Identifying the Effect of Unobserved Quality and Experts' Reviews in the Pricing of Experience Goods: Empirical Application on Bordeaux Wine

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Abstract

When an experience good is being released on the market, experts' opinions or grades are supposed to give information about the quality of the good to future customers. However, whether released experts' opinion affects price setting by itself remains an empirical question that seems difficult to answer. Actually, unobserved true quality of the good makes the experts' grades (supposed to be correlated with this quality) necessarily endogenous in any "hedonic" price equation for experience goods. Using panel data on French Bordeaux wine gathering information on prices, wine characteristics and wine tasters' grades, we propose a structural empirical approach *à la* Levinsohn and Petrin (2003) allowing to disentangle the informative value of grades on quality from the sole direct effect of grades on price. Our empirical results show that wine tasters' grades affect positively price setting of "en primeur" wine (that is, new vintages that have not been tasted by consumers) as well as unobserved wine quality. Finally, the identified wine quality is shown to be correlated with weather conditions at the growing season, an evidence consistent with Ashenfelter's findings about the effect of weather on prices of mature wines.

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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 as well as empirical research. The theoretical literature (Shaked and Sutton, 1982; Shapiro, 1983; Tirole, 1996; Mahenc and Meunier, 2003; among others) mainly considered firm's activity of quality signaling (through advertising, product labeling, reputation, etc.), while numerous empirical studies (Ackerberg, 2003; Caves and Greene, 1996; Jin and Leslie, 2003; etc.) measured the influence of these various sources of information on consumer demand. In this article, we contribute to this literature by empirically testing the influence of experts' reviews on the pricing of experience goods. The influence of experts' opinion (on consumer behavior) has been the focus of recent empirical work, see Ginsburgh (2003) and Reinstein and Snyder (2005) for an analysis of expert's influence in the art and movie markets respectively.

In this paper, we measure the influence of experts' grades on the pricing of "primeur" wine by producers from the Bordeaux region (France). Primeur wine is a typical experience good as it refers to a wine sold 6 to 8 months after the grape harvest. The wine, which is still in barrel at the time of "primeur" sales, is not yet finished. Only the producer, who knows exactly what happened during the grapes growing season and who followed each step of the wine making process, is supposed to know the "true" quality of his wine.[1] On the other hand, the only available information for consumers (and hence for econometricians) comes from reputation, labeling, and experts' judgment made during wine tasting sessions taking place before the opening of the "primeur" market.

Most of the châteaux in the Bordeaux region (France) have a long-time established reputation and a system of wine ranking, clearly labeled on the bottle, has been in existence since the

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

nineteenth century (Markham, 1997). Consumers can thus be assumed well informed about the quality of the wine that was produced in the past. Quality of the wine is however likely to vary from one vintage to another due in particular to the weather conditions that prevailed during the grapes-growing season.[2] There is thus some uncertainty remaining about wine quality when the "primeur" market opens, and consumers are thus likely to rely on experts' opinion. 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 main issue of this empirical work is that true quality, which is known by the producer but unobserved by the consumer and the econometrician, will not only influence the pricing of "primeur" wine, but true quality is also likely to be correlated with experts' reviews. We thus face a typical problem of omitted variable which may produce biased estimates if not controlled for. This endogeneity problem cannot 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) faced the same endogeneity problem when measuring the influence of movie critics on consumer demand, since, as stated in their paper, "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. 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. The authors provide several tests.

In this paper, we propose a different approach extending the one developed by Levinsohn and

[2] 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.

Petrin (2003) in order 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, exploits a structural assumption about the omitted variable. In our case, this assumption links wine grades and wine unobserved quality. This procedure not only controls for the omitted variable (unobserved wine quality in this particular study) but it also allows to identify it.

Using an unbalanced panel data set of 108 Bordeaux *châteaux* over five vintages (1994-1998), we find evidence that wine experts' grades affect the choice of the "primeur" price by the producer 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' grade in the pricing of "primeur" wine.

This article also contributes to the growing literature on wine markets. Even if most of the published work has focused on bottled wine (see Landon and Smith, 1997 and 1998, for an analysis of consumer behavior, or Lecocq and Visser, 2003, for a review of hedonic price models), econometric analysis of wine sold en primeur has also been the focus of recent work (see Hadj Ali and Nauges, 2004, and Hadj Ali et al., 2005). These papers however did not address the issue of unobserved quality.

