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Tecnhnology estimation for quality pricing in supply-chain relationships

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Technology estimation for quality pricing in supply-chain relationships

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Abstract

The paper designs an optimal payment system for a group of producers implementing it empirically. It shows how to implement the first best through higher prices for better quality commodities, deriving the optimal pricing schedule. It also takes into account producers' heterogeneity by modelling inefficiency and illustrating how technical efficiency interacts with producers' ability to produce output for a given level of inputs and hence affects revenues. The technology and the technical efficiency of producers are then estimated with a stochastic production function model. The estimation results are then used to simulate the pricing scheme.

1 Introduction

The payment systems for raw commodities and intermediate products define one of the most critical relationships of many vertically related industries, since they establish how revenues are distributed among growers and processing firms. Intermediate products payment systems also have a pivotal role in setting the incentives that growers and processing firms face: not only do they heavily influence the incentives to improve technical efficiency, they also have far-reaching implications for investment decisions.

For these reasons, measuring and evaluating the right attributes in raw materials, commodities, and intermediate products is a common problem in many sectors of the economy (Barkley and Porter, 1996; Buccola and Iizuka, 1997; Ladd and Martin, 1976). This happens to be true in food industries, where grapes are used for wine production, milk for cheese, canes for sugar, beans for coffee, but also in other industries, for instance with chips used in the computer industry, ores in steel production, steel in construction works, crude oil in refined oil production, just to name a few examples.

In this paper we show how to design an optimal payment system for a group of producers using mainly production data information. We first show how it is possible to implement the first best through higher prices for better quality commodities, deriving the optimal pricing schedule from a dual specification of the problem, i.e., with a restricted revenue function. We find that the quality choices of the optimal contract depend on the efficiency of producers and on the technological relationship between quality and quantity. The optimal pricing scheme, moreover, plainly mirrors market's preferences for quality.

We take into account producers' heterogeneity by modeling inefficiency and illustrating how technical efficiency interacts with producers' ability to produce outputs for a given level of inputs and hence affects revenues. After reformulating the pricing scheme in terms of primal measures, we estimate the technology and the technical efficiency of producers via a stochastic production function model. We hence use the estimation results to simulate the optimal quality choices and pricing scheme.

This study combines a theoretical model for contract design under symmetric information for a group of producers with the contributions of the literature on the parametric estimation of technology using Stochastic Frontier Analysis (SFA). By combining the contributions of these two strands of the literature, we design an optimal pricing scheme for a cooperative using an estimation of the technology. We use the pricing scheme with a specific dataset for market, weather, and soil quality conditions to show the impact on the choices and payments received by a group of farmers involved in grapes production in Italy. The model and the methodology however are general enough to be implementable for other groups and other industries as well.

The plan of the paper is the following. In the next section we explain the relevance of the problem at hand and review some of the literature. In the following we introduce a model of the behavior of producers and the cooperative and show what would be the first best pricing scheme. We then formulate the pricing scheme in terms of a primal specification of the technology, i.e., a production function, and of market demand information. We then show how to implement it using stochastic frontier analysis. We illustrate the data used in the empirical application in the following section. After introducing the results of the technology estimation, we simulate the results of the estimated pricing scheme and compare with the actual pricing schedule used by the group of producers analyzed. To conclude, we highlight some possible improvements for the methodology and directions for future research.

2 Facts and literature review

The wine-world market is characterized by two principal wine suppliers, the European, based on the Appellation of Origin (AO) type of organization, and the New World one, mainly promoted by new countries, with an organization based on the type of grapes. Wines in the AO system are often made by blending specific and sometimes local grapes varieties; their grapes production is regulated, with a maximum yield allowed per unit of land; and their production regions are very delimited. In other words, wine-making in the European Union is very regulated and based on tradition, with a big role assigned to local wines which name is generally associated with the production region, e.g., Bordeaux, Chianti, Rioja. The AO system has proven successful in guaranteeing a good reputation for many European wines and in assuring relatively high profits for wine producers, even for the relatively small vineyards typical of most European countries (Berthomeau, 2002).

Having traditionally been the biggest producers and exporters of wine, countries like France, Italy, Spain and Portugal in the last few years have endured, however, a tremendous growth of New World wine-makers. Indeed, the wine producers of Australia, California, Chile, and other emerging wine producing countries, are challenging the European leadership in world markets (Anderson, 2001; Economist, 1999). Common characteristics of the emerging wine producing countries are the lack of detailed rules, i.e., the freedom to experiment with new techniques; the bigger size of the farming, wine-making and trading operations, much bigger than the European ones; the production and marketing of wines according to single varieties, e.g., Chardonnay, sometimes associated with the production region; and a very intense use of marketing investments.

Contrary to the New World countries, the wine industry in Europe is very fragmented and appears relatively uninterested by the consolidation processes that are taking place worldwide, especially in Australia and the USA (Economist, 2003; Marsch, 2003). Apart from some notable exceptions, e.g., the Champagne, Bordeaux, or Tuscany regions, the wine industry in Europe is made of many small firms, which may lack adequate capital for the required investments in new technologies and marketing policies (Saulpic and Tanguy, 2004). A partial solution to the size problem, according to some practitioners, may be the collective organization by farmers through cooperatives. Indeed, cooperatives in the European wine industry are very common and in some regions have a considerable market share of production and processing facilities.[1]

The cooperative movement in the wine sector, however, has been suffering for a reputation for low quality,[2] lack of investment, and often the inability to retain the better members (Touzard *et al.*, 2000). One of the critical problems for cooperatives is the remuneration of members' raw commodities, e.g., grapes. Indeed, in many instances cooperatives have been plagued by excess supply of grapes of low quality which could only be processed to make relatively low quality and cheap wines (Golan and Shalit, 1993). By producing low quality wines, producers face tougher competition, often leading to losses or level of profits not high enough to remunerate investments. Better members, i.e., members with raw commodities of better quality, often find more remunerative market outlets by leaving the cooperative, which remains with the worst (quality) members. By changing remuneration schemes, it may be argued, cooperatives and other producer's groups may improve the quality of the raw commodities delivered by their members, commanding higher prices for processed commodities and ensuring higher profit levels for members (Jarrige and Touzard, 2001).

