

## ESTIMATION OF A HEDONIC PRICE EQUATION FOR BORDEAUX WINE: DOES QUALITY MATTER ?\*

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In this paper the hedonic price technique is applied to Bordeaux wine. In the hedonic price function we include not only the ‘objective’ characteristics appearing on the label of the bottle, but also the sensory characteristics of the wine. Our data come from an experimental study in which juries have evaluated and graded a sample of Bordeaux wines. The estimation of the hedonic price equation shows that the market price is essentially determined by the objective characteristics. The estimation of a jury grade equation shows that quality, unlike the market price, is essentially determined by the sensory characteristics.

Covering an area of more than 100,000 acres, the Bordeaux wine region is undoubtedly the world’s largest wine region. It produces more than 660 million bottles per year, varying from simple and plain table wines to the most prestigious wines such as Pétrus, Margaux, Lafite-Rothschild, Latour, Yquem, Haut-Brion and others. The Bordeaux wine region produces bottles that can cost just FF10 but also more than ten thousand francs, young wines that are ready to drink as well as wines that improve even after decades of keeping, wines that are made from different combinations and proportions of grape varieties, and wines that originate from various sorts of soils. Clearly, Bordeaux wines are not the same, but possess different characteristics and vary in quality. This makes Bordeaux wine a suitable product for a hedonic price analysis.

The hedonic price method is a useful approach to study the price–quality relationship of a product. The method amounts to a (possibly nonlinear) regression analysis of the price on the characteristics of the product. The implicit price of a characteristic is defined as the derivative of the price with respect to the product attribute. Rosen (1974) has shown under which market conditions the implicit price can be interpreted as the value consumers place on an additional unit of the characteristic. If the estimated implicit price turns out to be not significantly different from zero, then the characteristic is not valued by consumers, or the characteristic is not considered important or relevant in connection with the product.

The earliest reference to this literature seems to be Waugh (1928). He observed that prices of certain fresh vegetables varied considerably on the Boston wholesale market, and regressed the price on various physical characteristics of the vegetables. The notion ‘hedonic pricing method’ is generally attributed to Court (1939). He applied the method to automobiles, and included several technical characteristics of the car in the hedonic price equation. It was not until Griliches (1961) that Court’s work was really

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revived. Griliches' work on the hedonic price method had an important impact and immediately initiated a vast body of empirical work, with applications to the automobile industry (some recent references are Atkinson and Halverson (1984), Arguea and Hsiao (1993), and Couton *et al.* (1996)), the computer industry (Chow, 1967; Triplett, 1989), and the housing market (Witte *et al.*, 1979; Palmquist, 1984; Bartik, 1987).

As this list of applications shows, the hedonic price method has been applied mainly to durable goods. The application that we consider in this paper is different in two respects. The first obvious difference is that Bordeaux wine is not a durable good, but a food product.<sup>1</sup> The second difference is that, unlike durable goods, not all the relevant characteristics of wine are easy to identify and to measure.<sup>2</sup> Although the label on the wine bottle gives important information about the vintage year, the name of the château, the eventual ranking of the wine, etc..., this is only part of the story. Indeed, labels do not in general provide information on the sensory characteristics (taste, texture, or odour) of a wine. The purpose of this paper is to estimate a hedonic price function for Bordeaux wine that includes both the label characteristics and the sensory characteristics. This will allow us to assess how much value consumers implicitly place on the label and sensory characteristics. It will also allow us to answer the intriguing question posed in the title of this paper: does quality matter? As will be shown in the paper, there is strong evidence that, at least in our data, quality is mainly determined by the sensory characteristics of a wine. By examining the estimates of the parameters associated with the sensory characteristics, we are able to tell to what extent quality matters in explaining market prices.

As far as we know, there are two other studies on the hedonic pricing of wine. In Nerlove (1995), which came to our attention while the present paper was being revised, a hedonic price function is estimated using Swedish data. He argues that the Swedish wine market is not competitive (it is argued that the market prices and the product characteristics can be taken as exogenous to the Swedish consumer), and that a standard hedonic regression is not appropriate. The author proposes therefore an alternative method to draw inferences about consumer preferences. In Oczkowski (1994) the method is applied to Australian table wine. The main difference with the present study is that he essentially considers objective and easily observable characteristics (vintage year, vineyard region, grape variety, etc...). The sensory characteristics are lacking in his data set. Our data source, in contrast, contains detailed information about the sensory characteristics of wines, and has a number of other advantages over the sort of information one can find in wine guides.