2 Theoretical model, identification and estimation

The producer, who followed each step of the wine making process, is assumed to know the true quality (or quality at maturity) of his wine, q^*. Moreover, since the wine maker is aware of all the wine making process, it is usually acknowledged that he has more information than any other person to assess the quality of his wine. We can reasonably assume that the producer will price the wine sold on the primeur market, according to the true expected quality at maturity, q^*, that experts try to assess and signal by revealing some grades after tasting. Experts' grade are given during the wine tasting sessions that occur before the opening of the "primeur" market. Producers' pricing strategy may also depend on consumers' expected willingness to pay for the wine. The latter, who are not perfectly informed about quality, will likely refer to reputation, labeling, or experts' judgment to make their purchase decision. 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 will test this assumption by introducing experts' grade into the "primeur" price function.

Thus, we can define a "primeur" price function as:

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

where p represents "primeur" price, q^o is experts' grade given to "primeur" wine, q^* is true wine quality known by the producer and ε is an idiosyncratic random shock on the wine growers price setting such that $E(\varepsilon \mid q^*, q^o, x) = 0$. x is a vector of other price determinants linked for example to rank or region of origin.

2.1 Structural model

Writing the "primeur" price function (1) for château i and vintage t, and assuming that the price function $\pi(.,.,.)$ is additively separable between q^*, q^o, and x, we get:

$$\begin{aligned} \ln p_{it} &= E(\ln p_{it} \mid q^*_{it}, q^o_{it}, x_{it}) + \varepsilon_{it} \\ &= x'_{it}\beta + \gamma q^o_{it} + q^*_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

where β and γ are unknown parameters, and the coefficient of q^*_{it} (which is unobserved) has been normalized.

The 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 in general we will have

$$E\left(q_{it}^{*} \mid q_{it}^{o}, x_{it}\right) \neq 0.$$

Assuming that experts' grade is uncorrelated with true wine quality is of course a very unrealistic assumption since wine tasting is indeed performed in order to give information on the true wine quality. Thus we face an endogeneity problem in (2) because experts' opinion about the experience good i at period t (q_{it}^{o}) is supposed to signal the unobserved quality of the good (q_{it}^{*}). Thus, unless experts' grades are given completely at random with respect to the true quality of the good, expert's grade will be endogenous in the price equation.

A first simple solution would be to use instrumental variables to correct for this endogeneity problem. But finding instrumental variables would mean that one observes variables correlated with the wine grade, q_{it}^{o}, but not with unobserved wine quality, q_{it}^{*}. In this particular example of wine as an experience good, no natural instrumental variables appear 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 the 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.

Thus, we propose a structural approach exploiting a non-parametric relationship between unobserved quality and observed variables as well as orthogonality conditions about innovations in unobserved quality. This approach is related to the one developed in Levinsohn and Petrin (2003) allowing to deal with unobserved productivity shock in production functions that make input levels endogenous in the production function.

We define the innovation ξ_{it} to the unobserved quality conditionally on some information I_{it}

with:

$$\xi_{it} = q^*_{it} - E[q^*_{it}|q^*_{it-1}, I_{it}]. \tag{3}$$

In practice, information variables, I_{it}, will correspond to variables, like weather conditions, known before the wine grower can observe the realized wine quality, q^*_{it}, at period t. The innovation, ξ_{it}, represents random shocks that may have occurred during the grapes-growing season and/or during the wine making process.

Our method relies on the following set of assumptions:

A1 The experts' grade is such that

$$q^o_{it} = q_t(q^*_{it}, s_{it}) \tag{4}$$

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

The grade attributed to "primeur" wine is written as a function of unobserved quality, q^*_{it}, and some observable grade shifters, s_{it}.[3] The monotonicity assumption means that experts' grades are increasing with unobserved quality, i.e., wine ranking according to experts' grades match wine ranking according to unobserved quality, if the grade shifter variables s_{it} are the same.

Note that, instead of assumption **A1**, one can also simply do the following weaker assumption that is implied by **A1**:

A1b The true wine quality is such that

$$q^*_{it} = q_t^{*^{-1}}(q^o_{it}, s_{it}) \tag{5}$$

where $q_t^{*^{-1}}$ is an unknown function (not necessarily monotonous).

[3] 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.