Starting with the paper by Sexton (1986), it has been recognized that it may be better for the stability of a cooperative to use a non-linear pricing scheme. Recognizing the private information regarding different members' technology, Vercammen *et al.* (1996) take into account asymmetric information and show that a non-linear price could improve over the standard linear pricing even with asymmetric information. Bourgeon and Chambers (1999) show that when the bargaining power of a group of farmers corresponds to its relative importance in the farm population, the quantities produced are the first-best levels. Departures from equal sharing, i.e., redistribution of surplus, appear when the bargaining power of a group does not match its relative importance in the farm population.

Most of the contributions in this topic however consider the quantity choice problem and its optimal remuneration. Few contributions deal with quality remuneration in a cooperative setting. Lopez and Spreen (1987) consider the case of sugarcane cooperatives and compare two payment systems, a traditional and a new one. With the traditional payment, the processing costs are pooled and charged among producers proportionally to sugar production, while with the proposed new method some costs are assigned to individual producers according to their actual contribution to total operating costs. Lopez and Spreen show that their method may improve efficiency almost two-fold.

The sugar cane industry is indeed an instance in which the use of different payment systems is relatively well documented. There are indeed a number of different types of payments which may be separated into three main broad groups: fixed cane price systems, fixed revenue sharing systems, and variable revenue sharing systems (LMC, 2002). In the *fixed price system*, still present in very large sugar industries such as in China, India, and Pakistan, farmers

[1] In the early 90s, for instance, in Italy the market share of cooperatives in the wine sector was about 55%, in Spain 70%, and in France about 39-74% (Cogeca, 1998).

[2] ".. co-ops, which often lead to lowest-common-denominator wines - it's hard to control the quality of the grapes produced by members .." (Echikson, 2005: P4).

receive a fixed price per tonne of cane, with no premium or discounts paid for cane quality. Its key weakness is the lack of a link with the actual sugar price and thus it represents ".. a lopsided arrangement through which growers and millers do not share price risk.." (LMC, 2002: 2).

Under the *fixed revenue sharing system*, revenues are shared on the basis of a fixed percentage distribution between growers and millers. In this system, cane prices and mill margins are linked to sugar prices, but the fixed basis can weaken the incentive to improve technical performance and cane quality for both growers and millers. The *variable revenue sharing system* is the most sophisticated and is based on a formula ensuring that, beyond a benchmark level of cane quality and factory efficiency, growers are the residual claimants for cane quality improvements and millers cash-in the improvements in sucrose recovery at the factory. The system ensures that, at the margin, increased revenues from improvements in cane quality accrue to the grower, while millers capture any gains from milling efficiency (Larson and Borrell, 2001).

Touzard *et al.* (2001) consider the payment systems of the wine cooperatives in South-France and distinguish them into three main groups. The more *traditional system*, still used in one sixth of the surveyed cooperatives, is mainly based on sugar content, offering a linear price for sugar content based on the average price for the wine sold by the coop.[3] According to the authors, this first system is easy to manage but it does not seem to recognize the diversity of grapes delivered by the members and thus renders the cooperative a procurer of undifferentiated raw commodities.

A more common method, found in around half of the cooperatives interviewed, is used to *remunerate varietal grapes* such as Chardonnay, Merlot, etc. when they are particularly appreciated in the market. It uses a modified formula of the above mentioned method[4] and thus it applies a quality concept which is a priory based on technical criteria without much consideration for the market effects.

Last, a third set of methods is used in one-third of cooperatives, and it *differentiates across different plots* according to their contribution to the sales of the cooperative.[5] According to Touzard *et al.* (2001), this set recognizes the efforts made by the member, but it is more difficult to implement since it requires more information, and it leads to a greater inequality among members. In essence, it creates tensions among members to the extent that it introduces market forces into the cooperative.

[3] For the i^{th} producer, the remuneration is $R_i = v\,(P - C) \sum_j (q_{ij}\, s_{ij})$, where $v < 1$ is the coefficient for the transformation grapes-to-wine, P is the average price at which the cooperative sells the wine, C is the average cost for the transformation of the grapes, q_{ij} and s_{ij} are respectively the weight and the sugar content for the j^{th} plot.

[4] If we call A the first method, this second one is simply $A\, b_j$, with $b_j > 1$, for the premium varietal grapes.

[5] For the i^{th} producer, the remuneration is $R_i = \sum_j (q_{ij}\,(P_{ij} - C))$, where P_{ij} is the price at which the cooperative sells the wine coming from the j^{th} plot, C is the average cost for the transformation of the grapes, q_{ij} is the weight.

A different strand of the literature considers how to use the results of contract design under asymmetric information with a richer specification of the production technology. Bogetoft (2000), for example, shows how to use DEA estimates of the technology to design an optimal contract between a Principal and an Agent or a group of Agents. In a related series of papers, he exploits this idea under different information settings, that is with moral hazard and adverse selection, and with single and multiple output specification.

