Identifying the Effect of Unobserved Quality and Expert Reviews in the Pricing of Experience Goods: Empirical Application on Bordeaux Wine[a]

Pierre Dubois[b]

Céline Nauges[c]

JEL codes: C51, L15, Q11

Keywords: experience good, unobserved quality, expert reviews, structural econometrics, wine

[a] We would like to thank Daniel Ackerberg and two anonymous referees for their comments that improved this paper. All remaining errors are ours.

[b] Corresponding author. Affiliation: Toulouse School of Economics (GREMAQ, INRA, IDEI). Address: Manufacture des Tabacs, 21 Allée de Brienne, 31000 Toulouse, France. Tel: +33 5 61 12 85 55; Fax: +33 5 61 12 86 37; email: dubois@toulouse.inra.fr

[c] Affiliation: Toulouse School of Economics (LERNA-INRA). Address: Manufacture des Tabacs, 21 Allée de Brienne, 31000 Toulouse, France. email: cnauges@toulouse.inra.fr

Abstract

We propose a structural empirical approach *à la* Olley and Pakes (1996) to disentangle the effect of experts' grades from the effect of unobserved quality on the pricing of experience goods. Using a panel data set of 108 *châteaux* selling wine on the "en primeur" market of Bordeaux, we confirm that experts' grades affect producers' choice of "en primeur" price above the effect of unobserved wine quality. Our empirical results also show that failing to control for endogeneity caused by the omission of unobserved quality leads to over-estimate the influence of experts' grades on the "primeur" price.

1 Introduction

Since the work by Nelson (1970, 1974), experience goods (i.e., goods for which quality cannot be ascertained before effective consumption) have been the focus of extensive theoretical and empirical research. The theoretical literature (Shaked and Sutton, 1982; Shapiro, 1983; Tirole, 1996; Mahenc and Meunier, 2003; among others) mainly considers firm's activity of quality signaling (through advertising, product labeling, reputation, experts' ratings, etc.), while most empirical studies (Ackerberg, 2003; Caves and Greene, 1996; Jin and Leslie, 2003; etc.) measure the influence of these various sources of information on consumer demand.

Wine, and "en primeur" wine in particular, has been at the core of several recent papers, both theoretical and empirical. Wine sold "en primeur" is a typical experience good in the sense of Nelson, since the wine is sold six to eight months after the grape harvest, when the wine is not yet mature (the wine is kept in barrels for several more months after the "primeur" sales, before being bottled). Mahenc and Meunier (2003) and Mahenc (2004) provide theoretical evidence for "en primeur" pricing (which can be seen as forward trading) contributing to signal wine quality. Hadj Ali and Nauges (2007) and Hadj Ali, Lecocq and Visser (2008) estimate the impact of experts on the price set by wine producers at the time of "primeur" sales, using data from the Bordeaux region (France).[1] These authors, who estimate "en primeur" price models using panel data techniques and difference-in-differences methods respectively, find some evidence of a significant but moderate impact of wine experts' ratings on the price set by the producers. In these two articles, it is assumed that consumers rely on experts who are supposed to make correct assessment about "true" wine quality.[2] We argue that experts may be wrong in assessing wine quality at the time of primeur sales though, because the wine is not yet mature. Hence,

[1] The role of experts' opinion in purchasing behavior has been the focus of several articles in various fields such as art markets (Ginsburgh, 2003), movies markets (Reinstein and Snyder, 2005), or bottled wine markets (Landon and Smith, 1997, 1998).

[2] From now on, "true wine quality" and "wine quality" will stand for the quality the wine will reach at maturity, assuming optimal storage conditions.

it is very likely that only the producer, who has been following each step of the wine making process, knows the wine quality. This assumption, combined with the theoretical assertion that the "primeur" price is used by producers to signal wine quality, calls for the introduction of wine quality as a determinant of the price set by the producers. Because wine quality is unobservable to both the consumers and the econometrician, the main issue when estimating the equation describing the price set by the producers, is that quality may not only influence the pricing of "primeur" wine, but it is also likely to be correlated with experts' grades. We thus face a typical problem of omitted variable which may produce biased estimates if not controlled for.

This endogeneity problem is unlikely to be solved through natural instrumental variables techniques because it would require the availability of variables correlated with experts' grades but not with wine quality. Reinstein and Snyder (2005) face the same endogeneity problem when measuring the influence of movie critics on consumer demand: "*products receiving positive reviews tend to be of high quality, and it is difficult to determine whether the review or the quality is responsible for high demand*". To circumvent the problem, these authors take advantage of the timing of the reviews relative to a movie's release. Indeed, some reviews came during the opening weekend while other reviews came only after. A difference-in-differences estimator was thus applied using observations from this quasi-natural experiment. As mentioned by the authors, the validity of this approach relies on the assumption that the selection of movies to be reviewed during and after opening weekends is not correlated with quality reviews (see also Hadj Ali et al., 2008, for use of a similar estimation technique).

In this article, we use a methodology that builds on the recent literature on production function identification (see Olley and Pakes 1996, Levinsohn and Petrin 2003, or Ackerberg, Caves and Frazer, 2006). This approach not only allows to control for endogeneity bias due to variable omission, but also to disentangle the effect of experts' opinion from the effect of wine quality signaling and to identify unobserved quality of each wine in the sample. Three different models are estimated in order to test for robustness of various identification assumptions.

Using an unbalanced panel data set of 108 Bordeaux *châteaux* over five vintages (1994-1998), we confirm that experts' grades affect producers' choice of "primeur" price above the effect of unobserved wine quality (for previous evidence, see Hadj Ali and Nauges, 2007, and Hadj Ali et al., 2008). Our empirical results also show that failing to control for endogeneity caused by the omission of unobserved quality leads to over-estimate the influence of experts' grades on the "primeur" price.