The paper is organised as follows. In Section I the data are presented. In Section II we present the empirical results. Section III contains some concluding remarks.

<sup>1</sup> Other applications of the hedonic price technique to food products are Ladd and Suvannunt (1976), Stanley and Tschirhart (1991), and the references in these two papers.

<sup>2</sup> Waugh also considered food products, but the relevant product characteristics were measurable physical properties that were readily available to all consumers by simple observation.

## I. THE DATA

Natural candidates for our data source are the widely published and easily accessible wine guides. We feel, however, that most of these sources are inappropriate for estimating hedonic price equations. Indeed, wine guides do not in general verify the following conditions. First, all the wines that are tasted should be included in the sample, regardless of whether the wine is considered good or bad. In wine guides the wines of inferior quality are often deliberately under-represented for commercial reasons. High-quality wines, and in particular the well-known *cru classé* wines (like Lafite-Rothschild, Margaux, Latour, Haut-Brion, etc...), are the wines in which many wine fans are simply most interested.<sup>3</sup> Second, bottles that are specially prepared to participate in a wine contest must be avoided, as they are not, in general, representative for the overall production of the château. Third, in a concern for objectivity, the bottles must be evaluated and tasted by independent experts. In wine guides it is often the author, possibly assisted by a team of colleagues, who evaluates the wines. If at the same time the guide is sponsored by wine producers (which is often the case), then some objectivity may be lacking. Fourth, tasting must occur blindly. In evaluating a wine, the members of a jury must not be influenced in advance by the name of the château, the appellation, the ranking or the vintage. Fifth, all the wines in the sample must be bought under the same conditions. Differences in price levels between bottles of wine should reflect differences in wine characteristics, and not differences in purchase circumstances. This means that one should for instance avoid a sampling scheme in which part of the bottles are bought directly at the château, and another part at say the wine grocery.

To the best of our knowledge, the only data source satisfying these five conditions comes from an experimental study held by the *Institut National de la Consommation* (INC). The results from this study are published in the December 1992 issue of a French review called *50 Millions de Consommateurs*. We have extracted our data from this review.

Between 15 and 26 June 1992, about twenty collaborators of the INC and members of the *Confédération Syndicale du Cadre de Vie Aquitaine* visited at random 600 Bordeaux wine cultivators. In an effort to reproduce the environment in which an ordinary customer buys wine, no prior rendezvous was made with the wine cultivators. Fifty-nine cultivators were not present at the time of the visit. All the remaining 541 wine producers decided to participate in the study. At each participating château two bottles were purchased. The second bottle was purchased in case the first bottle had some defect. In most cases the buyers themselves have chosen the samples, in order to avoid the contest bottles. All the purchased wines were brought to the *Institut National de la Recherche Agronomique* (INRA) in Toulouse (France).

The tasting took place between 29 June and 4 July, in the tasting room of INRA. The experiment was organised by the oenology centre of the Paul-

<sup>3</sup> This is for instance the case with Bradfer *et al.* (1992), which is a guide on the best wines in France.

Sabatier University of Toulouse. Three juries took part in the test. Each jury consisted of four persons: a professor of oenology from the Paul-Sabatier University, a recently graduated oenologist, a practising oenologist, and a wine waiter. Although we know that each wine in the sample is evaluated by one jury, we cannot tell from our data which jury tasted which wine. Therefore, we cannot identify jury specific effects, and we will implicitly assume that the three juries are identical.

The evaluation of a wine generally consists of three parts: a visual examination, an olfactory examination, and a gustatory examination. The visual examination reveals the colour of the wine, its brilliance, and its limpidity. It allows the jury members to make a judgement about the maturation of a wine. The visual examination can influence the jury before the actual tasting (olfactory and gustatory examination) starts. For this reason it was decided by the INC to omit the visual examination from the experiment.