In the next section we represent the choices facing producers and we show how the efficiency parameter allow to distinguish among different producers and their choices. We then introduce the technology, showing how the efficiency parameter enters the primal representation of the technology which may be useful for the empirical implementation. We the proceed with the empirical estimation of the optimal pricing rule found in the theoretical section and expressed in terms of the primal parameters.

3 The model

A set of producers in a given region may sell their raw commodity into competitive markets or deliver it to a cooperative to be processed and marketed collectively.[6] After selling the processed product, e.g., wine, and subtracting processing and marketing costs, the cooperative pays the members according to the quantity and quality delivered. Suppose the N producers, $i \in I = \{1, .., N\}$, face the same production conditions and transform a vector of inputs $\mathbf{x} \in \Re^L_+$ into output $y \in \Re_+$ and $s \in \Re_+$, where y is a scalar indicating the production level in terms of quantity of output, i.e., total amount of grapes production per unit of land, and s is the output attribute, i.e., the components of grapes, like for example sugar content.[7] In this study we are interested in using a pricing schedule for grapes that takes into account their quality, i.e., sugar content. While a priory we do not impose any form on this pricing scheme, to give some generality we want to allow for the derivation of a possible non-linear pricing scheme. For this purpose, following what is standard in the literature on non-linear pricing (see, e.g., Wilson, 1993), we allow for producers' heterogeneity and introduce an efficiency parameter θ.

Producers are heterogeneous in the sense that some are more efficient than others, and are distinguished by their type or efficiency parameter θ. We assume that the type of the producer, θ, is related to how effectively outputs (y, s) are produced for a given input bundle $\mathbf{x}$. For empirical tractability, it is convenient to normalize the efficiency type over the support $\Theta \in (-\infty, 0]$. We can then specify the technology in terms of the output set $P(\mathbf{x}, s, \theta)$ defined as

$$P(\mathbf{x}, s, \theta) = \{y \in \Re_+ : \mathbf{x} \text{ can produce } y \text{ given } (s, \theta)\}.$$

[6] We consider the case of a cooperative but the analysis, with minor modifications, would remain valid with any processing firm buying raw inputs from a pool of upstream firms.

[7] In many wine cooperatives sugar content is the single most important quality attribute and the more the better to increase wine's quality. This may be as well the case with proteins content in milk for cheese production, sugar content in sugarcane cooperatives, etc.

We assume that for all $\mathbf{x}$ in $\Re^L_+$, $P(\mathbf{x},s,\theta)$ has the following properties:

$(P1)$ $P(\mathbf{x},s,\theta)$ is closed;

$(P2)$ $P(\mathbf{x},s,\theta)$ is a convex set;

$(P3)$ $(y,s) \in P(\mathbf{x},s,\theta) \Rightarrow (y\lambda, s\lambda) \in P(\mathbf{x},s,\theta), 0 < \lambda \leq 1.$

$(P4)$ $P(\mathbf{x},s,\theta) = P(\mathbf{x},s) + \theta$, with $P(\mathbf{x},s) \geq |\theta|$.

The first three properties are standard: $(P1)$ and $(P2)$ are regularity conditions allowing to use duality theory, while $(P3)$ allows outputs to be weakly disposable. The last property, $(P4)$, is the key to see the impact of the efficiency type on production: an increase in the type causes an additive increase in the output set, and $P(\mathbf{x},s) \geq |\theta|$ avoids the possibility of producing negative output.

The problem for a representative farmer may be represented as the following:

$$\max_{y,s,x} \quad \{p(s)y - \mathbf{wx} : y \in P(\mathbf{x},s,\theta)\},$$

where $p(s)$ is the unitary payment, which may be contingent on quality level s, received by the producer from the cooperative and $\mathbf{w}$ is the factor price for inputs $\mathbf{x}$. This program may be divided into two steps, the choice of the input bundle and the choice of the output bundle. We concentrate on the output side, in particular on the choices of quality by the farmers given the market prices or the payments offered by the cooperative. We thus represent each producer's technology by her restricted revenue function, $R(p,\mathbf{x},s,\theta)$,

$$R(p,\mathbf{x},s,\theta) = \max_{y} \quad \{py : y \in P(\mathbf{x},s,\theta)\}, \tag{1}$$

where p is the price received, s is the quality of the output, and θ the efficiency parameter which is assumed to be distributed according to a $G(\theta)$ strictly increasing and smooth on the support Θ. We also assume that producers are indexed negatively according to their efficiency, i.e., $R_\theta(p,\mathbf{x},s,\theta) < 0$. In addition, we assume that the efficiency parameter ranks both production and the marginal revenue effect of quality, that is $R_{p\theta}(p,\mathbf{x},s,\theta) < 0$ and $R_{s\theta}(p,\mathbf{x},s,\theta) < 0$.

Notice that in the restricted revenue function of eq. (1) we are considering the maximization over one output and hence we have the following

$$\begin{aligned} R(p,\mathbf{x},s,\theta) &= p\max_{y} \quad \{y : y \in P(\mathbf{x},s,\theta)\}, \quad (2) \\ &= pR(1,\mathbf{x},s,\theta), \end{aligned}$$

that is, the revenue function is the output price times the production function.

Producers could sell their products to a competitive market, in which the prevailing price would be p_m, independent of the actions taken by the producers or the cooperative. Analogously, it could be a situation in which the cooperative does not pay according to quality but it only offers a linear price given a minimum quality standard is reached. In any case, producers would choose quality s according to the following:

$$\Pi(\theta) = \max_{s} \{R(p_m,\mathbf{x},s,\theta)\},$$

which first order conditions for an interior solution are the following:

$$R_s(p_m, \mathbf{x}, s^*(\theta), \theta) = 0,$$

where $R_s(\cdot) = \frac{\partial R}{\partial s}(p(s), \mathbf{x}, s, \theta)$. The conditions for the choice of output are the following:

$$y^*(\theta) = R_p(p_m, \mathbf{x}, s^*(\theta), \theta),$$

and thus $\theta' < \theta$ implies that $y^*(\theta') > y^*(\theta)$.