2 Theoretical model, identification and estimation procedures

True wine quality, q^*, has to be considered as a potential determinant of the "primeur" price set by the producers as there exists theoretical evidence that primeur prices play an informational role as a signal on wine quality (Mahenc, 2004; Mahenc and Meunier, 2003, 2006). Mahenc (2004) has shown that a sufficiently high fraction of informed buyers acting in the market eliminates the lemons problem as discussed by Akerlof (1970).[3] We assume this assumption to be satisfied in the Bordeaux primeur market where buyers, for the most part, are wholesale merchants from the same region. The producer, who followed each step of the wine making process, is assumed to be the only one to know the true quality (or quality at maturity) of his wine, q^*. Indeed, assessing true wine quality is much more difficult for potential buyers since the wine is not yet mature at the time of "en primeur" release and hence does not present the same sensory characteristics as the wine delivered two years later (Mahenc and Meunier, 2006).[4]

Producers' pricing strategy is also likely to depend on consumers' expected willingness to pay for the wine. Consumers, who are not perfectly informed about quality, will likely take into account the quality of the wine which was produced in the past (or reputation) and refer to

[3] Akerlof's lemons problem would occur if producers of a low-quality wine would sell at the same price as producers of high-quality wine.

[4] Mahenc and Meunier (2006) mention that *"the samples may be drawn from a particular barrel that has been blended and set aside on purpose"*.

experts' judgment when making their purchase decision. We assume that quality-ranking and appellation, which are clearly labeled on the bottle, convey all information about reputation. We believe this is a reasonable assumption for the Bordeaux region where most of the *châteaux* have a long-time established reputation and where a system of wine quality-ranking (which is defined inside small geographical regions called "appellations") exists since the nineteenth century (Markham, 1997). However, wine quality is likely to vary from one vintage to another due in particular to the weather conditions that prevailed during the grapes-growing season.[5] There is thus some uncertainty remaining about wine quality when the "primeur" market opens. In that respect, we assume that consumers rely on experts' ratings to assess expected wine quality for the current vintage. Experts' opinion is measured by the grade attributed to the wine during blind tasting sessions that occur before the opening of the "primeur" market. If the producer believes that consumer's willingness to pay for the product is influenced by experts' judgment, then he might price the good accordingly. The choice of the "primeur" price by the producer may thus be influenced by the grade, denoted q_0, which is attributed to his wine. We test this assumption by introducing experts' grades into the "primeur" price function (see also Hadj Ali and Nauges, 2007, and Hadj Ali et al., 2008).

The "primeur" price function is written as follows:

$$\ln p = \pi(q^*, q^o, X) + \varepsilon \tag{1}$$

where p represents "primeur" price, q^o is experts' grade given to "primeur" wine, q^* is true wine quality known by the producer only, and the X-vector gathers wine characteristics, namely: categorical variables for vintage, quality-ranking and region of origin (also known as "appellation"). The error term ε is assumed uncorrelated with observed and unobserved covariates, at

[5] Contrary to most New World wine regions or countries (California, South Africa, New Zealand, Chile, etc.), weather conditions in the Bordeaux area can vary significantly from one year to another.

all time:

$$E(\varepsilon \mid q^*, q^o, X) = 0.$$

The term ε can be interpreted as idiosyncratic random shocks on price that are unanticipated by experts, or as independent measurement errors, or as independent idiosyncratic deviations when wine producers set the "primeur" price.

2.1 Structural model

Under the assumption that the primeur price function $\pi(.,.,.)$ is additively separable between q^*, q^o, and X, we have:

$$\ln p_{it} = E(\ln p_{it} \mid q^*_{it}, q^o_{it}, X_{it}) + \varepsilon_{it} = X'_{it}\beta + \gamma q^o_{it} + q^*_{it} + \varepsilon_{it}, \tag{2}$$

where i and t are indices for *château* and year or vintage, respectively. The β's and γ are unknown parameters, and the coefficient of q^*_{it} (which is unobserved) has been normalized. Wine quality, q^*_{it}, being unobserved, we cannot identify the coefficient of experts' rating, γ, because

$$E(\ln p_{it} \mid q^o_{it}, X_{it}) = X'_{it}\beta + \gamma q^o_{it} + E(q^*_{it} \mid q^o_{it}, X_{it})$$

and, since wine tasting is indeed performed in order to give information on true wine quality, we will have

$$E(q^*_{it} \mid q^o_{it}, X_{it}) \neq 0.$$

We face an endogeneity problem in (2) because experts' opinion about wine produced by *château* i and vintage t, q^o_{it}, is supposed to signal the true wine quality, q^*_{it}. Thus, unless experts' grades are given completely at random with respect to wine quality, these grades will be endogenous in the price equation.

A first simple solution would be to use instrumental variables. Valid instrumental variables should be correlated with experts' grade, q^o_{it}, and uncorrelated with unobserved wine quality, q^*_{it}. In this particular example of wine as an experience good, no natural instrumental variable appears to be available. Finally, note that a fixed-effects specification, which is the common approach to deal with unobserved heterogeneity in panel data, is not applicable in this particular case as wine quality is not constant over vintages.

To control for endogeneity and disentangle the influence of experts' ratings from the impact of true wine quality on price setting, we use a structural approach based on the methodology started in Olley and Pakes (1996) and further developed by Levinsohn and Petrin (2003) and Ackerberg et al. (2006).[6] The approach that we adopt relies on two main assumptions.

- **A1:** Unobserved true quality q^*_{it} is supposed to follow a first order Markov process, i.e.,

$$E[q^*_{it}|I_{it-1}] = E[q^*_{it}|q^*_{it-1}],$$

where I_{it-1} corresponds to the information set **of producers** at the end of period $t-1$.

Assumption **A1** means that average true quality conditionally on previous year information set I_{it-1} only depends on past true quality q^*_{it-1}.

- **A2:** We assume the following relationship between experts' ratings and unobserved true quality:

$$q^0_{it} = h(q^*_{it}, q^0_{it-1})$$

where h is strictly increasing in q^*_{it} and can depend on the past grade q^0_{it-1}.