Assumption **A1b** is implied by **A1**, and assumption **A1** implies then that ${q_t^*}^{-1}$ is the inverse of $q_t(.,.)$ with respect to its first argument.

Assumption **A1** or **A1b** is of course very important in the method 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 the grades given to "en primeur" wine correctly rank the wines in 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} on the price setting equation is independent of observable price determinants x_{it}, grade shifters s_{it}, and grade q_{it}^o:

$$E\left(\varepsilon_{it}|x_{it}, s_{it}, q_{it}^o\right) = 0. \tag{6}$$

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

A3 We assume that there exists variables z_{it-1} that are uncorrelated with the innovation ξ_{it} at period t:

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

Innovations ξ_{it} in wine quality can be interpreted as unobserved and unexpected idiosyncratic shocks occurring during the wine growing process. Idiosyncratic innovations to wine quality are uncorrelated with the variable z_{it-1} (which is granted by definition of the innovation if z_{it-1} belongs to the information variables I_{it}). We also assume that the variables z_{it-1} are uncorrelated with the error term ε_{it} in the price equation, i.e.,

$$E\left(\varepsilon_{it} z_{it-1}\right) = 0. \tag{8}$$

2.2 Identification and estimation procedure

As in 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 our main orthogonality conditions described in **A3**. The "primeur" price model is assumed linear in the parameters, that is:

$$\ln p_{it} = x'_{it}\beta + \gamma q^o_{it} + q^*_{it} + \varepsilon_{it} \tag{9}$$

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

$$\ln p_{it} = x'_{it}\beta + \phi_{it}(q^o_{it}, s_{it}) + \varepsilon_{it} \tag{10}$$

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 (10) 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[4] in q^o and s_{it} to approximate the non-parametric function $q^*_t(.,.)$:

$$\ln p_{it} = x'_{it}\beta + \sum_{m=0}^{k}\sum_{n=0}^{k-m} \rho_{mn} {q^o_{it}}^m s^n_{it} + v_{it} \tag{11}$$

where $E\left(v_{it} \mid q^o_{it}, x_{it}, s_{it}\right) = 0$ because of **A2**. 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

$$\hat{q}^*_{it} = \hat{\phi}_{it} - \gamma q^o_{it} \tag{12}$$

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 (11)).

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

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

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

$$\hat{q}^*_{it} = b_0 + b_1\hat{q}^*_{it-1} + b_2\hat{q}^{*2}_{it-1} + b_3\hat{q}^{*3}_{it-1} + b_4 I_{it} + w_{it}. \tag{13}$$

Given $\hat{\beta}$, γ, and $E[q^*_{it}|\widehat{q^*_{it-1}}, I_{it}]$, the sample residual of the price function ε_{it} plus the innovation ξ_{it} is

$$\widehat{\varepsilon_{it} + \xi_{it}} = \ln p_{it} - x'_{it}\hat{\beta} - \gamma q^o_{it} - E[q^*_{it}|\widehat{q^*_{it-1}}, I_{it}]. \tag{14}$$

Then, using the orthogonality conditions (7) and (8), the estimate $\hat{\gamma}$ of γ is defined as the solution to the following

$$\min_{\gamma} \sum_{i,t} \left(\left(\ln p_{it} - x'_{it}\hat{\beta} - \gamma q^o_{it} - E[q^*_{it}|\widehat{q^*_{it-1}}, I_{it}] \right) z_{it-1} \right)^2. \tag{15}$$

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 the price thanks to equation (9). This is important because then one can tell how much of the price variance is due to the wine quality itself and how much to the wine grade. Finally, note that once we have identified the parameters of the model, (12) shows that we can identify $\hat{q}^*_{it} = \hat{\phi}_{it} - \hat{\gamma} q^o_{it}$, that is the unobserved wine quality. Then, it is interesting to look at wine quality determinants by regressing $\hat{q}^*_{it}$ on some observed variables ω_{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[5] of 108 Bordeaux châteaux, over five vintages (from 1994 to 1998). 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

[5] 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.

time of "primeur" sales,[6] as well as a set of wine characteristics gathering vintage, "appellation" (the French equivalent of Protected Designation of Origin), and ranking. The database also contains some information about total production (in hectoliter per year) from all the château's vineyards.[7] We combine these data with weather data obtained from the firm Météo France. Weather data consist in daily data at Mérignac in the Bordeaux Region on minimum and maximum temperature, hours of sunshine and rainfall for all years from 1994 to 1998.