After the tasting the jury is requested to write a technical comment on the wine. In the comment, that is published by the review *50 Millions de Consommateurs*, the jury members report their olfactory findings (the aromatic intensity of the wine, the finesse of the aromas, the complexity of the aromas), their gustatory findings (the firmness of the attack, the suppleness of the wine, the flatness, whether the wine is considered fat, the harmony between the components, the finish, etc...), and they make some general remarks about the wine (about the alcohol level in the wine, whether the wine needs further keeping or not, etc...). In the sequel of the paper we shall refer to the above variables as the sensory characteristics of the wine. Each jury member also assigns a grade (between 0 and 20) to the wine. The review has published the average of the four grades, rounded off to the nearest quarter of a point (e.g. an average of 12.68 becomes 12.75).

For each wine, the review also gives information about the name of the château, the ranking of the wine (*grand cru classé* or *cru classé*, *cru bourgeois*, or *cru non classé*), the colour of the wine (red or white; there are no rosé wines in the sample), the vintage (1989, 1990, or 1991), and the appellation (all the 54 Bordeaux appellations are represented in our sample; for practical reasons, these 54 appellations are regrouped into six larger appellations according to criteria proposed by the *Conseil Interprofessionnel du Vin de Bordeaux*). We shall refer to these variables as the objective characteristics of the wine. Recall that the objective characteristics are not known by the jury. Finally, the review gives for each wine the price level at which the bottle is purchased.

From the original sample of 541 observations we retain 519 wine bottles. Three bottles were eliminated because they were not evaluated (two samples were defective, and one was corked). The remaining observations were dropped because they were purchased at the wine merchant and not at the château (violation of condition five), or because the wine was extracted from the cask or the vat. Table 1 contains the complete list of the available variables in the sample, together with their abbreviations and some simple descriptive statistics.

Before turning to the model and the empirical results we need to give some

Table 1  
*Descriptive Statistics*

Variables	Abbreviations	Modalities	Descriptive statistics
Price	<i>PRICE</i>	Continuous	Mean = 52.78 Standard deviation = 31.05
Jury grade	<i>GRADE</i>	Continuous	Mean = 11.21 Standard deviation = 2.41
Sensory characteristics			
Olfactory examination			
Aromatic intensity	<i>INTE</i>	Strong = 3; Classic = 2; Discreet = 1	45.08; 32.64; 22.28
Finesse of aromas	<i>FINE</i>	Yes = 2; No = 1	15.61; 84.39
Complexity of aromas	<i>COMP</i>	Yes = 2; No = 1	23.70; 76.30
Gustatory examination			
Firmness of attack	<i>FIRM</i>	Yes = 2; No = 1	19.85; 80.15
Excessive acidity	<i>ACID</i>	Yes = 2; No = 1	13.87; 86.13
Suppleness	<i>SUPP</i>	Yes = 2; No = 1	28.90; 71.10
Flatness	<i>FLAT</i>	Yes = 2; No = 1	8.29; 91.71
Fat	<i>FAT</i>	Plump = 3; Medium = 2; Lean = 1	17.34; 79.19; 3.47
Well-concentrated	<i>WCON</i>	Yes = 2; No = 1	19.08; 80.92
Harmony between the components	<i>HARM</i>	Well balanced = 3; Balanced = 2; Unbalanced = 1	18.69; 50.29; 31.02
Presence of fine tannins	<i>TANI</i>	Yes = 2; No = 1	19.08; 80.92
Finish	<i>FINI</i>	Long = 3; Medium = 2; Short = 1	34.20; 50.78; 15.02
General remarks			
Alcohol excess	<i>ALCO</i>	Yes = 2; No = 1	15.41; 84.59
Traces of staleness	<i>STAL</i>	Yes = 2; No = 1	10.60; 89.40
Touch of reduction	<i>REDU</i>	Yes = 2; No = 1	3.47; 96.53
Keeping in vault needed	<i>KEEP</i>	Yes = 2; No = 1	29.87; 70.13
Objective characteristics			
Ranking	<i>RANK</i>	Cru or grand cru classé = 3; Cru bourgeois = 2; Cru non classé = 1	6.74; 9.25; 84.01
Red wine	<i>RED</i>	Yes = 2; No = 1	82.08; 17.92
White wine	<i>WHIT</i>	Yes = 2; No = 1	17.92; 82.08
1989 vintage	<i>AN89</i>	Yes = 2; No = 1	61.66; 38.34
1990 vintage	<i>AN90</i>	Yes = 2; No = 1	33.33; 66.67
1991 vintage	<i>AN91</i>	Yes = 2; No = 1	5.01; 94.99
Bordeaux group	<i>BORD</i>	Yes = 2; No = 1	15.99; 84.01
Côtes group	<i>COTE</i>	Yes = 2; No = 1	15.22; 84.78
Médoc and Graves group	<i>MEGR</i>	Yes = 2; No = 1	20.81; 79.19
Saint-Emilion Pomerol Fronsac group	<i>SEPF</i>	Yes = 2; No = 1	30.06; 69.94
Blancs Secs group	<i>BLSE</i>	Yes = 2; No = 1	12.91; 87.09
Blancs Doux group	<i>BLDO</i>	Yes = 2; No = 1	5.01; 94.99

