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Abstract

We propose a structural empirical approach *à la* Levinsohn and Petrin (2003) 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 Bordeaux "en primeur" market, we provide some empirical validation for the theoretical result that the price set by wine producers is used as a signal for wine quality. 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., those 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 6 to 8 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 et al. (2005) and Hadj Ali and Nauges (2006) 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 difference-in-differences method and panel data techniques 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 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).

[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 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 week-end 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 week-end is not correlated with quality reviews (see also Hadj Ali et al., 2005, for use of a similar estimation technique).

In this article, we propose a different approach which 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. It is based on the technique developed by Levinsohn and Petrin (2003) to deal with unobserved productivity shocks when estimating production functions. This approach (which would be usable even if one does not have data coming from a natural experiment) relies on a structural assumption which links the omitted variable (wine quality in our model) with some observed variables (experts' ratings and average weather conditions in our case).

Using an unbalanced panel data set of 108 Bordeaux *châteaux* over five vintages (1994-1998), we provide some empirical validation for the theoretical result that the price set by wine producers at the time of "primeur" sales is used as a signal for wine quality (Mahenc and Meunier, 2003; Mahenc, 2004). We also confirm that experts' grades affect producers' choice of "primeur" price above the effect of unobserved wine quality (Hadj Ali et al., 2005; Hadj Ali and Nauges, 2006). Our empirical results finally 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

True wine quality, q^*, should 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

[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.

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 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") has been in existence 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 the 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 et al., 2005, and Hadj Ali and Nauges, 2006).

The "primeur" price function is written as follows:

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

[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*".

[5]Contrary to most of 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.

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 ε is an idiosyncratic random shock on the wine growers price setting such that $E(\varepsilon \mid q^*, q^o, x) = 0$. The x-vector gathers price determinants outside experts' grade and wine quality, such as categorical variables for vintage, quality-ranking and region of origin.

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 β 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 coefficients β and 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 i at period t (q^o_{it}) is supposed to signal wine true quality (q^*_{it}). Thus, unless experts' grades are given completely at random with respect to the true wine quality, expert's grade 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. One could think of using lagged values of experts' grades as potential instruments, i.e., grades attributed to the wine from older vintages. However, these instruments will be valid only under the strong assumption that unobserved wine quality is not serially correlated, which is not acceptable in the present case. 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 propose a structural approach based on the one developed in Levinsohn and Petrin (2003).[6] This method relies on the following set of assumptions:

A1 The experts' grade is such that

$$q_{it}^{o} = q_t(q_{it}^{*}, s_{it}) \quad (3)$$

where $q_t(.,.)$ is monotonic in its first argument.

Experts' grade given to "primeur" wine is written as a function of unobserved quality, q_{it}^{*}, and some observable grade shifters or proxies, s_{it}, that will be discussed later. The monotonicity assumption means that experts' grades are increasing with unobserved quality. In other words, given a set of proxies s_{it}, wine ranking according to experts' grades will match wine ranking according to unobserved quality.[7,8]

Assumption **A1** is of course crucial here and is not testable. It is a structural assumption that may seem more or less appropriate according to the good considered and which in the present case means that experts' grades given to "en primeur" wine correctly rank wines in

[6]Levinsohn and Petrin (2003) use this technique to deal with unobserved productivity shocks in production functions. See also Ackerberg et al. (2005) for related discussions.

[7]Quality, q_{it}^{*}, may be perceived by experts with some error. It corresponds to the case where the grade attributed to the wine can be written as a function of $q_{it}^{*} - \zeta_{it}$ and s_{it}, where ζ_{it} is an i.i.d. perception error. This extension is dealt with in the Appendix.

[8]Note that, instead of assumption **A1**, one can also simply do the following weaker assumption **A1b** (that is implied by **A1**): the true wine quality is such that $q_{it}^{*} = q_t^{*^{-1}}(q_{it}^{o}, s_{it})$ where $q_t^{*^{-1}}$ is an unknown function (not necessarily monotonous).

terms of unobserved quality (even if the absolute differences between qualities may be wrongly represented by differences between grades).