This monotonicity assumption means that experts' grades are increasing with unobserved quality, given the previous vintage grade. In other words, given lagged ratings q^0_{it-1}, ranking of wine of vintage t according to experts' grades matches the ranking according to the unobserved true quality.[7] Assumption **A2** is a "structural" assumption that is crucial for identification.

[6] Olley and Pakes (1996) introduce a technique to deal with unobserved productivity shocks in production functions. See also Levinsohn and Petrin (2003) and Ackerberg et al. (2006) for discussions and alternative methods.

[7] Quality, q^*_{it}, may be perceived by experts with some error. This extension is dealt with in the Appendix.

Our main model of interest thus corresponds to the structural equation (2) with assumptions **A1** and **A2**. To test for the validity of **A2**, we estimate alternative models that do not rely on the monotonicity assumption. This however comes at the cost of additional restrictions on the pricing model which consist either in restricting **A1** to **A1b** or in putting a restriction directly on (2) as it is described in turn.

Alternative A

Assumption **A1** is maintained but we assume that q^*_{it} is the only unobservable in the model (there is no additional error term). The model becomes

$$\ln p_{it} = X'_{it}\beta + \gamma q^o_{it} + q^*_{it}.$$

Alternative B

The structure (2) is maintained but we make a more restrictive assumption **A1b** regarding unobserved true quality.

- **A1b:** Unobserved true quality follows an AR(1) process:

$$E[q^*_{it}|I_{it-1}] = \lambda q^*_{it-1}.$$

Let us now describe the additional assumptions that are needed in order to solve the endogeneity problem under the three alternatives:

- **A3**: The variables in X_{it-1} (categorical variables for vintage, quality-ranking and region of origin) are part of the information set I_{it-1}.
- **A4**: There is state dependence in ratings, i.e., experts' ratings are correlated across time for reasons other than correlation in true quality over time.

This assumption holds because ratings are provided by a unique expert (namely, Robert Parker) for all years covered by our sample. Any wine expert is likely to exhibit preferences for some wine characteristics related to the grapes or the wine-making process, that are going to be independent of weather conditions and persistent over time.[8]

- **A5**: Lagged experts' rating, q^o_{it-1}, does not enter the pricing equation at time t.

We assume that wine producers do not price wine taking into account experts' rating of the previous vintage and that consumers do not assess quality of a wine produced in t from experts' opinion on the wine produced in $t-1$. The main reason is that wine quality in the Bordeaux region can vary significantly from one year to another due to changing weather conditions, which is not the case in most New World wine countries.[9] Hence, experts' rating for a wine produced by *château* i in $t-1$ is likely not to be very informative in itself in terms of the quality of the wine produced in t. Assumption A5 can be interpreted either as a specification restriction or as a bounded rationality constraint. It could be that even if demand is rational and based on q^0_{it} and q^0_{it-1}, the supply side rationally chooses price such that q^0_{it-1} does not enter the price equation $\ln p_{it} = X'_{it}\beta + \gamma q^o_{it} + q^*_{it}$ because there is a one to one relationship between q^*_{it} and q^0_{it-1} given q^0_{it} and thus q^0_{it-1} does not bring information given q^*_{it} and q^o_{it}. However, consumers do not observe true quality and this specification is thus quite restrictive. It can then be interpreted as a bounded rationality assumption on producers or consumers such that producers set prices according to true quality and current grade but not past vintage grade.

[8] It was acknowledged that some wine makers from the Bordeaux region made their wine according to Robert Parker's own tastes.

[9] "*In California, for example, it never rains in the summer, and it is always warm in the summer. There is a simple reason for this. In California a high-pressure weather system settles each summer over the California coast and produces a warm, dry growing season for the grapes planted there. In Bordeaux this sometimes happens but sometimes it does not. Summers in Bordeaux can be hot and dry, hot and wet, cool and dry, and, most unpleasant of all, cool and wet. In general, high quality vintages for Bordeaux wines correspond to the years in which August and September are dry, the growing season is warm, and the previous winter has been wet.*" (Ashenfelter 2007).

2.2 Estimation procedure

The estimation procedure and identification strategy for the three alternatives are now described. The first main method is related to Olley and Pakes (1996). Due to the monotonicity assumption, the relationship in **A2** can be inverted to obtain:

$$q^*_{it} = g(q^0_{it}, q^0_{it-1})$$

and substituted into the pricing equation (2) to get:

$$\ln p_{it} = X'_{it}\beta + \gamma q^o_{it} + g(q^0_{it}, q^0_{it-1}) + \varepsilon_{it}.$$

Estimation now proceeds as follows: the pricing equation, which is linear in X_{it} and non-parametric in $g(q^o_{it}, q^o_{it-1})$, is estimated by OLS. A K-order polynomial expansion in q^o_{it} and q^o_{it-1} is used to approximate the non-parametric function $g(.,.)$.[10] OLS estimation produces consistent estimates of the β's. From the set of β estimates, we compute the implied true quality as:

$$q^*_{it}(\gamma) = \ln p_{it} - X'_{it}\hat{\beta} - \gamma q^o_{it}.$$

Given **A1**,

$$q^*_{it} = E[q^*_{it}|q^*_{it-1}] + \xi_{it}$$

where ξ_{it} is uncorrelated with the information set at $t-1$: $E[\xi_{it}|I_{it-1}] = 0$. The ξ_{it}, also known as the "innovation" in the production function literature, represents unobserved and unexpected idiosyncratic shocks that may have affected wine quality q^*_{it} during the grapes-growing season and/or during the wine-making process. Such shocks could be local weather events such as frost episodes or pest attacks. The residuals $\xi_{it}(\gamma)$ are obtained from the non-parametric regression of $q^*_{it}(\gamma)$ on $q^*_{it-1}(\gamma)$ such that:

$$\xi_{it}(\gamma) = q^*_{it}(\gamma) - \sum_{k=1}^{K} \hat{b}_k q^{*k}_{it-1}(\gamma).$$

[10] In the forthcoming empirical application, we specify a polynomial of order $K = 3$.