The data base 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[8] and has been largely unchanged to this day. 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*

[6] Tasting normally 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.

[7] 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.

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

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 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. 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 (and maybe market power) of the château (Hadj Ali and Nauges, 2004).

The consistency of our method relies first, on the choice of the proxy (s_{it}) which, by assumption, is uncorrelated with both the innovation and the error term in the price model, and, second, on the validity of the orthogonality conditions (7) and (8). 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 appears as natural candidates for the vector of proxies, s_{it}. To check for the robustness of our results, we will also consider as an additional proxy, some estimates of (unobserved by the econometrician) inputs affecting the wine making process that could be assessed by experts and that we measure by the unexplained part of observed wine production (see below for greater details).

As for the variable z_{it-1} to be used in (15), 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 innovation, both written at time t.

One also has to choose the set of information variables, I_{it}, to enter the definition of the innovation equation. 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 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 are cumulative rainfall and hours of sunshine from January to September, in year t.

c) the z_{it-1} variable in equation (15) 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 endogeneity bias is thus quite significant. The estimated impact of experts' grade is found equal to 1.31 (significant at the 10% level) showing evidence that experts' opinion influence the choice of "primeur" price. In other words, once the "primeur" price has been chosen based on objective wine characteristics and on 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. 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.

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, 2004). 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 the innovation equation, and z_{it-1} variables to be used in equation (15). Until now, cumulative rainfall and cumulative hours of sunshine (from January to September) in year 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, and a large of set of weather variables. We also include unobservable château effects, assumed constant over time. The model is estimated using a Within estimation technique. 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 in the innovation equation (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 (15) 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.[9] Estimated effect of Parker's grade is found to be quite robust to the settings. Under different sets of information variables, proxy variables, and variables z_{it-1} considered in (15), the estimated effect of Parker's grade, when significant, is found to lie in the range 1.3-1.4.

[Table 6 around here]

Finally, we test whether the estimated effect of Parker's grade change if some of the wines are removed from the sample. 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 Parker's 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.[10]

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

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

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

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.[11] Predicted wine quality 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).[12]

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 in the price determination of primeur wine.

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

[11] 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.

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

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]

We show in Table 10 simple statistics on predicted wine quality for each of the vintages from 1994 to 1998, and corresponding distributions on Figure 1. 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 true quality in the pricing equation of wine producers that are better informed to assess the wine quality at maturity.

[Table 10 and Figure 1 around here]

4 Conclusion

Using panel data on French Bordeaux wine gathering information on prices, wine characteristics and wine tasters' grade, our empirical results show that wine tasters' grades affect positively price setting of en "primeur" wine (that is, new vintage that has not been tasted by consumers) above the effect of unobserved wine quality. This empirical illustration using data on "primeur" wine also emphasizes that not controlling for unobserved quality leads to over-estimate the impact of experts' information. The estimation procedure exploits the structural assumption between wine grades and unobserved wine quality. One of its nice features is that it allows to recover estimates of unobserved wine quality by disentangling wine quality from the effect of grades on wine prices. Finally, we show evidence that the identified unobserved wine quality is actually correlated with weather conditions as already demonstrated using prices of mature wines by Ashenfelter et al. (1995).

Appendix: The case of a perception error

The case where the perceived quality is not the true quality because of a perception error can also be handled. 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:

$$q_{it}^{o} = q_t(q_{it}^{*} - \zeta_{it}, s_{it}). \tag{16}$$

Contrary to Levinsohn and Petrin (2003), we now allow the function relating q_{it}^{*} and q_{it}^{o} not to be deterministic since it is affected by unobserved shocks ζ_{it}. The interpretation of the error ζ_{it} as a perception or reporting error depends on whether one assumes that experts do observe or not q_{it}^{*} at period t. If one can assume that it is observed by them, then ζ_{it} is more a "reporting error", if one assume that they do not yet observe perfectly q_{it}^{*} then ζ_{it} is a "perception error".

We first need to assume that the perception error about quality is uncorrelated with grade shifters 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:

$$\ln p_{it} = x_{it}'\beta + \gamma q_{it}^{o} + q_{it}^{*} + \varepsilon_{it}, \tag{17}$$

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

It can be written

$$\ln p_{it} = x_{it}'\beta + \phi_{it}(q_{it}^{o}, s_{it}) + \zeta_{it} + \varepsilon_{it} \tag{18}$$

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

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

Now q_{it}^{o} is endogenous because correlated with ζ_{it}. We thus need to use some instrumental variables for q_{it}^{o} that would not be correlated with the perception error ζ_{it}. Remark that while it is difficult to think about 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 the perception error ζ_{it}.