Looking at the problem for the cooperative, we can suppose its management has the objective of maximizing the members' returns by the choice of payments.[8] In other words, the group of producers's management needs to design an optimal payment schemes to induce members to deliver a quality raw commodity to the cooperative according to market demand and at the minimum cost for them. The management is considering giving an extra payment to members in exchange for better deliveries, i.e., some quality requirements. We assume that s and y are observable and contractible, and thus the cooperative may offer a payment contingent on them, in particular on s. Since the optimal choice of s by the farmer depends on her efficiency parameter, the price is also a function of the efficiency parameter. In other words, $p(\theta) = \widehat{p}(s(\theta))$.

The management of the cooperative is planning to offer a set of specific contracts, $\{p(\theta), s(\theta) : \theta \in \Theta\}$, to the members. If these agree to participate, they would receive an increased price for the delivery of better raw commodities. Otherwise, they can sell their commodity to a competitive market or remain with the old pricing scheme,[9] in any case receiving $\Pi(\theta)$, their outside opportunity. Hence, a farmer of type θ will participate voluntarily in such a scheme iff:

$$R(p(\theta), \mathbf{x}, s(\theta), \theta) \geq \Pi(\theta). \tag{IR}$$

The cooperative's problem is to design a pricing scheme that rewards quality and breaks even. We assume that in the market for the processed commodity the cooperative receives a price $P(S(\theta))$ that is a function of the average quality defined as the following[10]

$$S(\theta) = \frac{\int_\Theta s\,(\theta)\, R(1, \mathbf{x}, s, \theta)\, dG\,(\theta)}{\int_\Theta R(1, \mathbf{x}, s, \theta)\, dG\,(\theta)}, \tag{3}$$

where $R(1, \mathbf{x}, s, \theta) = \frac{\partial R(p, \mathbf{x}, s, \theta)}{\partial p}$ is, by the envelope theorem, the optimal production level chosen by the producers and hence $\int_\Theta R(1, s, \mathbf{x}, \theta)\, dG\,(\theta)$ is the total

[8] See Appendix 1 for the results of a survey of wine coops whose Directors and managers where asked about their objectives.

[9] Wilson, in the context of Ramsey pricing, shows that it is possible to design non-linear prices (for quantity) that leaves no consumers worse off than with previous linear prices, i.e., Pareto-improving tariffs.

[10] To simplify, we consider this price to be net of variable processing costs and we assume there are no fixed costs for processing facilities. We are aware of the literature on the equilibria and different pricing schemes when there are fixed costs (see, e.g., Vercammen *et al.*, 1996), but adding them would complicate the problem without changing the main results and intuitions of this analysis.

production for the group of producers. Eq. (3) says that the average quality for the group of producers is the weighted average of the quality levels for different types, with the weight given by the production for each type. The revenue for the group of producers is then given by $P(S(\theta)) \int_\Theta R(1, \mathbf{x}, s, \theta)\, dG(\theta)$. On the other hand, the net processing revenue is redistributed back to members via the payments, and hence the total payments for the group of producers are $\int_\Theta p(\theta)\, R(1, \mathbf{x}, s, \theta)\, dG(\theta)$, i.e., the average price times the total production. The break even constraint is thus of the form

$$P\left(\int_\Theta s(\theta)\, R(1, \mathbf{x}, s, \theta)\, dG(\theta) \Big/ \int_\Theta R(1, \mathbf{x}, s, \theta)\, dG(\theta)\right) \int_\Theta R(1, \mathbf{x}, s, \theta)\, dG(\theta) = \tag{4}$$
$$= \int_\Theta p(\theta)\, R(1, \mathbf{x}, s, \theta)\, dG(\theta)\,.$$

We can simplify by assuming that

$$P = a + b\left(\int_\Theta s(\theta)\, R(1, \mathbf{x}, s, \theta)\, dG(\theta) \Big/ \int_\Theta R(1, \mathbf{x}, s, \theta)\, dG(\theta)\right) \tag{5}$$

so that this constraint can be rewritten as

$$a \int_\Theta R(1, \mathbf{x}, s, \theta)\, dG(\theta) + b \int_\Theta s(\theta)\, R(1, \mathbf{x}, s, \theta)\, dG(\theta) = \tag{BC}$$
$$= \int_\Theta p(\theta)\, R(1, \mathbf{x}, s, \theta)\, dG(\theta)\,.$$

The break-even constraint in (BC) ensures that the net processing revenues are redistributed back to members via the payments. Let $Q(\theta) = R(p(\theta), \mathbf{x}, s(\theta), \theta)$ be the producer's return given the price-quality contract structure. Then, we assume that the cooperative's objective function is to maximize members' total revenues, $N \int_\Theta Q(\theta)\, dG(\theta)$. We may represent the program for the cooperative as the following:

$$\max_{p(\Theta), s(\Theta)} \quad \left\{ N \int_\Theta Q(\theta)\, dG(\theta) : (BC), (IR) \right\}, \tag{6}$$

assuming there are N members. Because we are maximizing returns subject to a budget constraint, we can avoid introducing a reservation utility constraint except at the bottom of the efficiency distribution so that we can ensure everyone participates voluntarily.