The $\xi_{it}(\gamma)$ are finally used to form a sample analogue of the moment condition:

$$E[\xi_{it}q^0_{it-1}] = 0$$

where experts' rating at time $t-1$ belongs to the information set at time $t-1$ and should not be correlated with the innovation in quality at time t. Under assumptions **A4** and **A5**, experts' rating at time $t-1$ is a suitable instrument for experts' rating at time t: first, under assumption **A4**, experts' rating at time $t-1$ is going to be informative for experts' rating at time t and second, under assumption **A5**, experts' rating in $t-1$ do not directly affect price setting in t. So, experts' rating in $t-1$ belongs to the information set I_{t-1}, which implies that ξ_{it} and q^0_{it-1} are uncorrelated. The estimate $\hat{\gamma}$ of γ is then defined as the solution to the following minimization:

$$\min_{\gamma} \sum_{i,t} \left(\xi_{it}(\gamma)q^0_{it-1}\right)^2.$$

This method allows to obtain consistent estimates (Olley and Pakes, 1996) under model (2) and assumptions **A1**, **A2**, **A3**, **A4** and **A5**.

We now describe the estimation procedure for the two alternative models:

Alternative A

In this case, a Generalized Method of Moments (GMM) estimation method can be used. Based on some guess of the parameters (β, γ), we compute the implied true quality:

$$q^*_{it}(\beta, \gamma) = \ln p_{it} - X'_{it}\beta - \gamma q^o_{it}.$$

Then we do as in the second step of the Olley and Pakes (1996) method. We compute the residuals $\xi_{it}(\beta,\gamma)$ from the non-parametric regression of $q^*_{it}(\beta,\gamma)$ on $q^*_{it-1}(\beta,\gamma)$, and then solve the sample analogue of the moment condition

$$E[\xi_{it}(\beta, \gamma)q^0_{it-1}] = 0$$

as previously explained, where q^0_{it-1} is an element of the information set I_{t-1} that should be orthogonal to $\xi_{it}(\beta,\gamma)$. Other instruments belonging to the information set (lagged weather variables for example) could also be used to estimate the model parameters by GMM.

Alternative B

In this case, the assumption **A1b** imposes an AR(1) process for unobserved quality implying that $q^*_{it} = \lambda q^*_{it-1} + \xi_{it}$. We also apply a GMM procedure, using

$$\begin{aligned}\eta_{it}(\beta,\gamma,\lambda) &= \xi_{it} + \varepsilon_{it} - \lambda\varepsilon_{it-1} \\ &= \left(q^*_{it} + \varepsilon_{it}\right)(\beta,\gamma) - \lambda\left(q^*_{it-1}+\varepsilon_{it-1}\right)(\beta,\gamma)\end{aligned}$$

where $\left(q^*_{it} + \varepsilon_{it}\right)(\beta,\gamma) = \ln p_{it} - X'_{it}\beta - \gamma q^o_{it}$.

Then, under the assumption that ε_{it} is not serially correlated and also uncorrelated with observed and unobserved covariates at all time, the moment condition that $\eta_{it}(\beta,\gamma,\lambda)$ is orthogonal to the information set I_{t-1} is valid. We can then solve the sample analogue of the moment condition

$$E[\eta_{it}(\beta,\gamma)q^0_{it-1}] = 0$$

as previously, where q^0_{it-1} is an element of the information set I_{t-1} that should be orthogonal to $(\xi_{it},\, \varepsilon_{it})$, and that we suppose uncorrelated with ε_{it-1}.

In the following empirical application, we compare the "Olley-Pakes" methodology with the alternatives A and B that do not rely on the "inversion" technique of Olley and Pakes (1996), at the cost of more restrictive assumptions. The comparison of the three sets of results will be informative on the reliability of the monotonicity assumption in the first main method if the restrictions used for methods A and B are valid. Note also that when the estimation procedure involves two steps, standard errors are computed using the bootstrap technique along the lines of Levinsohn and Petrin (2003).

3 Empirical analysis

3.1 The data and specification issues

The data, that were provided by one of the most famous broker house in Bordeaux, cover "primeur" wine sales of 108 Bordeaux *châteaux*, over five vintages (from 1994 to 1998).[11] Primeur price is the price of a 75cl bottle in constant euro (1990 base). For each wine, we have data on grades given by Robert Parker (one of the most famous wine experts) to each wine at the time of "primeur" sales, as well as a set of wine characteristics gathering vintage, "appellation" (the French equivalent of Protected Designation of Origin), and ranking.[12] We combine these data with weather data obtained from the company Météo France. Weather data consist in daily observation at Mérignac in the Bordeaux Region, of minimum and maximum temperature, hours of sunshine and rainfall for all years from 1993 to 1998.

The database gathers *châteaux* belonging to ten different "appellations": Haut Médoc (HM), Margaux (MA), Moulis (MO), Pauillac (PA), Pessac Léognan (PL), Pomerol (POM), Saint Emilion Grand Cru (SEGC), Saint Estèphe (SES), Saint Julien (SJ). Some of these *châteaux* are ranked, either inside a region (i.e., a group of appellations) or inside a unique appellation. There are three ranking systems currently in use in the Bordeaux area:

1. The first ranking was created for wines from the *Médoc* region (appellations HM, MA, MO, PA, SES, SJ). This ranking dates back to 1855 and has been largely unchanged to this day.[13] Wines have been classified following a five-tier classification system ranging from top-quality *Premiers Crus* or First Growth (ME-1 from now on) to *Cinquièmes Crus* or Fifth Growth (ME-5). Later on, in 1920, some of the non-ranked *châteaux* have been classified in a sixth-group called *Crus Bourgeois* (ME-6).

[11] Only the price is observed. The data base does not contain any information on quantities sold by each *château* at the time of "primeur" sales.

