect of terroir or of weather conditions, and that vines can be grown in almost any place, as long as the weather permits, and the right combination of vines is made.[23] But the French "terroir" legend does obviously not hold, at least in the Haut-Médoc region, which is probably one of the most famous in the world, not even when considering, as we did, terroir in the narrower sense of physical enowments. Nowadays, high quality wines are produced in many different environments, including Languedoc in the South of France, a region which was supposed to be able to grow table wines only, where Mas de Daumas Gassac produces a "vin de pays" sold at prices comparable to Second-Growth Pauillacs or Margaux.

Old-world producers--Italy, Spain and more specifically France--use intensively a terroir-based strategy to convince consumers that they produce top-

[19] One quality equation (1) plus as many equations of type (2) as there are endogenous technological variables that enter equation (1).

[20] As pointed out by Maddala (1985, p. 221), if the model contains a large number of truncated variables, estimation by maximum likelihood may be infeasible, because it involves the evaluation of multiple integrals. Though computing possibilities have increased tremendously since Maddala's writing, making the computations converge remains problematic.

[21] See Maddala (1985), pp. 234 and ff.

[22] See the technical appendix.

[23] On this issue, see Ashenfelter (1998).

quality wines (good wines, best terroir and old-world are synonymous). Conversely, new-world producers have favoured a brand-based strategy (sun, good oenologists and sophisticated wineries are key ingredients to make top-of-the-range wines; terroir is not a crucial factor). Nevertheless, none of the two strategies seems satisfactory in the very competitive world market that prevails nowadays. Indeed, in order to improve market shares, some new-world producers are intending to develop a certification system, i.e. a terroir-based strategy, recognizing implicitly the validity of the alternative strategy. In that respect, the Napa Valley example is interesting and illustrative. In this region, several producers like Dominus Estate are currently applying to get an official appellation from the Bureau of Alcohol, Tobacco and Firearms. On the other hand, old-world producers, by the mean of their inter-professional organizations (Bordeaux and Burgundy essentially) have decided to advertise more to develop their generic brand. In doing so, French producers try to mitigate the numerous drawbacks of their "Appellation d'Origine Contrôlée" (AOC) system[24] in order to recover their lost market shares. AOC laws are now much too strict. Many exceptional wines such as Daumas-Gassac, for example, are unable to obtain an AOC label essentially because they use vines that are not in conformity with the AOC rule. As a result, producers are forced to sell under the appellation "vin de pays," a low grade for a wine.[25] On the contrary, discovering the holy grail is apparently not very difficult: Didier Daguenau, who is known to produce outstanding Pouilly-Fumé wines, obtained an AOC label for his worst production, a lemon he calls "quintessence of my balls" (sic), produced with bad quality grapes that are however in conformity with the AOC tradition. In its current version, the complex and costly French AOC system seems unable to produce more than just horizontal differentiation (typicity). As a matter of fact, it cannot guarantee a high level of quality (vertical differentiation).

This does not mean that a wine with a St Estephe taste can be grown in Napa Valley or in Chile, but that wines of comparable quality can be. Since the taste of a wine is a horizontal quality, some consumers will prefer the St Esthephe, others will prefer the wine from Chile, but they will agree that both are good wines.

[24] For Barham (2003), the AOC label of origin may be seen as an application of the concept of terroir. It is conceived "*to make the transition from produit de terroir as a concept to the "qualified" agro-food entity that becomes an AOC label product*".

[25] French wines are classified into four categories, "Appellation d'origine contrôlée (AOC)," "Appellation d'origine vin délimité de qualité supérieure (AOVDQS)," "Vin pays," and "Vin de table."

References

Angrist, Joshua and Alan Krueger (2001), Instrumental variables and the search for identification: From supply and demand to natural experiments, *Journal of Economic Perspectives* 15, 69-85.

Ashenfelter, Orley, David Ashmore and Robert Lalonde (1995), Bordeaux wine vintage quality and the weather, *Chance* 8, 7-14.

Ashenfelter, Orley (1998), Using the hedonic approach to infer optimum vineyard locations for grape planting, paper presented at the VDQS meeting, Thessaloniki.

Ashenfleter, Orley and Karl Storchmann (2001), The quality of vineyard sites in the Mosel valley of Germany, Paper presented at the Napa Valley Conference of the VDQS Society.

Barham, Elizabeth (2003), Translating terroir : the global challenge of French AOC labelling, *Journal of Rural Studies* 19, 127-138.

Bettane, Michel and Thierry Desseauve (2000), *Le classement des vins et domaines en France 2001*, Paris: Editions de la Revue du Vin de France.

Broadbent, Michael (1991), *The New Great Vintage Wine Book*, New York: Alfred A. Knopf.

Di Vittorio, Albert and Victor Ginsburgh (1996), Des enchères comme révélateurs du classement des vins, *Journal de la Société Statistique de Paris* 137, 19-49.