3.1 First best

We assume that producers in the competitive market face a price that does not recognize the quality differentials.[11] The cooperative on the other hand

[11] In some cases agricultural products are paid according to their characteristics. For instance, when forward contracts are available, the commodities usually have to reach a minimum quality standard. With other contracts, the price may even be contingent on quality. However, for simplicity we assume this is not the case here. Having members' outside opportunities depending on quality would require a different analysis, since there would most likely be type-dependent outside opportunities.

is envisioning a pricing scheme that pays according to quality with a general pricing scheme that likely sorts out producers with different efficiency parameters. Quality is costly and to ensure voluntary participation it needs to be paid. However, even in the case of symmetric information, in which the cooperative can observe the member's type, the cooperative's optimal policy must accommodate for the break-even constraint to ensure that profits created are redistributed back to producers.

Although the problem in eq. (6) involves choosing p and s for each type, conventional maximization techniques can be used and hence we may write the first-best policy for the cooperative as the solution of the following Lagrangian

$$\max_{p(\Theta),s(\Theta)} \mathcal{L}$$

with

$$\mathcal{L} = N \int_{\Theta} \{Q(\theta) + \mu \left[aR(1,\mathbf{x},s,\theta) + bs(\theta)\, R(1,\mathbf{x},s,\theta) - p(\theta)\, R(1,\mathbf{x},s,\theta)\right]\} \, dG(\theta)\,, \tag{7}$$

where μ is a Lagrange multiplier for the budget constraint. The Lagrange multiplier μ gives the shadow value of the increase in payments to each member type from relaxing the constraint on the total revenues received by the group.

The management chooses p and s for each type, i.e., it chooses infinitely many $p(\theta)$ and $s(\theta)$.[12] Taking the first-order conditions for the choice variables and assuming interior solutions we can have the following

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial p} &= R(1,\mathbf{x},s,\theta) - \mu R(1,\mathbf{x},s,\theta) = 0, \quad \forall \theta && (8)\\
\frac{\partial \mathcal{L}}{\partial s} &= pR_s(1,\mathbf{x},s,\theta) + \mu\left((a + b\, s(\theta) - p(\theta))\left(R_s(1,\mathbf{x},s,\theta)\right) + \right.\\
&\qquad\qquad\qquad\qquad \left. + b\, R(1,\mathbf{x},s,\theta) = 0, \quad \forall \theta \right.\\
\frac{\partial \mathcal{L}}{\partial \mu} &= a\int_{\Theta} R(1,\mathbf{x},s,\theta) + b\int_{\Theta} s(\theta)\, R(1,\mathbf{x},s,\theta) - \int_{\Theta} p(\theta)\, R(1,\mathbf{x},s,\theta) = 0, \quad \forall \theta.
\end{aligned}$$

Notice that from the first of these equations we get that $\mu(\theta) = 1$, and if we substitute it in the second equation we get that $s(\theta) = -\frac{a}{b} - \frac{R(1,\mathbf{x},s,\theta)}{R_s(1,\mathbf{x},s,\theta)}$. Substituting this last equation in the third equation above, and assuming that the following is the unique solution, we obtain the following

$$\begin{aligned}
\mu(\theta) &= 1, && (9)\\
s(\theta) &= -\frac{a}{b} - \frac{R(1,\mathbf{x},s,\theta)}{R_s(1,\mathbf{x},s,\theta)},\\
p(\theta) &= -b\frac{R(1,\mathbf{x},s,\theta)}{R_s(1,\mathbf{x},s,\theta)}.
\end{aligned}$$

[12] Wilson (1993, ch. 4) derives the optimal tariff starting from the demand profile (a representation of preferences that keeps more information than the aggregate demand regarding consumers' heterogeneity), but he also shows its equivalent derivation using the calculus of variation and pointwise maximization.

The first equation in the system (9) says that the shadow value of the increased revenue for the cooperative is equal to one, i.e., for each additional dollar received by the group, its value is unitary. This is easy to see once we recognize that each dollar received is distributed back to members. The other interesting equation is the third one. Each member should receive a unitary payment for quality which is dependent on what the group gets from a unit of quality, i.e., the coefficient b, "corrected" by an adjustment factor which depends on the trade-off between quantity and quality. Indeed, the denominator is the marginal impact on the production level of an increase in quality, $R_s(1, \mathbf{x}, s, \theta)$, impact which is most likely negative, i.e., there is a trade-off between quality and quantity. This marginal impact is "weighted" by the production level $R(1, \mathbf{x}, s, \theta)$.

The third equation in the system (9) above says that if the denominator is negative, i.e., there is in fact a trade-off between quality and quantity, then the cooperative should pay members a greater price than the market unit price for quality. In words, if the technology relationships are such that an increase in quality calls forth a reduction in supply, then all producers are better-off when offered a price for quality that is higher than what the market would pay for quality. The higher the trade-off between quality and quantity and the higher should be the price for quality.

4 Empirical implementation

To implement the pricing scheme derived in the previous section, we pursue the following strategy. First of all, we take into account the heterogeneity among producers borrowing from the literature on efficiency analysis. Indeed, since a good deal of variability in the production choices is unaccounted for by the explanatory variables considered, we believe that the analysis cast in the framework of the efficiency literature can help in making the best use of the data available for the estimation, that is in explaining producers' heterogeneity. In the efficiency literature on stochastic frontiers the distance of each firm from the frontier is expressed as a composite error term: one, a symmetric component, is the standard white noise, normally distributed with zero mean, while the other asymmetric component reflects firm's inefficiency.