[12] Tasting usually takes place in spring of each year, before the opening of the "primeur" market. The tasting is generally made in single-blind conditions, i.e., experts do not know the name of the *château* when judging the wine. Wines are graded on a 50-100 scale.

[13] See Markham (1997) for an history of the classification system.

2. *Saint Emilion* wines belonging to the SEGC appellation, formally classified in 1955 (subsequently revised every ten years), follow a three-tier ranking system: *Premiers Grands Crus Classés A* (SE-1), *Premiers Grands Crus Classés B* (SE-2), and *Grands Crus Classés* (SE-3).

3. Wine from the region of *Graves* (appellation Pessac Léognan) started to be officially classified in 1953.

Some of the *châteaux* belonging to the three-above cited regions (Médoc, Saint Emilion, Graves) are not ranked. In the empirical analysis these *châteaux* will be gathered into the "non-classified" group. This group will also include all the *châteaux* belonging to the Pomerol appellation that has always refused to rank its own wines.

Tables 1 to 4 show descriptive statistics on "primeur" price and grade by appellation and by rank.

[Tables 1 to 4 around here]

Robert Parker's grade varied from 73 to 98 over the period, with an average of 87.47. Wines belonging to the Haut Médoc and Margaux appellations got, on average over the 1994-1998 vintages, a lower grade than the other appellations in the database (Table 1). Table 2 shows the average "primeur" price across vintages for each appellation. Primeur price varied significantly from 3.61 to 86.02 euros per bottle, with an average of 15.59. On average over the period, wines belonging to the Pomerol appellation were sold at the highest price, followed by wines from Saint Emilion and wines from Pauillac. The highest ranks (ME-1 and SE-1) got the best grade on average and were priced significantly above the average for all *châteaux* (Table 3 and Table 4). The second-highest in the Médoc and in the Saint Emilion region (ME-2 and SE-2 respectively) are priced significantly above the lower ranks from the same region. Note finally that the high "primeur" price for non-classified wines is mainly driven by the wines from the Pomerol region, and especially the famous *Château Pétrus*.

The "primeur" price model (1) assumes that the price depends on true quality, q^*, experts' grade, q^o, and a vector X of price determinants. We include in X a dummy variable for each "appellation", a dummy variable for each official ranking class, and a dummy variable for each vintage. Note that, unfortunately, we cannot consider weather variables in the price model since they are the same for all *châteaux* and only vary across years. These three observable elements are labeled on each bottle of wine (ranking is indicated as long as the wine is ranked). The ranking classification may also be considered as an indirect measure for reputation of the *château* (Hadj Ali and Nauges, 2007).

3.2 Estimation results and tests on vintage quality and the weather

Main estimates of the model

We report in Table 5 estimation results obtained under the three alternatives (standard errors are computed using 500 bootstrap replications).

[Table 5 around here]

The estimated effect of Parker's rating is found positive and significant in the three models, ranging from 1.64 in the Olley-Pakes' model to 2.84 in Alternative B. Remind that alternatives A and B do not rely on the monotonicity assumption **A2** but on stronger hypotheses on the Markov process of unobserved quality. Therefore, if unobserved quality satisfies these stricter conditions, the comparison of the results obtained under alternatives A and B with results obtained with the "Olley-Pakes" methodology, provides a good assessment of the validity of the monotonicity assumption. It shows that results obtained under the monotonicity assumption, and in particular the impact of Parker's grade on the price set by the producer, are quite robust.

We thus find evidence that experts' opinion has some influence on producers' pricing decision. In other words, once the "primeur" price has been chosen on the basis of objective wine characteristics and wine quality, an additional premium is added which depends on experts' judgment. This premium is such that a one percentage-point increase on the average grade induces an increase of the "primeur" price by 1.6% to 2.8%. These results would tend to confirm the idea that Robert Parker is influential in the Bordeaux area (see Hadj Ali et al., 2008, for a discussion of Robert Parker's role in the Bordeaux region). However, our results are not directly comparable to the ones reported in Hadj Ali et al. (2008) as these authors consider "primeur" sales in a different period (2002-2003) and measure the impact on the "primeur" price of being graded by Robert Parker.[14]

Ranking is also found to have a significant influence on the pricing of "primeur" wine, in the three models. Wines belonging to all ranks, except top-growths from the *Médoc* region (ME-1) and second-growths from the *Saint-Emilion* region (SE-2), are priced significantly below the top-growths of *Saint-Emilion* (SE-1) which were taken as the reference group. The rank effect provides an indirect measure of a reputation premium and may also reflect the market power of *châteaux* belonging to top-growths ranking (Hadj Ali and Nauges, 2007). Appellation groups do not come out significantly in the estimated models. Estimates of the β's in Olley-Pakes' model are quite close to estimates of the β's in Alternatives A and B, but, in most cases, the significance is higher in the two latter models. Using the estimation results obtained with the Olley-Pakes' method, we find evidence that the appellation, ranking and vintage variables explain 45% of the total variance of prices, while Parker's grade explains around 10%. The remaining total variance of prices is thus explained by unobserved quality and random shocks.

In order to get an idea of the magnitude of endogeneity bias, we estimate the pricing model (1)

[14] For the first time, in 2003, Robert Parker wine grades have been published in autumn, after the prices were determined by the producers. Combining these data with observations on prices and grades from 2002, the authors estimate the effect of being graded by Parker using a difference-in-differences procedure. They find an overall effect equal to almost 3 euros per bottle. As stated in their paper, the validity of this approach relies on the so-called "parallel trend assumption" which states that, "had Parker not graded any wine in two subsequent years, the price evolution would have been the same for all wines". In our case, we do not rely on such assumption.

using a simple OLS regression. OLS regression would produce consistent estimates of the γ parameter if the expert's grade was not correlated with unobserved true quality or if unobserved true quality did not enter the pricing model. When estimating the model by OLS, the coefficient for the expert's grade is estimated at 3.95 (significant at the 1% level), which indicates that failing to control for endogeneity of unobserved quality in the pricing model leads to over-estimate the impact of Parker's review on the "primeur" price.