Efron, Bradley and Robert J. Tibshirani (1998), *An Introduction to the Bootstrap*, London: Chapman & Hall/CRC.

Ginsburgh, Victor, Muriel Monzak and Andras Monzak (1994), *Red Wines of Medoc: What is Wine Tasting Worth*, Verona: Vineyard Data Quantification Society.

Maddala, G. S. (1985), *Limited-Dependent and Qualitative Variables in Econometrics*, Cambridge: Cambridge University Press.

Parker, Robert M. (1985), *Bordeaux, The Definitive Guide for the Wines Produced since 1961*, New-York: Simon and Schuster.

Parker, Rober M. (1990), *Les Vins de Bordeaux*, Paris: Solar.

Tinlot, Robert (2001), Le terroir: un concept à la conquête du monde, *Revue des Œnologues et des Techniques Vitivinicoles et Œnologiques* 101, 9-11.

Wilson, James (1998), *Terroir: The Role of Geology, Climate and Culture in the Making of French Wines*, Berkeley: University of California Press.

Table 1
Testing for exogeneity of technologies and for the contribution of endowments and technologies on quality and prices
(Two-stage least squares estimation)

	Parker	B&D	Broadbent	Prices
Testing for exogeneity of technologies (Durbin-Wu-Hausman test)				
χ^2-test	21.99	27.25	2.61	4.18
Degrees of freedom	5	7	5	4
Significance	(0.000)	(0.000)	(0.760)	(0.383)
Testing for the contribution of endowments and technologies				
H_{0E}: Endowments have no effect				
F-test	0.79	2.34	11.54	1.70
Degrees of freedom	4,92	3,91	1,56	5,41
Significance level	(0.537)	(0.079)	(0.001)	(0.157)
H_{0T}: Technologies have no effect				
F-test	8.01	6.83	4.53	4.82
Degrees of freedom	5,92	7,91	5,56	4,41
Significance level	(0.000)	(0.000)	(0.002)	(0.003)

Table 2
Testing for the contribution of endowments and technologies on quality and prices
(Two-step estimation; second step is an ML ordered probit)

	Parker	B&D
H_{0E}: Endowments have no effect		
χ^2-test	6.60	11.98
Degrees of freedom	4	3
Tabulated significance levels		
1%	13.23	11.34
5%	9.49	7.81
10%	7.78	6.25
Simulated significance levels		
1%	23.37	16.39
5%	18.11	11.77
10%	16.66	8.87
H_{0E}: Technologies have no effect		
χ^2-test	41.50	56.46
Degrees of freedom	5	7
Tabulated significance levels		
1%	15.09	18.48
5%	11.07	14.07
10%	9.24	12.02
Simulated significance levels		
1%	36.15	31.84
5%	27.04	23.35
10%	23.86	21.05

Appendix Table 1
Effects of natural endowments and technologies on quality
(Two-stage least squares estimation, variables selected by stepwise regressions)

	Parker		**B&D**		**Broadbent**		**Prices**	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Natural endowments								
Soil								
Clay-chalk	0.317	0.485	0.263	0.303				
Gravel								
Gravel-sand								
Sand								
Nitrogen							-0.121	0.123
Phosphoric acid								
Potassium								
Lime (CaO)								
Magnesia (MgO)			0.568	0.511				
Exposure								
Altitude ("high")					0.336	0.099[a]		
East	0.542	0.341	0.521	0.245[b]			0.490	0.186[b]
South-East								
South	0.122	0.440					0.209	0.130
South-West	0.225	0.378					-0.032	0.149
West							-0.363	0.187[c]
Technologies								
Age of vines								
5-20 years old								
20-40 years old			1.492	0.798[c]				
More than 40			0.853	0.797				
Grape varieties								
Cabernet Sauvignon								
Merlot	-0.129	0.042[a]	-0.061	0.030[b]				
Cabernet franc					-0.008	0.008		
Petit Verdot								

Variables selected (among 15 variables representing endowments and 21 representing technological choices) by stepwise regressions. See text.

Appendix Table 1 (cont.)
Effects of natural endowments and technologies on quality
(Two-stage least squares estimation)

	Parker		B&D		Broadbent		Prices	
	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.	Coeff.	St. err.
Technologies (continued)								
Vinification								
Manual picking	0.955	0.955	1.176	0.590[b]	0.492	0.168[a]	0.026	0.264
Manual sorting	0.946	1.687						
Crushing								
Heating								
Open float	-0.737	0.694	-0.674	0.464	-0.119	0.116	-0.285	0.196
Closed								
O sub								
No. of pressings					-0.116	0.071		
Oak barrels	1.913	1.206	1.522	0.722[b]	0.133	0.126	0.632	0.286[b]
Kieselguhr filtration			-1.815	0.854[b]				
Asbestos								
Adsorption								
Fresh eggs							0.108	0.267
Intercept	3.569	1.348[a]	0.422	1.236	0.433	0.245[c]	4.551	0.368[a]
R-square	**0.168**		**0.233**		**0.420**		**0.425**	
No. of observations	102		102		63		51	

Variables selected (among 15 variables representing endowments and 21 representing technological choices) by stepwise regressions. See text.