A2 The random shock ε_{it} in the price model (2) is independent of observable price determinants x_{it}, proxies s_{it}, and experts' grade q^o_{it}:

$$E\left(\varepsilon_{it}|x_{it}, s_{it}, q^o_{it}\right) = 0. \tag{4}$$

The endogeneity problem in (2) comes only from unobserved quality q^*_{it} (because $E\left(q^*_{it}q^o_{it}\right) \neq 0$ and no other omitted unobserved heterogeneity affects prices).

A3 Wine quality q^*_{it} may be affected by unobserved and unexpected idiosyncratic shocks, ξ_{it}, that occurred during the grapes-growing season and/or during the wine-making process. For example, these shocks can be local weather events such as gel episodes (that will not be captured by average weather conditions) or pest attacks. They are defined as follows:

$$\xi_{it} = q^*_{it} - E[q^*_{it}|q^*_{it-1}, I_{it}]. \tag{5}$$

In practice, information variables, I_{it}, will correspond to variables, like average weather conditions over the entire region, known before the wine grower can observe the realized wine quality, q^*_{it}, at period t.[9] We assume that there exists variables z_{it-1} that are uncorrelated with the idiosyncratic shocks on wine quality, ξ_{it}, at period t:

$$E\left(\xi_{it}z_{it-1}\right) = 0, \tag{6}$$

and uncorrelated with the error term ε_{it} in the price equation, i.e.,

$$E\left(\varepsilon_{it}z_{it-1}\right) = 0. \tag{7}$$

[9] The ξ_{it} random shock represents "innovation" in a production function framework (Levinsohn and Petrin, 2003).

2.2 Identification and estimation procedure

Following Levinsohn and Petrin (2003), we develop an estimation procedure exploiting the longitudinal dimension of the data that allows to identify the structural model thanks to the orthogonality conditions in **A3**. The "primeur" price model is assumed linear in the parameters, that is:

$$\ln p_{it} = x'_{it}\beta + \gamma q^o_{it} + q^*_{it} + \varepsilon_{it} \tag{8}$$

where γq^o_{it} is the effect of wine grade and q^*_{it} represents true wine quality. It can be written

$$\ln p_{it} = x'_{it}\beta + \phi_{it}(q^o_{it}, s_{it}) + \varepsilon_{it} \tag{9}$$

where $\phi_{it}(q^o_{it}, s_{it})$ is defined as

$$\phi_{it}(q^o_{it}, s_{it}) = \gamma q^o_{it} + {q^*_t}^{-1}(q^o_{it}, s_{it}).$$

In the first-stage, the price model (9), which is linear in x_{it} and non-parametric in $\phi_{it}(q^o_{it}, s_{it})$, is estimated using a k-order polynomial expansion in q^o and s_{it} to approximate the non-parametric function $q^*_t(.,.)$:

$$\ln p_{it} = x'_{it}\beta + \sum_{m=0}^{k}\sum_{n=0}^{k-m} \rho_{mn} {q^o_{it}}^m s^n_{it} + v_{it} \tag{10}$$

where $E\left(v_{it} \mid q^o_{it}, x_{it}, s_{it}\right) = 0$ because of **A2**.[10] An OLS estimation produces consistent estimates of the $\beta' s$. 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 true quality q^*_{it} that we denote $\hat{q}^*_{it}$. For any candidate value γ, let

$$\hat{q}^*_{it} = \hat{\phi}_{it} - \gamma q^o_{it} \tag{11}$$

where $\hat{\phi}_{it} = \sum_{m=0}^{k}\sum_{n=0}^{k-m} \widehat{\rho}_{mn} {q^o_{it}}^m s^n_{it}$ ($\widehat{\rho}_{mn}$ coming from the OLS estimation of equation (10)). Using these values, a consistent (non-parametric) approximation to $E[\hat{q}^*_{it}|\hat{q}^*_{it-1}, I_{it}]$ is given by

[10] In practice, we will use k=3 or 4.

the predicted values $E[q^*_{it}|\widehat{q^*_{it-1}}, I_{it}]$ from the regression

$$\hat{q}^*_{it} = b_0 + b_1\hat{q}^*_{it-1} + b_2\hat{q}^{*2}_{it-1} + b_3\hat{q}^{*3}_{it-1} + b_4 I_{it} + w_{it}. \tag{12}$$

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

$$\widehat{\varepsilon_{it} + \xi_{it}} = \ln p_{it} - x'_{it}\hat{\beta} - \gamma q^o_{it} - E[q^*_{it}|\widehat{q^*_{it-1}}, I_{it}]. \tag{13}$$