*Notes* : The descriptive statistics are based on the complete sample of 519 wines; for the continuous variables we give the mean and standard deviation; for the discrete variables we give the percentage of observations that is equal to the relevant modality; for *INTE* and *FINI* the descriptive statistics are based on the subsample of 193 wines.

further details about the sensory characteristics. Ideally, the sensory characteristics are determined from standard predefined forms in which the jury evaluates the different characteristics of the wine by ticking appropriate boxes. As outlined above, this is unfortunately not the way our sensory characteristics are defined. Instead, they come from the technical comment provided by the jury. To a certain extent it is up to the jury to decide how to write and what to include in its comment. Although the 519 comments in the sample show much resemblance (remember that there are only three juries), there is some heterogeneity, and in particular in a considerable number of technical comments some subjective characteristics are missing. To solve this missing variable problem we have to make some working hypotheses.

First we consider the case when the sensory characteristic is a dichotomous variable. If the characteristic is not mentioned in the comment we then assume that the wine does not possess this characteristic. The assumption we have made here does not appear very strong in the sense that *the absence* of a characteristic is never mentioned. Hence it is very likely that juries indeed only mention a sensory characteristic if the wine actually possesses it.

Next we consider the case when the sensory characteristic is a polytomous variable. For the *FAT* variable, the medium modality is never mentioned. Only the plump and lean modalities appear in the comments, the former indicating a quality and the latter a default. Following the same kind of reasoning as for the dichotomous variables, we assume that if the *FAT* variable is missing then the wine is medium fat. For the *HARM* variable, we can infer the missing observations from other characteristics or other indications available in the jury's comment. Details can be obtained from the authors upon request. For the two remaining polytomous variables, *INTE* and *FINI*, we cannot rely on the hypothesis made in the case of the *FAT* variable, because the medium modality appears relatively often. Therefore, if *INTE* or *FINI* are missing we cannot assume that they are equal to the medium modality. Furthermore, contrary to the *HARM* variable, if *INTE* or *FINI* are missing they cannot be inferred from other indications in the comments. The variables *INTE* and/or *FINI* are missing for 326 observations. Hence there are 193 observations for which all characteristics are available.

## II. EMPIRICAL RESULTS

### II.1. *A Preliminary Analysis*

In our hedonic price equation the dependent variable is the logarithm of the price of Bordeaux wine, and in the explanatory variables we include all the characteristics of the bottle (the objective and the sensory variables defined in Section I). It is tempting here to include also the jury grade in the vector of explanatory variables. This, however, would not be correct for two reasons. First, the jury grade is not really a characteristic of the wine, but rather a quality index that depends on the attributes of this wine. In Rosen's (1974) pure competition framework a hedonic price equation is supposed to be a function of intrinsic characteristics alone, and so the jury grade should not be