Analysis of predicted wine quality

A nice feature of our approach is that it allows to recover estimates of the unobserved quality, q^*_{it}, for each *château* i and vintage t. In this section, we propose to test the validity of our quality estimates by analyzing their relationship with other factors such as experts' grade, weather conditions and official rankings[15]. A first test is made by computing simple correlation coefficients between, on the one hand, expected wine quality as predicted by our model, $\hat{q}^*_{it}$, and experts' grade and weather variables on the other hand. As for the latter we consider cumulative rainfall and cumulative hours of sunshine from January to September. Correlation coefficients along with probability values corresponding to the significance level of each correlation coefficient, are shown in Table 6.

[Table 6 around here]

Correlation coefficients have the expected signs and are all significant at the 5% level. Correlation coefficient between experts' grade and predicted wine quality is 0.26, 0.19 and 0.37 in Alternatives A and B, and Olley-Pakes' model respectively.[16] Predicted wine quality is found

[15] We assume that local weather conditions on vineyards do not enter the price equation. Including the weather conditions in the X_{it} could be done but it would mean, in this case, that we assume that these weather variables are publicly observed. This is likely to be a too strong assumption though, considering variables like the daily maximum and minimum temperature or the number of hours of sunshine.

[16] Graphical tests show that the relationship between experts' grade and wine quality is monotonic. The graph is not shown here but is available from the authors upon request.

positively correlated with cumulative hours of sunshine over the January-September period (correlation coefficient is 0.25 in the three models), and negatively correlated with cumulative rainfall over the same period (correlation coefficient is -0.12 in Alternatives A and B , and -0.16 in Olley-Pakes' model).[17]

Evidence about the effect of weather on wine quality is consistent with Ashenfelter's findings (see Ashenfelter, Ashmore and Lalonde 1995 and Ashenfelter 2007, for a discussion of the relationship between weather conditions and vintage quality), even after disentangling unobserved wine quality from the pure signaling effect of experts' grading on price. Ashenfelter et al. (1995) and Ashenfelter (2007) show that the quality for red Bordeaux wines, based on the price of mature wines, can be predicted by weather conditions observed during the grapes-growing season. Here, we find evidence that wine quality known by the producer and taken into account for the pricing of "en primeur" wine, can actually be explained by the weather conditions during the grapes-growing season. It is remarkable that such consistent evidence can be found also on the quality as identified by our structural model after disentangling quality effects from experts' opinion effects.

We then check if wine quality as predicted by our model corresponds to the existing ranking in the *Médoc* and *Saint Emilion* appellation groups (see Table 7).

[Table 7 around here]

As for the wines from *Saint Emilion*, the ranking based on our predicted quality perfectly matches the "official ranking" inside the appellation group: predicted quality for top-growths wines (SE-1) is found to be higher, on average, than predicted quality for second-growths wines (SE-2), itself being higher than predicted quality of third-growths wines (SE-3). As for the wines produced in the *Médoc* region, the ordering based on predicted quality matches the of-

[17] Note that correlation coefficients between experts' grade and weather variables are never found significantly different from 0.

ficial ordering at the top, i.e., top-growths wine (ME-1) and second-growths wine (ME-2) are respectively ranked 1 and 2. This is no longer true for the other groups: ME-3 to ME-6. These findings should not come as a surprise though, knowing that official ranking of wine from the *Saint Emilion* appellation group is subsequently revised every ten years while the ranking in the *Médoc* region has remained almost the same since it was created in the nineteenth century. Our findings would thus support the view of some Bordeaux producers who claim that the official ranking in the *Médoc* region should be revised.

4 Conclusion

In this article, we propose an empirical analysis of wine producers' pricing strategy at the time of "primeur" sales in the Bordeaux region. "En primeur" wine is a typical experience good in the sense of Nelson since the wine is not yet mature at the time of "primeur" sales. We use a structural empirical approach, which is based on Olley and Pakes (1996), to disentangle the effect of experts' grades from the effect of true quality on the pricing of experience goods. This technique is particularly useful when one does not have any valid instrumental variables at hand or when panel data techniques allowing for individual specific effects are not well suited. We estimate two alternative models to test the robustness of our main estimation results.

Using a panel data set of 108 *châteaux* selling wine on the Bordeaux "en primeur" market, we confirm that experts' grades affect producers' choice of "en primeur" price above the effect of unobserved wine quality (Hadj Ali and Nauges, 2007, and Hadj Ali et al., 2008). Our empirical results also show that failing to control for endogeneity caused by the omission of unobserved quality leads to over-estimate the influence of experts' grades on the "primeur" price.

Finally, an interesting feature of this approach is that it allows to recover unobserved quality of each wine in the sample. The identified wine quality is shown to be correlated with weather conditions at the growing season, an evidence which is consistent with findings by Ashenfelter et al. (1995) on the effect of weather on prices of mature wines.

Appendix: The case of a perception error

In the case of the main method of identification that follows Olley and Pakes (1996), we show here how to add a perception error and still obtain identification. We assume that the relationship between q_{it}^* and q_{it}^o is no longer deterministic and is affected by unobserved shocks, ζ_{it}, whatever the signal s_{it} that can be q_{it-1}^o or some other variable in this structural model:

$$q_{it}^o = q_t(q_{it}^* - \zeta_{it}, s_{it}). \tag{3}$$

The interpretation of the error ζ_{it} as a perception or reporting error depends on whether one assumes that experts do observe or not wine quality q_{it}^* at period t. If one can assume that wine quality is observed by experts, then ζ_{it} is more a "reporting error". If one assumes that experts do not yet observe perfectly wine quality q_{it}^* then ζ_{it} should be seen as a "perception error".

We first need to assume that the perception error is uncorrelated with signals s_{it}:

$$E\left(\zeta_{it} s_{it}\right) = 0.$$

We develop our estimation procedure similarly. The “primeur” price model is assumed linear in the parameters, that is:

$$\ln p_{it} = X_{it}'\beta + \gamma q_{it}^o + q_{it}^* + \varepsilon_{it}, \tag{4}$$

where γq_{it}^o is the effect of wine grade and q_{it}^* is true wine quality.