Then, using the orthogonality conditions (6) and (7), the estimate $\hat{\gamma}$ of γ is defined as the solution to the following

$$\min_{\gamma} \sum_{i,t} \left(\left(\ln p_{it} - x'_{it}\hat{\beta} - \gamma q^o_{it} - E[q^*_{it}|\widehat{q^*_{it-1}}, I_{it}] \right) z_{it-1} \right)^2. \tag{14}$$

By construction, the parameter γ is identified, which allows to disentangle the effects of true quality, q^*_{it}, and the effect of experts' grade, γq^o_{it}, on primeur price. From that, one can tell how much of the price variance is due to wine quality itself and how much is due to experts' grade. Finally, note that once parameters in model (14) have been identified, we can identify unobserved wine quality using (11): $\hat{q}^*_{it} = \hat{\phi}_{it} - \hat{\gamma} q^o_{it}$.

3 Empirical analysis

3.1 The data and specification issues

The data, which 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] The database also

[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 using a 50-100 scale.

contains some information about total production (in hectoliter per year) from all the château's vineyards.[13] We combine these data with weather data obtained from the firm 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 1994 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.[14] 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).

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.

[13]Each château may produce different wines (wines of different quality, sold under different names) from his whole set of vineyards. We only observe total production which, in most cases, does not correspond to the production of the wine followed in the database.

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

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 choose to include in x a dummy variable for each "appellation", a dummy variable for each official ranking class, and a dummy variable for each vintage.[15] These three observable elements are labeled on each bottle of wine (ranking

[15] We cannot consider weather variables in the price model since they are the same for all châteaux and only vary across years.

is indicated as long as the wine is ranked). The ranking classification may also be considered as an indirect measure for reputation (and maybe market power) of the château (Hadj Ali and Nauges, 2006).

The consistency of our method relies first, on the choice of the proxy (s_{it}) which, by assumption, is uncorrelated with both the idiosyncratic shocks on wine quality (ξ_{it}) and the error term in the price model (ε_{it}), and, second, on the validity of the orthogonality conditions (6) and (7). In our model, the s_{it} variable is interpreted as a variable affecting judgment on wine quality during tasting sessions of "primeur" wine. Experts' grade attributed at the time of primeur sales is intended to inform consumers on expected wine quality at maturity. As experts taste a wine which is not yet finished (the wine which is tasted is a wine which is still in barrels), its future quality (or quality at maturity) is difficult to ascertain. Wine quality at maturity is likely to depend on quality at the time of "primeur" sales, but also on weather conditions that prevailed during the grapes-growing season, because weather conditions have an impact on wine's development over the years. So, from one vintage to another, experts may have different beliefs about overall quality based on general weather information or conveyed by the producers themselves. Weather conditions thus appear as natural candidates for the vector of proxies, s_{it}. We will also consider estimates of inputs affecting the wine making process (that could be assessed by experts and that we measure by the unexplained part of observed wine production), as an additional proxy (see below for greater details).[16]

As for the variable z_{it-1} to be used in (14), we will consider three possible candidates: a constant, cumulative rainfall in year $t-1$ (from January to September), and cumulative hours of sunshine in year $t-1$ (from January to September). Weather conditions in year $t-1$ can be reasonably assumed to be uncorrelated with the error term of the price equation and the random

[16] It would also be possible to use some observable variables from the x vector as extra proxies. The associated parameters in the primeur price model would still be identified (for the same reason that γ, the coefficient of experts' grade, is identified). In our model, the x vector, which gathers wine characteristics such as appellation and ranking, cannot be used as proxies because tasting is generally made in single-blind conditions. This also precludes the use of variables such as quality of the wine produced in the past to be used as proxies.

shocks on wine quality, both written at time t.

One also has to choose the set of information variables, I_{it}, to enter equation (3) defining the random shocks on wine quality. We will present estimation results corresponding to three different sets: I1) weather variables (cumulative rainfall and hours of sunshine from January to September, standard deviation of rainfall and hours of sunshine, from January to September), I2) weather variables (I1) + production by château i in year t, I3) weather variables (I1) + appellation dummies.