Table 2  
*Hedonic Price Equation*

	(1)	(2)
Sensory variables		
<i>WCON</i>	0.163 (0.072)	
<i>KEEP</i>	0.207 (0.073)	0.158 (0.037)
Objective variables		
<i>RANK</i>	0.307 (0.051)	0.309 (0.030)
<i>AN89</i>	0.664 (0.111)	0.654 (0.075)
<i>AN90</i>	0.506 (0.112)	0.488 (0.077)
<i>BORD</i>	-0.418 (0.085)	-0.484 (0.052)
<i>COTE</i>	-0.204 (0.088)	-0.314 (0.050)
<i>SEPF</i>	0.260 (0.079)	0.162 (0.042)
<i>BLDO</i>	0.261 (0.096)	0.308 (0.073)
Constant	1.352 (0.327)	1.912 (0.225)
Number of observations	193	519
$\bar{R}^2$	0.662	0.631

*Notes:* Standard errors in parentheses; (1) results based on the subsample of 193 wines; (2) results based on the complete sample of 519 wines.

included. Second, since the bottles are purchased *before* tasting takes place, the jury grade cannot, logically speaking, have any influence on the price level.<sup>4</sup>

In Table 2, column (1), we present the OLS estimates of the hedonic price equation based on the 193 observations for which all the characteristics are available.<sup>5</sup> The  $\bar{R}^2$  is equal to 0.662, indicating that the overall fit of the hedonic price equation is relatively good. Given the large number of explanatory variables, we have used a stepwise procedure to select the regressors that are significant at the 5% level. It does not matter here whether we use a backward procedure or a forward procedure. In both cases the final set of selected explanatory variables is the same. In this sense the results are thus very robust. There are nine selected variables (and a constant).

The parameters corresponding to the first five variables in Table 2 take the expected sign: the price level increases if the wine is well concentrated, if the wine needs keeping, and if the wine is well ranked; the price level is also higher for the 1989 and 1990 vintages (the vintages of 1989 and 1990 are generally considered good compared to the 1991 vintage, see for example Johnson (1994)). Not much can be said in advance about the signs of the parameters associated with the remaining variables in Table 2. The outcome is essentially an empirical matter. It appears from Table 2 that the price level decreases when the wine originates from the Bordeaux or the Côtes appellation group; the price level increases when the wine originates from the Saint-Emilion Pomerol Fronsac or the Blancs Doux appellation group. It is remarkable that

<sup>4</sup> The jury grade can have an impact on future prices. In fact, following the publication of the *50 Millions de Consommateurs* review, many châteaux that received a good grade saw the demand for their wine augment considerably (personal communication with the INC). It is likely that these châteaux have responded by augmenting the price of their bottles. Unfortunately we do not have the data to study this interesting phenomenon.

<sup>5</sup> The estimation results in this paper are obtained with the Stata (version 4.0) software package.

among the nine variables in Table 2, only two belong to the set of sensory variables.<sup>6</sup> This suggests that the price of a wine is essentially determined by the objective characteristics of the bottle, i.e. the characteristics that are easily identifiable and identically perceived by all consumers.

We have given two arguments why it would not be appropriate to include the jury grade as an independent variable in the hedonic price equation. Instead, it seems of interest to consider the logarithm of this variable as a dependent variable, in an equation where the explanatory variables are the characteristics of the wine. In Table 3, column (1), we present the OLS

Table 3  
*Jury Grade Equation*

	(1)	(2)
Sensory variables		
<i>INTE</i>	0.034 (0.010)	0.034 (0.006)
<i>FINE</i>		0.076 (0.019)
<i>COMP</i>	0.105 (0.018)	0.075 (0.018)
<i>ACID</i>		0.056 (0.021)
<i>FIRM</i>		0.044 (0.018)
<i>SUPP</i>		0.051 (0.016)
<i>FAT</i>	0.055 (0.017)	0.070 (0.016)
<i>WCON</i>	0.051 (0.022)	0.061 (0.021)
<i>REDU</i>		-0.078 (0.038)
<i>ALCO</i>	-0.085 (0.030)	
<i>HARM</i>	0.044 (0.012)	0.100 (0.011)
<i>TANI</i>		0.040 (0.018)
<i>FINI</i>	0.066 (0.013)	0.061 (0.015)
<i>KEEP</i>	0.059 (0.021)	0.110 (0.018)
Objective variables		
<i>AN91</i>	-0.095 (0.030)	
<i>AN90</i>		0.041 (0.017)
<i>BLDO</i>	-0.055 (0.026)	
<i>WHIT</i>		-0.067 (0.020)
<i>SEPF</i>		0.075 (0.018)
Constant	2.007 (0.081)	1.284 (0.099)
Number of observations	193	519
$\bar{R}^2$	0.658	0.597