The dataset available is driving some of the choices for the empirical implementation. The data are provided by the "Istituto Agrario di San Michele all'Adige", located in the Northern Italian Alps. As we extensively explain in a section to follow, members of the cooperative that participated in the experimental study were implementing the agronomic practices suggested by the cooperative's agronomist, and responded to the economic incentives common to all members. Indeed, their production was paid according to the schemes normally implemented by the cooperative for its members. Given the nature of the data, to be described shortly, we find most appropriate to use a primal approach estimating a restricted production function.[13]

[13] An alternative would be to estimate the techology parameters via a dual approach, for instance using a revenue function or better a profit function, but this approach would be based

4.1 The estimation of the technology

In this section we represent the choices of the members of the cooperative and present the empirical strategy to estimate the technology. Given the data that are available, and the theory we derived earlier, in particular eq. (2), a production function estimation is the most suitable approach.

To proceed with the empirical implementation of the pricing rule derived in earlier sections, we can show that the asymmetric production function is additive as in the following

$$R(1, \mathbf{x}, s, \theta) = r(1, \mathbf{x}, s,) + \theta, \tag{10}$$

where $R(1, \mathbf{x}, s, \theta)$ is the restricted production function, and $r(1, \mathbf{x}, s,)$ and θ are its two components. Indeed, the additive structure of the production function is related to property $(P4)$ by the following

$$\begin{aligned} P(\mathbf{x}, s, \theta) &= \{y : R(1, \mathbf{x}, s, \theta) \geq y\}, \\ &= \{y : r(1, \mathbf{x}, s) + \theta \geq y\}, \\ &= \{y + \theta - \theta : r(1, \mathbf{x}, s) \geq y - \theta\}, \\ &= \theta + \{y - \theta : r(1, \mathbf{x}, s) \geq y - \theta\}, \\ &= \theta + P(\mathbf{x}, s). \end{aligned} \tag{11}$$

To be able to estimate the pricing rule derived earlier, we opt for a relatively simple functional form for $r(1, \mathbf{x}, s)$ like the following

$$r(1, \mathbf{x}, s) = \beta_0 + \frac{1}{2}\sum_l^L \sum_j^L \beta_{lj} x_l x_j + \sum_l^L \beta_l x_l + s \sum_l^L \beta_{sl} x_l + \beta_s s, \tag{12}$$

where x_l are the inputs, and s is the sugar content of grapes. Notice that $\beta_{lj} = \beta_{jl}$. With this functional form we have that

$$R_s(1, \mathbf{x}, s, \theta) = \frac{\partial r(1, s, \mathbf{x})}{\partial s} = \sum_l^L \beta_{sl} x_l + \beta_s. \tag{13}$$

Substituting this latter equation for the optimal quality level in (9) we have the following

$$\begin{aligned} s(\theta) &= -\frac{a}{b} - \frac{r(1, \mathbf{x}, s(\theta)) + \theta}{r_s(1, \mathbf{x}, s(\theta))}, \\ &= -\frac{a}{b} - \frac{\beta_0 + \frac{1}{2}\sum_l^L \sum_j^L \beta_{lj} x_l x_j + \sum_l^L \beta_l x_l + s \sum_l^L \beta_{sl} x_l + \beta_s s + \theta}{\sum_l^L \beta_{sl} x_l + \beta_s} \end{aligned} \tag{14}$$

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mostly on economic data, which on the inputs side were not available for this study.

and thus the optimal quality level as a function of the parameters to be estimated is the following

$$s(\theta) = -\frac{a}{2b} - \frac{\beta_0 + \frac{1}{2}\sum_l^L \sum_j^L \beta_{lj} x_l x_j + \sum_l^L \beta_l x_l + \theta}{2\left(\sum_l^L \beta_{sl} x_l + \beta_s\right)}. \tag{15}$$

Notice that the optimal quality level depends on the demand parameters via the term $-\frac{a}{2b}$. In addition, there is a "correction factor" which depends on the inefficiency term θ, and on the trade-off between quality and quantity as measured by $R_s(1, \mathbf{x}, s, \theta) = \sum_l^L \beta_{sl} x_l + \beta_s$. Since this latter is presumably negative, the correction factor is negative and increasing with efficiency. In other words, we should expect greater quality production the lower the trade-off with quantity and the greater the efficiency of producers.

In order to obtain the optimal pricing rule in eq. (9), notice that with an additive structure it becomes

$$p(\theta) = -b\frac{r(1, \mathbf{x}, s(\theta)) + \theta}{r_s(1, \mathbf{x}, s(\theta))}, \tag{16}$$

and thus we have that

$$p(\theta) = -b\frac{\beta_0 + \frac{1}{2}\sum_l^L \sum_j^L \beta_{lj} x_l x_j + \sum_l^L \beta_l x_l + s\sum_l^L \beta_{sl} x_l + \beta_s s + \theta}{\sum_l^L \beta_{sl} x_l + \beta_s}. \tag{17}$$

Notice that to estimate eq. (17) (and eq. (15)), we need an estimate of b, the unit price of sugar in the market, i.e., the marginal willingness to pay that can be inferred from the aggregate inverse demand curve for quality, and of a, the vertical intercept of the inverse demand curve for quality. Another important piece of information is related to θ, for which we get an estimate $\widehat{\theta}_i$ using the stochastic frontier approach we will introduce shortly. Moreover, for the quality s we use the optimal value computed with eq. (15). In addition, we need to estimate the coefficients of the asymmetric production function to get $\widehat{\beta}_0$, $\widehat{\beta}_{lj}$, $\widehat{\beta}_l$, $\widehat{\beta}_{sl}$, and $\widehat{\beta}_s$. Finally, notice that we compute the optimal quality level and the optimal pricing schedule based on the average input values, $\overline{x}_l$.