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 using our structural model, where:

a) the information set (I_t) contains four weather variables: cumulative rainfall and hours of sunshine from January to September, standard deviation of rainfall and hours of sunshine, from January to September, all for year t.

b) the proxy variables (s_t) are cumulative rainfall and hours of sunshine from January to September, in year t.[17]

c) the z_{it-1} variable in equation (14) is the constant term.

We also report estimated coefficients using a simple OLS regression, which does not take into account the endogeneity of Parker's grade.

[Table 5 around here]

The estimated effect of Parker's grade is larger when using OLS relative to the structural model, showing that failing to control for unobserved quality leads to an over-estimation of the impact of Parker's judgment on the "primeur" price. The estimated impact of experts' grade is found equal to 1.31 (significant at the 10% level) showing evidence that experts' opinion influence

[17] Identification of all parameters except the coefficients of the vintage dummies is possible even if information variables and proxy variables vary only over time.

the choice of "primeur" price. 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 increases the "primeur" price by 1.3%. These results would tend to confirm the idea that Robert Parker is influential in the Bordeaux area (see Hadj Ali et al., 2005, 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. (2005) 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.[18]

Ranking is also found to have a significant influence on the pricing of "primeur" wine. 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, 2006). Appellation groups do not come out significantly in the estimated model.

Robustness check:

We now run several specification tests in order to check the robustness of our findings. In particular, we re-estimate the model using different sets of proxies, information variables in model (3) defining random shocks on wine quality, and z_{it-1} variables to be used in equation (14). Until now, cumulative rainfall and cumulative hours of sunshine (from January to September) in year

[18]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.

t have been used as proxies (our s_{it} variables). We propose to include as an additional proxy the residual from a regression fitting production. We estimate a linear model where total production of château i in year t is regressed on vintage dummies, weather variables, and unobservable château effects (assumed constant over time). The model is estimated using a Within estimation technique.[19] The estimated residual (including the estimated château effect) is denoted by $\hat{u}_{it}^{h}$ and is used as an extra proxy. The estimated residual of the production model seems a good candidate for the set of proxy variables as it is likely to capture, in addition to unobserved château specific effects, unobserved inputs to production that could also be correlated with unobserved wine quality.

Until now, we have been using as information variables (I_{it}), a set of four weather variables: cumulative rainfall and hours of sunshine, standard deviation of rainfall and hours of sunshine, all four variables computed over the January-September period. We consider two extended sets of information variables: 1) weather variables + production of château i in year t; 2) weather variables + appellation dummies.

Also, the z_{it-1} variable in equation (14) was the constant term. We now try two other variables: cumulative rainfall over the January-September period in year $t-1$, and cumulative hours of sunshine over the January-September period in year $t-1$.

We re-estimate the model combining these different assumptions. We present the estimated coefficient of Parker's grades in Table 6.[20] Estimated effect of Parker's grade is found to be quite robust to the different settings. Under different sets of information variables, proxy variables, and variables z_{it-1} considered in (14), the estimated effect of Parker's grade, when significant, is found to lie in the range 1.3-1.4.

[Table 6 around here]

[19] Estimation results are not shown here but are available from the authors upon request.

[20] Full estimation results are not shown here but are available upon request.

Finally, we test whether the estimated effect of Parker's grade may vary across different subsamples of wines. Estimates of the coefficient associated to Parker's grade are shown in Table 7.

[Table 7 around here]

Results show that the estimated coefficient of experts' grade is not very sensitive to the removal of some wines, either from some particular region or quality ranking.

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 correlation with other factors such as experts' grade, rank dummies, vintage years, and weather conditions.[21]

The consistency of our approach relies on the structural assumption **A1** that experts' grade, q^0, can be written as a function of wine quality, q_{it}^*, and grade shifters or proxies, s_{it}. As explained before, weather variables appeared to be natural candidates for the vector of proxies. A simple test for this relationship is to compute 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. Correlation coefficients along with probability values corresponding to the significance level of each correlation coefficient, are shown in Table 8.

[Table 8 around here]

Correlation coefficients have the expected signs and are all significant at the 1% level. Correlation coefficient between experts' grade and predicted wine quality is 0.29.[22] Predicted wine qual-

[21] We predict wine quality from the coefficients estimated with the structural approach and displayed in Table 5.