*Notes:* Standard errors in parentheses; (1) results based on the subsample of 193 wines; (2) results based on the complete sample of 519 wines.

estimates of this jury grade equation, based on the same sample of 193 bottles. For the jury grade equation the  $\bar{R}^2$  is equal to 0.658, again indicating a relatively good overall fit. We use a stepwise procedure to select the regressors that are significant at the 5% level. Again, it does not matter whether we use a backward procedure or a forward procedure. There are ten selected variables (and a constant).

<sup>6</sup> One might argue that since the objective variables are highly correlated with the sensory variables, the presence of the former variables prevents the latter to enter the hedonic price equation. To verify this possibility, we have regressed the logarithm of the price on the sensory variables alone. This time again only *WCON* and *KEEP* are the significant variables.

The parameters take the expected sign: the jury grade increases if the aromatic intensity of the wine is strong, if the wine has a complex nose, if the wine is considered fat, if the wine is well concentrated, if the harmony between the components is well balanced, if the finish is long, and if the wine needs keeping; the jury grade decreases if the alcohol level in the wine is too high, and if it concerns a 1991 vintage. Not much can be said in advance about the sign of *BLDO*. Table 3 shows that wines from the Blancs Doux group are generally not appreciated by the jury members. Whereas in the hedonic price equation the majority of significant variables are the objective characteristics, the opposite is true for the jury grade equation. Among the ten significant variables in Table 3, eight are sensory variables. This result, together with the fact that all the coefficients of the sensory variables take the expected sign, seems to justify (*ex post*) our codification of the sensory variables. Notice that, contrary to the hedonic price equation, *RANK* does not have a significant effect in the jury grade equation. This result is in support of the widely heard criticism that the ranking system is too old (the Médoc ranking system dates from 1855; the Graves ranking system dates from 1959; the Saint-Emilion ranking system dates from 1954, but is revised every 10 years, the last time in 1986), often irrelevant and needs to be updated. Our result appears in accordance with the conclusions drawn from a wine-tasting session held in January 1995, in San Francisco (as far as we know, the results of this study were only reported in the press). On the initiative of G. Getty, an American billionaire and a fan of Bordeaux wine, ten of the most famous wine tasters in the world were reunited in San Francisco to taste blindly a sample of Bordeaux wines. The sample contained all the Médoc wines with a ranking (some Graves were also included, but the results regarding these wines were not published). In 1855, 61 Médocs were ranked in five categories, and the jury members in Getty's study were requested to establish a new classification (from 1 to 61). Although the reshuffling did not turn out to be dramatic (for instance, the four first-category wines are still in the top 15), the 1855 and 1995 classifications were certainly not identical (for instance, one fifth-category wine can be found in the top 10). The fact that the hierarchy in the Médoc ranking system is somewhat challenged here is of course not very surprising. Since 1855 a lot of things have changed. Many châteaux have changed ownership, certain châteaux have doubled or even tripled their cultivation surface, new vinification methods have been introduced, etc...

Until now the hedonic price and jury grade equations have been estimated separately. However, the coefficient of correlation between the price level and jury grade is 0.443. It is therefore not unlikely that, conditionally on the explanatory variables, there is dependence as well. Hence, it is not unlikely that the error terms in the hedonic price level and jury grade equations are dependent. For this reason we perform a seemingly unrelated regression of the two equations. The estimated standard errors remain practically unchanged, and the Breusch–Pagan test rejects the hypothesis of dependence between the error terms. This means that, conditionally on the explanatory variables, the price level and jury grade are independent variables.