Appendix Table 2
Effects of natural endowments and technologies on quality
(Two-step estimation; second step is an ML ordered probit)

	Parker			B&D		
	Coeff.	St. err.	B. st. err.*	Coeff.	St. err.	B. st. err.*
Natural endowments						
Soil						
Clay-chalk	0.284	0.394	0.467	0.338	0.336	0.455
Gravel						
Gravel-sand						
Sand						
Nitrogen						
Phosphoric acid						
Potassium						
Lime (CaO)						
Magnesia (MgO)				0.765	0.574	0.719
Exposure						
Altitude ("high")						
East	0.559	0.259	0.272[w]	0.747	0.256	0.307[w]
South-East						
South	0.106	0.338	0.457			
South-West	0.340	0.304	0.366			
West						
Technologies						
Age of vines						
5-20 years old						
20-40 years old				2.340	0.902	0.875[w]
More than 40				1.483	0.848	0.981
Grape varieties						
Cabernet Sauvignon						
Merlot	-0.147	0.034	0.044[w]	-0.100	0.033	0.045[n,p]
Cabernet franc						
Petit Verdot						

* Standard error obtained from 200 bootstrap replications.
n, p, b and w indicate that the coefficient is significantly different from zero at the 5 percent level according to the confidence intervals using three different approaches: normal approximation (n), percentile (p) and bias corrected bootstrap (b); w is used if all methods point to significance at the 5 percent level. See Efron and Tibshirani (1998, chapters 12-14).

Appendix Table 2 (cont.)
Effects of natural endowments and technologies on quality
(Two-step estimation; second step is an ML ordered probit)

	Parker			B&D		
	Coeff.	St. err.	B. st. err.*	Coeff.	St. err.	B. st. err.*
Technologies (continued)						
Vinification						
Manual picking	1.261	0.752	0.785	1.694	0.645	0.703[n,p]
Manual sorting	1.095	1.259	1.947			
Crushing						
Heating						
Open float	-1.047	0.548	0.687	-1.072	0.486	0.677[p,bc]
Closed						
O sub						
No. of pressings						
Oak barrels	1.119	0.907	1.062	2.091	0.791	0.803[w]
Kieselguhr filtration				-2.664	1.002	1.295[n,p]
Asbestos						
Adsorption						
Fresh eggs						
Yield						
Cut values						
1	-3.013	1.072	1.337[w]	0.234	1.274	1.379
2	-2.024	1.058	1.266	1.465	1.275	1.334
3	-1.593	1.057	1.278	2.456	1.305	1.297[p]
4	-0.969	1.059	1.266	4.010	1.378	1.392[w]
5	-0.672	1.063	1.280			
Pseudo R-square	0.234			0.314		
No. of observations	102			102		

* Standard error obtained from 200 bootstrap replications.
n, p, bc, w indicate that the coefficient is significantly different from zero at the 5 percent level according to the confidence intervals using three different approaches: normal approximation (n), percentile (p) and bias corrected (bc); w is used if all methods point to significance at the 5 percent level. See Efron and Tibshirani (1998, chapters 12-14).

Technical appendix: Deriving the quantiles of the likelihood ratio statistic

The asymptotic distribution of likelihood ratio statistic under the null hypothesis is not known *a priori*. Therefore, one has to simulate this distribution for each hypothesis that needs to be tested. For this, we first regress (using ordered probit maximum likelihood) each quality equation under the null hypothesis. For example, if we want to test "H_{0E}: Endowments have no effect," we regress quality equation on technical variables, ignoring endowments:

(i) $$Q = T\beta + u.$$

The estimated parameters are used to construct a prediction for the latent variable, Q_h, to which one adds a random error w.[26] This generates simulated quality, say Q_{hw}, under H_{0E}. Recall that the original observations for quality are integer-valued. The values generated by this procedure can take any value, and have to be discretized by rounding. The simulated rounded values are then used as a dependent variable to estimate parameters of both the unconstrained and the constrained models (ii) and (iii):[27]

(ii) $$Q_{hw} = E\alpha + T\beta + u$$

(iii) $$Q_{hw} = T\beta + u.$$

The two regressions are bootstrapped 200 times in order to construct simulated values for the likelihoods of both equations, and this leads to 200 likelihood ratio satistics. Since the likelihood ratio statistic distributions derived from this procedure did not match with the chi-square distribution, we extracted and used the appropriate empirical quantiles (1%, 5% and 10%) for inference purposes.[28]

[26] We experimented with a normal distribution and a Student distribution with five degrees of freedom. Results were insensitive to the choice of the distribution.

[27] Note here that adding a small noise differentiates randomly equation (iii) from equation (i).

[28] Changing the number of replications did not change the results.