[22] 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.

ity is found positively correlated with cumulative hours of sunshine over the January-September period (correlation coefficient is 0.48), and negatively correlated with cumulative rainfall over the same period (correlation coefficient is -0.41).[23]

Evidence about the effect of weather on wine quality is consistent with Ashenfelter's findings (see Ashenfelter et al., 1995, 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) 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.

Simple statistics on predicted wine quality by quality ranking are shown in Table 9. On average, our wine quality estimates are found to match the official quality rankings. The greatest predicted wine qualities are obtained for wines classified as first top-growths in the Médoc and Saint Emilion regions (ME-1 and SE-1, respectively). Our predictions of wine quality, on average, match the overall ranking in the Saint Emilion region. In the Médoc region, we do not find much differences in quality across wines belonging to ranks ME-3, ME-4, and ME-5. Wines in the Graves region (GR ranking) have a predicted quality which is in the range of the predicted quality of Médoc wines classified as ME-3 or ME-4. The high predicted wine quality for wines in the non-classified group is explained by the presence in this group of famous wines from the Pomerol region (like *Château Pétrus*).

[Table 9 around here]

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

In Table 10 (and Figure 1), we show simple statistics (and corresponding distributions) on predicted wine quality for each of the vintages from 1994 to 1998. Wines from vintages 1995 and 1998 are generally considered by all wine experts as the best wines over the period. On average, our model predicts the highest qualities in 1997 and 1998, but predicted quality in 1995 is not as high. Interestingly, the 1997 vintage is described as the highest quality vintage by our model. At the time of "primeur sales" (in Spring 1998), the 1997 vintage was described as a "bad year" by experts. However the latter changed their mind few years after and assessed that their first judgment was wrong and that Bordeaux wines from 1997 would be of high quality when reaching maturity. Our methodology thus seems to manage to detect the fact that 1997 is a good wine vintage by disentangling the effect of experts' grades from the effect of true quality in the pricing equation of wine producers who are better informed to assess wine quality at maturity.

[Table 10 and Figure 1 around here]

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 propose a structural empirical approach, which is based on Levinsohn and Petrin (2003), 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.

Using a panel data set of 108 châteaux selling wine on the Bordeaux "en primeur" market, we provide some empirical validation for the theoretical result that the price set by wine producers is used as a signal for wine quality (Mahenc and Meunier, 2003; Mahenc, 2004). We confirm that experts' grades affect producers' choice of "en primeur" price above the effect of unobserved wine quality (Hadj Ali et al., 2005; Hadj Ali and Nauges, 2006). 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 wine 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 consistent with Ashenfelter et al. (1995)'s findings about the effect of weather on prices of mature wines.

Appendix: The case of a perception error

We assume that the relationship between q_{it}^* and q_{it}^o is no longer deterministic and is affected by unobserved shocks, ζ_{it}:

$$q_{it}^o = q_t(q_{it}^* - \zeta_{it}, s_{it}). \tag{15}$$

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 proxies 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:

$$\ln p_{it} = x_{it}'\beta + \gamma q_{it}^o + q_{it}^* + \varepsilon_{it}, \tag{16}$$

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

It can be written

$$\ln p_{it} = x_{it}'\beta + \phi_{it}(q_{it}^o, s_{it}) + \zeta_{it} + \varepsilon_{it} \tag{17}$$

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_{it}^o but not with unobserved quality q_{it}^*, it is easier to think about an instrumental variable correlated with q_{it}^o (and q_{it}^*) but not with the perception error ζ_{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 (Newey and Powell, 2003; Darolles, Florens and Renault, 2003). Then, in the first-stage, the price model (9) 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

$$\hat{q}^*_{\zeta it} = \hat{\phi}_{it} - \gamma^* q^o_{it}. \tag{18}$$

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

$$\hat{q}^*_{\zeta it} = b_0 + b_1\hat{q}^*_{\zeta it-1} + b_2\hat{q}^{*2}_{\zeta it-1} + b_3\hat{q}^{*3}_{\zeta it-1} + b_4 I_{it} + w_{it}. \tag{19}$$

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)