Using eq. (14), we can also notice that $\left(s(\theta) + \frac{a}{b}\right) = -\frac{r(1,\mathbf{x},s(\theta))+\theta}{r_s(1,\mathbf{x},s(\theta))}$, and so we obtain that the optimal pricing rule now becomes

$$p(\theta) = a + b\, s(\theta). \tag{18}$$

The optimal pricing schedule is a function of the optimal quality level, $s(\theta)$, and hence of θ, the inefficiency parameter to be estimated. Once one estimates the optimal quality level $s(\theta)$, eq. (18) above says that the optimal price schedule is a linear function of the optimal quality, where all parameters of the pricing schedule are those of the inverse market demand. In other words, it is worth noticing that the optimal price thus reflects the market preferences for quality, that is the inverse demand parameters (see eq. (5)). Thus in a group in which the objective for the management is to maximize members' welfare, the cooperative offers a price schedule that exactly matches that faced by the group itself on the market.

4.2 Econometric strategy

In this section we introduce the parametric estimation of the asymmetric production frontier introduced in eq. (12) using cross-sectional data. In general, we can specify the production frontier as the following (modified from Aigner, Lovell and Schmidt, 1976; Kumbhakar and Lovell, 2000)

$$R(1, \mathbf{x}_i, s_i, \theta_i) = r(1, \mathbf{x}_i, s_i; \beta) + \theta_i, \tag{19}$$

where $R(1, \mathbf{x}_i, s_i, \theta_i)$ is the maximum (scalar) output of producer i, $\mathbf{x}_i$ is the vector of inputs used by producer, s_i is the quality of production, and $r(1, \mathbf{x}_i, s_i; \beta)$ is the production frontier where β is a vector of parameters to be estimated.

In this formulation, $R(1, \mathbf{x}_i, s_i, \theta_i)$ is the maximum feasible value of $r(1, \mathbf{x}_i, s_i; \beta)$ if and only if $\theta_i = 0$. When $\theta_i < 0$, there is a shortfall of observed output from maximum feasible output and this provides a measure of the efficiency of type θ_i. Since in this deterministic frontier the entire shortfall of production is attributed to the (technical) inefficiency, to recognize that random shocks can affect production it is useful to use a stochastic production frontier like the following

$$R(1, \mathbf{x}_i, s_i, \theta_i) = r(1, \mathbf{x}_i, s_i; \beta) + v_i + \theta_i, \tag{20}$$

where $r(1, \mathbf{x}_i, s_i; \beta) + v_i$ is now the stochastic production frontier with v_i a standard noise component to incorporate the effect of random shocks on each producer.[14] We choose a stochastic frontier since the random error component allows to account for measurement errors and other random factors, such as weather and unobserved soil conditions, that are important in agricultural production like in grapes production for wine-making.

The stochastic frontier models thus acknowledge the fact that random shocks outside the control of producers can affect output and allow to estimate the parameters of the technology plus the inefficiency term of each producer. If the production frontier is quadratic as in eq. (10), we can write the following

$$R(1, \mathbf{x}_i, s_i, \theta_i) = \beta_0 + \frac{1}{2} \sum_{l}^{L} \sum_{j}^{L} \beta_{lj} x_{li} x_{ji} + \sum_{l}^{L} \beta_l x_{li} + s_i \sum_{l}^{L} \beta_{sl} x_{li} + \beta_s s_i + v_i - u_i, \tag{21}$$

[14] The alternative would be a deterministic frontier that while parametric, hence permitting to estimate the parameters β of the technology, would attribute all deviations from maximum production to inefficiency.

where v_i is the two-sided noise component and $u_i = -\theta_i$ is the nonnegative technical inefficiency component of the error term that guarantees that $R(1, \mathbf{x}_i, s_i, \theta_i) \leq r(1, \mathbf{x}_i, s_i; \beta)$.

We also want to take into account the possibility that some exogenous variables $\mathbf{z}$ may influence the efficiency of producers.[15] We thus specify the asymmetric component with the following

$$u_i = \gamma_0 + \sum_p^P \gamma_p z_{pi} + e_i, \tag{22}$$

where $p = 1, .., P$ are the exogenous variables that affect the technical efficiency of producers.[16]

In the composed error models it is usually assumed that the noise component is *iid* and symmetric, distributed independently of u_i. Even if u_i and v_i are distributed independently of x_{li}, the estimation of eq. (21) by OLS does not provide consistent estimates of β_0, since $E(\varepsilon_i) = -E(u_i)$, where $\varepsilon_i = v_i - u_i$, and does not provide estimates of producer-specific technical efficiency. In other words, while OLS estimation results for the coefficients besides the intercept are consistent, to have consistent estimates of β_0 and estimates of the producer-specific inefficiency terms u_i, other estimation methods are required, all based on specific distributional assumptions for u_i and v_i.