## II.2. Results Based on the Complete Sample

The estimations presented in Section II.1 are based on 193 observations. They come from an initial sample of 519 wine bottles, from which 326 are discarded because one or two explanatory variables are missing. This is a drastic sample reduction, and one might wonder therefore whether the results presented in Section II.1 are (partly) due to the relatively small size of the sample. To answer this question we perform OLS regressions of the hedonic price equation and jury grade equation on the complete sample of 519 observations, by adding in both equations two dummy variables that indicate if the variables *INTE* or *FINI* are missing. The first dummy equals 1 if *INTE* is missing and is equal to 0 otherwise, the second dummy equals 1 if *FINI* is missing and is equal to 0 otherwise. If *INTE* or *FINI* are missing we set these variables equal to 0. The estimates we obtain via the stepwise procedure (again it does not matter whether we use a backward procedure or forward procedure: the set of selected variables is exactly the same in both cases) suggest that the parameters associated with the two dummies are not significantly different from zero in the hedonic price equation. This in turn suggests that for the hedonic price equation it is not important to control for the fact that *INTE* and *FINI* can be missing. In the jury grade equation the parameter associated with the first dummy is also insignificant, but the parameter corresponding to the second dummy is significantly different from zero. Furthermore, as in Section II.1, the parameter corresponding to *FINI* is significant. As far as the jury grade equation is concerned it appears important, therefore, to control for the fact that the variable *FINI* can be missing. In summary, we present the estimates of the following hedonic price and jury grade equations

$$\ln PRICE_i = \mathbf{X}_i\boldsymbol{\alpha} + u_i, \quad i = 1, \dots, n, \quad (1)$$

$$\ln GRADE_i = \mathbf{Z}_i\boldsymbol{\beta} + D_i\gamma + v_i, \quad i = 1, \dots, n, \quad (2)$$

where  $\mathbf{X}_i$  and  $\mathbf{Z}_i$  are the vectors of significant explanatory variables for observation  $i$  in the hedonic price equation and jury grade equation respectively,  $D_i$  is the dummy variable that is equal to 1 if  $FINI_i$  is missing and 0 otherwise,  $\boldsymbol{\alpha}$ ,  $\boldsymbol{\beta}$  and  $\gamma$  are unknown parameters ( $\boldsymbol{\alpha}$  and  $\boldsymbol{\beta}$  are vectors and  $\gamma$  is a scalar),  $u_i$  and  $v_i$  are error terms with the usual properties, and  $n$  represents the total number of observations.

Before discussing the results we want to address the following issue. The jury reports, from which we extract the sensory variables, vary in length. In general, long reports are associated with high-quality wines (i.e. high grades), and *vice versa*.<sup>7</sup> This simply reflects the fact that jury members tend to be more enthusiastic as the tasted wine gets better. The variable *FINI* is more likely to be missing if the jury report is short. As a consequence, the subsample containing the observations with known *FINI* consists of wine bottles with comparatively high jury grades. This in turn might imply that a wine with a large error term is more likely to be in the subsample of wines with known

<sup>7</sup> Whereas a high-quality wine is in most cases described by a report of six or seven lines, the report of a low-quality wine rarely exceeds three lines.

*FINI*, and *vice versa*. In terms of (2), this can be interpreted as a negative correlation between the variable  $D_i$  and the error term  $v_i$ . It is well known that OLS estimation of (2) leads to inconsistent estimates if an explanatory variable is correlated with the error term. We must therefore test whether  $E(D_i v_i) = 0$ . To do this we apply the Hausman (1978) test, which in the present context amounts to adding in (2) a variable  $\hat{D}_i$ , and testing whether the associated parameter of this variable is equal to zero. Here  $\hat{D}_i$  denotes the fitted value in a regression of  $D_i$  upon a vector of instrumental variables  $\mathbf{W}_i$ , i.e.  $\hat{D}_i = \mathbf{W}_i \hat{\boldsymbol{\delta}}$ , where  $\hat{\boldsymbol{\delta}}$  is the OLS estimate. The vector of instrumental variables  $\mathbf{W}_i$  includes  $\mathbf{Z}_i$  and all other objective and sensory variables that do not have a significant effect on the jury grade. Since  $D_i$  is a binary variable it may be more appropriate to perform the Hausman test by considering  $\hat{D}_i = \Phi(\mathbf{W}_i \hat{\boldsymbol{\delta}})$ , where  $\Phi(\cdot)$  is the distribution function of a standard normal random variable, and  $\hat{\boldsymbol{\delta}}$  is the ML estimate obtained from a probit analysis (in this case  $\hat{D}_i$  is sometimes called a probability instrument, see Bowden and Turkington (1984)). In both cases the Hausman test rejects the null hypothesis, and we thus conclude that OLS estimation of (2) leads to consistent estimates of the parameters of interest.