Dependent variable: $\ln p_{it}$	Structural model		OLS$^{(a)}$	
List of explanatory variables:	Coef.$^{(b)}$	Std. Err.	Coef.$^{(b)}$	Std. Err.
Parker's grade (log q_{it}^{o}) ($\widehat{\gamma}$)	1.306*	0.757	3.946***	0.414
Médoc (appellation groups)				
Haut Médoc	-0.536*	0.313	-0.613***	0.160
Margaux	-0.318	0.303	-0.444***	0.153
Moulis	-0.359	0.307	-0.441**	0.186
Pauillac	-0.232	0.294	-0.325**	0.143
Saint Estèphe	-0.193	0.282	-0.311**	0.158
Saint Julien	-0.220	0.309	-0.313**	0.158
Saint Emilion (appellation groups)				
SEGC	-0.647	0.455	-0.641***	0.156
Graves (appellation groups)				
Pessac Léognan	-0.188	0.247	-0.286**	0.125
Pomerol	.	.	.	.
Vintages				
1997 vintage	.	.	0.464***	0.039
1998 vintage	.	.	0.380***	0.041
Médoc (ranking system)				
ME-1	-0.781	0.696	-0.674***	0.248
ME-2	-1.442**	0.699	-1.422***	0.248
ME-3	-1.718**	0.704	-1.729***	0.252
ME-4	-1.792**	0.712	-1.812***	0.250
ME-5	-1.835***	0.708	-1.850***	0.245
ME-6	-1.899***	0.693	-1.908***	0.252
Saint Emilion (ranking system)				
SE-1	.	.	.	.
SE-2	-0.861	0.666	-0.958***	0.146
SE-3	-1.293**	0.659	-1.375***	0.142
Graves (ranking system)				
GR	-1.674**	0.731	-1.701***	0.237
Non-classified	-1.603	0.693	-1.681***	0.200

(a): constant not shown in OLS estimates.

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

Table 6: Estimated coefficient of Parker's grade (standard error in parentheses)

Variable (z_{it-1}) and set of proxies (s_{it})	Innovation equation, set of information variables (I_{it}): Weather conditions$_t$[(a)]	Weather conditions$_t$ + Production$_{it}$[(b)]	Weather conditions$_t$ + Appellation dummies$_i$
1) z_{it-1} =constant			
s_{it}={RAIN$_t$, SUN$_t$}	1.306* (0.757)	1.132 (0.860)	1.315* (0.777)
s_{it}={RAIN$_t$, SUN$_t$, $\hat{u}^h_{it}$}	1.425* (0.749)	1.328* (0.748)	1.592* (0.914)
2) z_{it-1} =RAIN$_{t-1}$			
s_{it}={RAIN$_t$, SUN$_t$}	1.125 (0.737)	0.988 (0.956)	1.125 (0.844)
s_{it}={RAIN$_t$, SUN$_t$, $\hat{u}^h_{it}$}	1.494* (0.768)	1.347* (0.754)	1.610* (0.906)
3) z_{it-1} =SUN$_{t-1}$			
s_{it}={RAIN$_t$, SUN$_t$}	1.419** (0.667)	1.246 (0.954)	1.436** (0.670)
s_{it}={RAIN$_t$, SUN$_t$, $\hat{u}^h_{it}$}	1.432* (0.715)	1.348* (0.775)	1.606* (0.905)

Definition of variables:
RAIN$_t$: cumulative rainfall from January, 1, to September, 30 (year t).
SUN$_t$: cumulative hours of sunshine from January, 1, to September, 30 (year t).
$\hat{u}^h_{it}$: residual from the production model (château i, year t).
(a): includes RAIN$_t$, SUN$_t$, SDRAIN$_t$ (standard deviation of rainfall over Jan 1 - Sep 30), SDSUN$_t$ (standard deviation of hours of sunshine over Jan 1 - Sep 30).
(b): Production (hl) for château i in year t.