It can be written

$$\ln p_{it} = X_{it}'\beta + \phi_{it}(q_{it}^o, s_{it}) + \zeta_{it} + \varepsilon_{it} \tag{5}$$

where $\phi_{it}(q_{it}^o, s_{it})$ is defined as

$$\phi_{it}(q_{it}^o, s_{it}) = \gamma q_{it}^o + {q_t^*}^{-1}(q_{it}^o, s_{it}).$$

In this framework, experts' grade q_{it}^o is endogenous because correlated with ζ_{it}. We thus need to use some instrumental variables for q_{it}^o that are uncorrelated with the perception error

ζ_{it}. Remark that while it is difficult to find any instrumental variable that would be correlated with q^o_{it} but not with unobserved quality q^*_{it}, it is easier to think about an instrumental variable correlated with q^o_{it} (and q^*_{it}) but not with the perception error ζ_{it} (a valid instrument would for example be equal to the unobserved quality plus a white noise, and would actually be excluded from the structural equation of q^o_{it}).

If one wants to estimate $\phi_{it}(q^o_{it}, s_{it})$ non-parametrically, then one has to use non-parametric instrumental variables techniques (Darolles, Florens and Renault, 2003; Newey and Powell, 2003). Then, in the first-stage, the price model (5) which is linear in X and non-parametric in $\phi_{it}(q^o_{it}, s_{it})$, is estimated consistently, which provides $\hat{\phi}_{it}$. A second step is necessary to identify the experts' grade coefficient γ.

The second stage starts by computing, up to a scalar constant, a prediction for the perceived true quality $q^*_{it} - \zeta_{it}$ that we denote $\hat{q}^*_{\zeta it}$. For any candidate value γ^*, let

$$\hat{q}^*_{\zeta it} = \hat{\phi}_{it} - \gamma^* q^o_{it}. \tag{6}$$

Using these values, a consistent (non-parametric) approximation to $E[\hat{q}^*_{\zeta it}|\hat{q}^*_{\zeta it-1}, I_{it}]$ is given by the predicted values $E[q^*_{\zeta it}|\widehat{q^*_{\zeta it-1}}, I_{it}]$ from the regression

$$\hat{q}^*_{\zeta it} = b_0 + b_1\hat{q}^*_{\zeta it-1} + b_2\hat{q}^{*2}_{\zeta it-1} + b_3\hat{q}^{*3}_{\zeta it-1} + b_4 I_{it} + w_{it}. \tag{7}$$

Then, using the fact that $q^*_{\zeta it} = q^*_{it} - \zeta_{it}$ and denoting $\kappa_{it} = E[q^*_{it}|q^*_{it-1}, I_{it}] - E[q^*_{it}|q^*_{\zeta it-1}, I_{it}]$ the error in the equation defining unobserved shocks on wine quality due to the conditioning on $q^*_{\zeta it-1}$ instead of q^*_{it-1}, we have

$$q^*_{it} - E[q^*_{it}|q^*_{\zeta it-1}, I_{it}] = \xi_{it} + \kappa_{it}.$$

Using $E[\zeta_{it}|q^*_{\zeta it-1}, I_{it}] = 0$, we can write

$$\begin{aligned} q^*_{\zeta it} - E[q^*_{\zeta it}|q^*_{\zeta it-1}, I_{it}] &= q^*_{it} - E[q^*_{it}|q^*_{\zeta it-1}, I_{it}] + \zeta_{it} \\ &= \xi_{it} + \kappa_{it} + \zeta_{it}. \end{aligned}$$

Given $\hat{\beta}$, γ^*, and $E[q^*_{it}|\widehat{q^*_{it-1}}, I_{it}]$, we get

$$\varepsilon_{it} + \zeta_{it} \widehat{+} \kappa_{it} + \xi_{it} = \ln p_{it} - X'_{it}\hat{\beta} - \gamma^* q^o_{it} - E[q^*_{\zeta it}|\widehat{q^*_{\zeta it-1}}, I_{it}].$$

Then, the estimate $\hat{\gamma}$ of γ is defined as the solution to the following

$$\min_{\gamma^*} \sum_{i,t} \left(\left(\ln p_{it} - X'_{it}\hat{\beta} - \gamma^* q^o_{it} - E[q^*_{it}|\widehat{q^*_{\zeta it-1}}, I_{it}] \right) z_{it-1} \right)^2,$$

where z_{it-1} is a valid instrumental variable. Moreover, these errors being independent and identically distributed, we have $E\left(q^*_{\zeta_{it}} \mid q^*_{it}\right) = q^*_{it}$ so that the average of $q^*_{\zeta it}$ for a given *château*, over vintages, is a consistent estimator of the average of q^*_{it} over vintages. Also the average of $q^*_{\zeta it}$ over a set of *châteaux* is a consistent estimator of the average of q^*_{it} over a set of *châteaux* for a given vintage t.

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Tables

Table 1: "Primeur" grade by appellation (average across vintages)

	Number of châteaux	Mean	Std. Dev.	Min.	Max.
Médoc					
Haut Médoc (HM)	10	85.05	2.85	77	90
Margaux (MA)	16	85.65	4.20	75	98
Moulis (MO)	3	86.39	1.95	83.5	90
Pauillac (PA)	18	88.32	3.89	73.5	96
Saint Estèphe (SES)	8	87.14	3.95	75	93
Saint Julien (SJ)	10	88.49	2.48	83.5	95
Saint Emilion					
Saint Emilion Grand Cru (SEGC)	19	88.13	3.43	77	94.5
Graves					
Pessac Léognan (PL)	16	88.00	2.65	79.5	92
Pomerol (POM)	8	87.96	4.56	73	95.5
Overall	108	87.47	3.72	73	98

Table 2: "Primeur" price by appellation, in euro/bottle (average across vintages)