Table 2, column (2), gives the estimates of the hedonic price equation based on the complete sample. A comparison with column (1) shows that the variable *WCON* is no longer significant, but that otherwise the set of significant variables is exactly the same. The signs of the parameters are also identical, and their magnitudes are of comparable order. Table 3, column (2), gives the estimates of the jury grade equation, in which we control for the fact that the variable *FINI* can be missing. The estimate of  $\gamma$  is 0.070, and the standard error is 0.034. The estimate of this parameter takes the wrong sign, since we expect that *FINI* is missing when wines are of lower quality. Since  $D$  is found to be exogenous, this unanticipated result is apparently not due to endogeneity problems. Let us first look at the results for the sensory variables. Comparing column (2) with column (1) we see that *ALCO* is no longer significant, but that otherwise the effect of a larger sample size is to increase the number of significant sensory variables. We only discuss the effects of the newly entered sensory variables (since the parameters corresponding to the variables already present in column (1) take the same sign). The jury grade increases if the wine has a fine nose, if the attack of the wine is considered firm, if the wine is supple, and if the wine contains fine tannins; the jury grade decreases if there is a touch of reduction (bad smell or bad taste due to the presence of sulphur). The only sensory variable that does not have the expected effect is *ACID*: the jury grade increases if the wine is considered too acid. As far as the objective variables are concerned, we see that the variables *ANg1* and *BLDO* are no longer significant. The newly entered variables are *ANg0* and *SEPF* (positive effects), and *WHIT* (negative effect).

Summarising the results,<sup>8</sup> we see that the general picture that emerged from Section II.1 is confirmed here, and even reinforced: the hedonic price equation

<sup>8</sup> A seemingly unrelated regression of (1) and (2) leads to the same conclusion as in Section II.1: the estimated standard errors remain practically unchanged, and the Breusch–Pagan test rejects the hypothesis of dependence between the error terms.

is essentially determined by the objective variables and the jury equation is essentially determined by the sensory variables. We will comment more in detail on these findings in the conclusion.

### III. CONCLUSION

The empirical results in this paper indicate that the market price of Bordeaux wine can be explained primarily by the objective characteristics appearing on the label of the bottle. On the other hand, the quality of Bordeaux wine, as measured by a jury grade assigned by professional wine tasters, can be explained primarily by the sensory characteristics of the wine. Many variables that are important in explaining quality apparently do not play a role in the determination of the market price. We have two explanations for this conclusion. First, one might argue that tastes are not similar among jury members and consumers, and that they even differ between consumers. Some consumers may have a preference for say tannic wines, while others may prefer non-tannic wines. The effect of the first group of consumers would then be offset by the effect of the second group. In this case, the sensory characteristic would have no effect on the price of wine. This explanation is perhaps not so convincing for economists, since they rarely make the assumption that tastes are heterogeneous. For example, Stigler and Becker (1977) argue that 'tastes neither change capriciously nor differ importantly among people'.

The second explanation is in terms of imperfect information. In Rosen's pure competition framework, consumers are supposed to make their decisions on the basis of perfect information: all information is available for all consumers without any cost. This assumption is obviously unrealistic for certain products. Some characteristics may simply be easier to identify or perceive than others. In the case of Bordeaux wine, the objective characteristics (those mentioned on the label) are much easier to identify by consumers than the sensory characteristics. Therefore, it is more difficult, and thus more expensive, to obtain information about the latter than about the former. According to Lévy-Garboua (1976), if information is imperfect, rational consumers gather information about a characteristic if the marginal cost of obtaining the information is smaller than or equal to the marginal utility it generates. As it is expensive to obtain information about the sensory characteristics (only available through tasting, learning, and reading wine guides), consumers may decide to make their (wine) choice primarily on the basis of the objective characteristics, thus explaining the absence of almost all sensory characteristics in the hedonic price function.

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