Table 7: Estimated impact of Parker's grade - different sub-samples

	Number of châteaux	Structural Model Coef.	Structural Model Std. Err.	OLS Coef.	OLS Std. Err.
Whole sample	108	1.306*	0.757	3.946***	0.414
All wines except					
wines from the Médoc region	43	2.084**	0.883	5.075***	0.753
wines from the Saint Emilion region	89	1.386*	0.743	3.926***	0.460
top-growths (ME-1 and SE-1)	103	1.352**	0.668	3.912***	0.426
wines from ME-1, ME-2, SE-1 and SE-2	86	1.425**	0.606	3.999***	0.457

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

Table 8: Correlation coefficients between predicted quality and other variables

	Correlation coefficient between predicted quality and[a]
Experts' grade	0.2885 (0.0000)
Cumulative hours of sunshine	0.4837 (0.0000)
Cumulative hours of rainfall	-0.4080 (0.0000)
Standard deviation of hours of sunshine	0.3366 (0.0000)
Standard deviation of hours of rainfall	-0.1450 (0.0040)

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

Table 9: Statistics on predicted quality, by rank

	Mean	Std Dev.	Min	Max
ME-1	0.334	0.124	0.182	0.544
ME-2	0.281	0.118	0.127	0.528
ME-3	0.232	0.047	0.155	0.322
ME-4	0.241	0.062	0.126	0.364
ME-5	0.249	0.089	0.139	0.598
ME-6	0.225	0.069	0.125	0.486
SE-1	0.325	0.118	0.170	0.443
SE-2	0.270	0.119	0.124	0.540
SE-3	0.267	0.108	0.139	0.470
GR	0.240	0.069	0.136	0.368
Non-classified	0.280	0.167	0.093	0.767

Table 10: Statistics on predicted quality, by vintage

	Mean	Std Dev.	Min	Max
1994	0.176	0.044	0.093	0.368
1995	0.206	0.049	0.111	0.446
1996	0.284	0.096	0.133	0.671
1997	0.344	0.121	0.148	0.720
1998	0.302	0.100	0.145	0.767

Figures

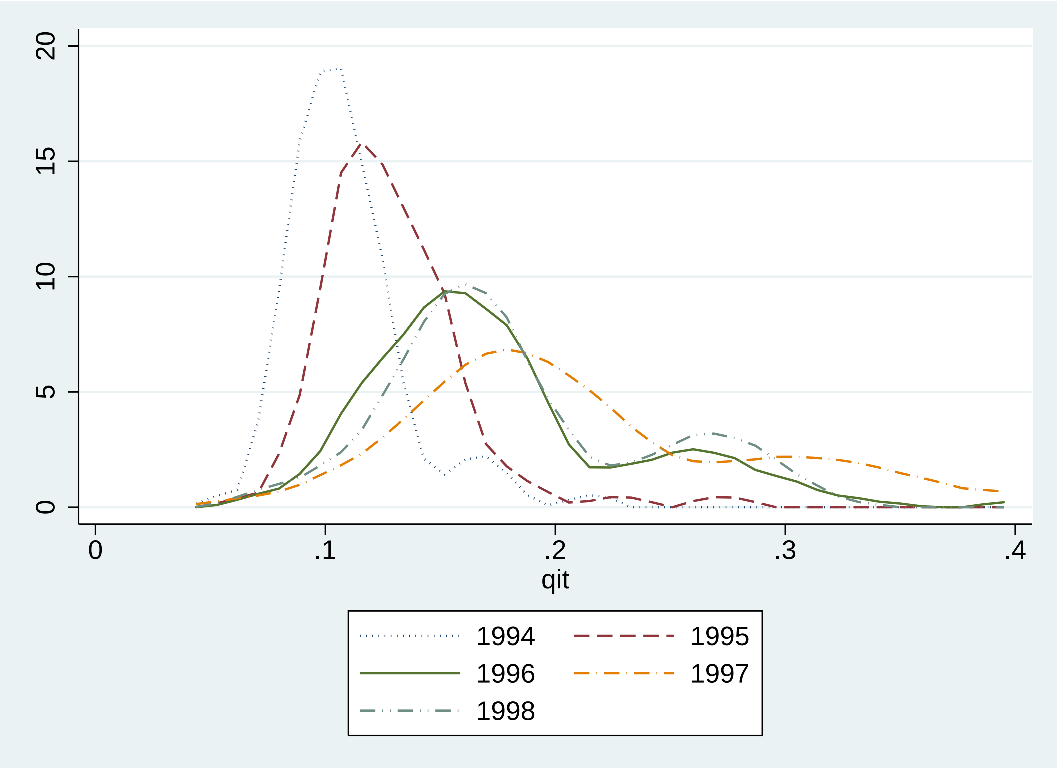

Figure 1: Distribution of predicted wine quality, by vintage