If one wants to estimate $\phi_{it}(q_{it}^o, s_{it})$ non-parametrically, then one has to use non-parametric instrumental variables techniques (Newey and Powell (2003) and Darolles, Florens and Renault (2003)). Then, in the first-stage, the price model (10) which is linear in x and non-parametric in $\phi_{it}(q_{it}^o, s_{it})$, 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

$$\hat{q}_{\zeta it}^* = \hat{\phi}_{it} - \gamma^* q_{it}^o. \tag{19}$$

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 $E[q_{\zeta it}^* \widehat{| q_{\zeta it-1}^*}, I_{it}]$ of the regression

$$\hat{q}_{\zeta it}^* = b_0 + b_1 \hat{q}_{\zeta it-1}^* + b_2 \hat{q}_{\zeta it-1}^{*2} + b_3 \hat{q}_{\zeta it-1}^{*3} + b_4 I_{it} + w_{it}. \tag{20}$$

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 innovation 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 have

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

Given $\hat{\beta}$, γ^*, and $E[q_{it}^* \widehat{| q_{it-1}^*}, I_{it}]$, the sample residual of the price function ε_{it} plus the innovation ξ_{it} and the perception error ζ_{it} is

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

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 ($\log q^o_{it}$) ($\widehat{\gamma}$)	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

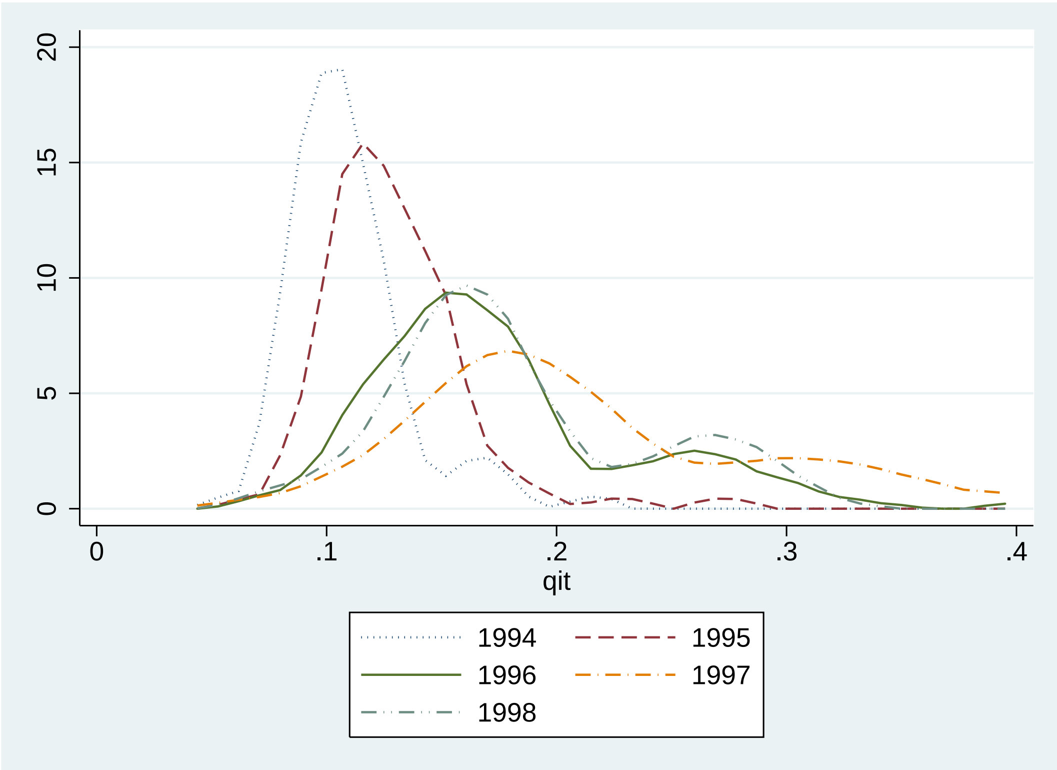

Figure 1: Distribution of predicted wine quality, by vintage