	Number of châteaux	Mean	Std. Dev.	Min.	Max.
Médoc					
Haut Médoc (HM)	10	7.05	2.70	3.61	15.22
Margaux (MA)	16	13.32	11.20	5.00	66.17
Moulis (MO)	3	8.40	1.57	6.28	10.32
Pauillac (PA)	18	18.41	15.37	5.70	66.17
Saint Estèphe (SES)	8	13.62	8.24	5.87	37.05
Saint Julien (SJ)	10	14.68	6.34	7.09	33.08
Saint Emilion					
Saint Emilion Grand Cru (SEGC)	19	19.26	15.77	6.25	86.02
Graves					
Pessac Léognan (PL)	16	13.38	4.34	7.23	27.32
Pomerol (POM)	8	20.90	14.44	6.67	55.93
Overall	108	15.59	12.26	3.61	86.02

Table 3: Primeur grade by rank (average across vintages)

	Number of châteaux	Mean	Std. Dev.	Min.	Max.
Médoc					
ME-1	4	92.48	2.28	88	98
ME-2	12	88.81	3.95	75	95.5
ME-3	8	85.92	3.11	75	91.5
ME-4	9	86.91	2.04	80	91.5
ME-5	13	86.75	3.52	73.5	95
ME-6	16	84.78	3.39	75	90
Saint Emilion					
SE-1	1	91.70	1.15	90.5	93
SE-2	5	88.13	3.44	79	94.5
SE-3	11	87.90	3.50	77	93.5
Graves	11	87.58	2.59	79.5	91.5
Non-classified	18	88.05	3.96	73	95.5
Overall	108	87.47	3.72	73	98

Table 4: Primeur price by rank (average across vintages)

	Number of châteaux	Mean	Std. Dev.	Min.	Max.
Médoc					
ME-1	4	43.74	15.67	25.01	66.17
ME-2	12	18.45	8.46	7.09	37.05
ME-3	8	10.15	2.10	6.81	15.88
ME-4	9	10.72	2.99	5.74	15.88
ME-5	13	10.55	4.11	5.70	26.47
ME-6	13	7.87	2.79	3.61	15.22
Saint Emilion					
SE-1	1	62.68	23.48	31.96	86.02
SE-2	5	20.84	9.47	9.45	43.67
SE-3	11	13.36	5.70	6.95	24.48
Graves	11	12.87	3.89	7.23	20.85
Non-classified	18	18.45	12.79	6.25	55.93
Overall	108	15.59	12.26	3.61	86.02

Table 5: Estimation of the price equation - 392 observations (108 châteaux)

	Alternative A		Alternative B		Olley-Pakes	
	Coef.$^{(a)}$	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Parker's grade ($\log q^o_{it}$) ($\widehat{\gamma}$)	2.322**	0.987	2.836***	0.798	1.643***	0.632
Médoc (appellation groups)						
Haut Médoc	-0.613**	0.291	-0.613**	0.291	-0.683*	0.404
Margaux	-0.444	0.285	-0.444	0.285	-0.487	0.381
Moulis	-0.441	0.312	-0.441	0.312	-0.553	0.360
Pauillac	-0.325	0.280	-0.325	0.280	-0.415	0.372
Saint Estèphe	-0.311	0.289	-0.311	0.289	-0.440	0.387
Saint Julien	-0.313	0.295	-0.313	0.295	-0.430	0.382
Saint Emilion (appellation groups)						
SEGC	-0.641	0.427	-0.641	0.427	0.029	0.714
Graves (appellation groups)						
Pessac Léognan	-0.286	0.273	-0.286	0.273	-1.183**	0.507
Pomerol (reference group)	.	.	.	.	.	.
Vintages						
1997 vintage	0.464***	0.026	0.464***	0.026	0.319***	0.028
1998 vintage	0.380***	0.031	0.380***	0.031	0.304***	0.036
Médoc (ranking system)						
ME-1	-0.674	0.689	-0.674	0.689	.	.
ME-2	-1.422**	0.694	-1.422**	0.694	-0.587	0.531
ME-3	-1.729**	0.703	-1.729**	0.703	-0.884*	0.537
ME-4	-1.812***	0.698	-1.812***	0.698	-0.911*	0.547
ME-5	-1.850***	0.698	-1.850***	0.698	-1.002*	0.535
ME-6	-1.908***	0.700	-1.908***	0.700	-1.009*	0.544
Saint Emilion (ranking system)						
SE-1 (reference group)	.	.	.	.	.	.
SE-2	-0.958	0.631	-0.958	0.631	-0.837	0.533
SE-3	-1.375**	0.623	-1.375**	0.623	-1.273**	0.534
Graves (ranking system)						
GR	-1.701**	0.704	-1.701**	0.704	.	.
Non-classified	-1.681**	0.684	-1.681**	0.684	-0.870	0.532

(a): ***, **, * indicates significance at the 1, 5, and 10% level respectively.

Table 6: Correlation coefficients between predicted quality and other variables[(a)]

	Alternative A	Alternative B	Olley-Pakes
Experts' grade	0.2578 (0.0000)	0.1921 (0.0001)	0.3719 (0.0000)
Cumulative hours of sunshine	0.2482 (0.0000)	0.2517 (0.0000)	0.2481 (0.0000)
Cumulative hours of rainfall	-0.1164 (0.0212)	-0.1190 (0.0185)	-0.1568 (0.0018)

(a): p-value corresponding to the significance level of each correlation coefficient in parentheses.

Table 7: Ranking based on predicted quality,
for Médoc and Saint Emilion appellation groups

	Alternative A	Alternative B	Olley-Pakes
Médoc (ranking system)			
ME-1	1	1	1
ME-2	2	2	2
ME-3	5	6	5
ME-4	4	4	4
ME-5	3	3	3
ME-6	6	5	6
Saint Emilion (ranking system)			
SE-1	1	1	1
SE-2	2	2	2
SE-3	3	3	3