Maximum likelihood (ML) methods and methods of moments can be used. For both methods, distributional assumptions are needed for estimating both the parameters and the inefficiency terms. Different options are available, such as the half-normal, the exponential, the gamma, but the more common model is the Normal-Half Normal model.[17] Stevenson (1980) suggested a generalization of the half-normal specification, the truncated normal, that can be considered when the asymmetric error component has a systematic component, such as $\gamma_0 + \sum_p^P \gamma_p z_{pi}$, associated with the exogenous variables. Indeed, Kumbhakar, Ghosh and McGuckin (1991) suggested assuming that $u_i \sim N^+(\gamma_0 + \sum_p^P \gamma_p z_{pi}, \sigma_u^2)$, that is the one-sided error component representing technical inefficiency has a truncated normal structure with a variable mode depending on the $\mathbf{z}$'s. Assuming that $v_i \sim N(0, \sigma_v^2)$, $u_i \sim N^+(\gamma_0 + \sum_p^P \gamma_p z_{pi}, \sigma_u^2)$, and that u_i and v_i are distributed independently (but not identically), the parameters in eq. (21) can be estimated using MLE.[18]

[15] Notice that, as it is standard in the literature, we consider $\mathbf{x}$ to be a vector of variables that affect the frontier (maximal) level of output, while $\mathbf{z}$ a set of variables tha affect the deviation of output from the frontier, i.e., the technical inefficiency. Both $\mathbf{x}$ and $\mathbf{z}$ are considered exogenous, that is there is a lack of feedback from $\mathbf{y}$, the production, to $\mathbf{x}$ and $\mathbf{z}$ (Wang and Schmidt, 2002).

[16] Not including the intercept term, γ_0, in the mean may result in biased estimators (Battese and Coelli, 1995: footnote 3).

[17] Ritter and Simar suggests the use of simple distributions, such as the half normal or the exponential. Kumbhakar and Lovell (2000: 90) argues that ".. the choice between the two one-parameter densities is largely immaterial ..".

[18] Assuming that the regressors are independent of the error terms, while common a practice in the literature on stochastic frontier analysis, may be problematic when more than one

With the maximum likelihood estimation method, in the case of the Normal-Truncated normal distribution, the density function of $u \geq 0$ is

$$f(u) = \frac{2}{\sqrt{2\pi}\sigma_u \Phi(-\frac{\mu}{\sigma_u})} \exp\left\{-\frac{(u-\mu)^2}{2\sigma_u^2}\right\}, \tag{23}$$

where μ is the mode of the normal distribution, which is truncated below at zero, and $\Phi(\cdot)$ is the standard normal cumulative distribution. Since the density function for v is

$$f(v) = \frac{1}{\sqrt{2\pi}\sigma_v} \exp\left\{-\frac{v^2}{2\sigma_v^2}\right\}, \tag{24}$$

their joint density, assuming independence, becomes

$$f(u,v) = \frac{2}{\sqrt{2\pi}\sigma_u\sigma_v \Phi(-\frac{\mu}{\sigma_u})} \exp\left\{-\frac{(u-\mu)^2}{2\sigma_u^2} - \frac{v^2}{2\sigma_v^2}\right\}. \tag{25}$$

Letting $\varepsilon = v - u$, the joint density of u and ε becomes

$$f(u,\varepsilon) = \frac{1}{2\pi\sigma_u\sigma_v \Phi(-\frac{\mu}{\sigma_u})} \exp\left\{-\frac{(u-\mu)^2}{2\sigma_u^2} - \frac{(\varepsilon+u)^2}{2\sigma_v^2}\right\}, \tag{26}$$

from which we can obtain the marginal density by integrating u out of $f(u,\varepsilon)$ to get

$$\begin{aligned} f(\varepsilon) &= \int_0^\infty f(u,\varepsilon)\, du \qquad (27) \\ &= \frac{1}{\sqrt{2\pi}\sigma\Phi(-\frac{\mu}{\sigma_u})} \Phi\left(\frac{\mu}{\sigma\lambda} - \frac{\varepsilon\lambda}{\sigma}\right) \exp\left\{-\frac{(\varepsilon+\mu)^2}{2\sigma^2}\right\}, \\ &= \frac{1}{\sigma} \frac{\phi\left(\frac{\varepsilon+\mu}{\sigma}\right)\ \Phi\left(\frac{\mu}{\sigma\lambda} - \frac{\varepsilon\lambda}{\sigma}\right)}{\Phi\left(-\frac{\mu}{\sigma_u}\right)}, \end{aligned}$$

where $\sigma = \sqrt{\sigma_v^2 + \sigma_u^2}$ and $\lambda = \frac{\sigma_u}{\sigma_v}$ are estimated jointly with the technology parameters β, and $\phi(\cdot)$ is the standard normal density function (Kumbhakar and Lovell, 2000).

The log-likelihood function for a sample of I producers, recognizing that the asymmetric error term has a systematic component, is a simple generalization of that of the truncated normal model with constant mode μ being replaced by the variable mode $\mu_i = \gamma_0 + \sum_p^P \gamma_p z_{pi}$ (Kumbhakar and Lovell, 2000: 267). We thus have the following

output is considered for estimation, like in the case of our restricted production function. Moreover, when using non-experimental data it is possible that some problems of simultaneous equations estimation may in fact arise also with respect to inputs.

$$\ln L = K - I \ln \sigma - \sum_i \ln \Phi \left(\frac{\gamma_0 + \sum_p^P \gamma_p z_{pi}}{\sigma_u} \right) + \sum_i \ln \Phi \left(\frac{\mu_i^*}{\sigma^*} \right) - \frac{1}{2} \sum_i \frac{(e_i + \gamma_0 + \sum_p^P \gamma_p z_{pi})^2}{\sigma^2}, \quad (28)$$

where K is a constant, $\mu_i^* = \frac{\sigma_v^2 (\gamma_0 + \sum_p^P \gamma_p z_{pi}) - \sigma_u^2 e_i}{\sigma^2}$, $\sigma^{*2} = \frac{\sigma_\nu^2 \sigma_u^2}{\sigma_\nu^2 + \sigma_u^2}$, and $e_i = v_i - u_i = R_i(1, s, \mathbf{x}, \theta) - r_i(1, s, \mathbf{x}; \beta)$ are the residuals obtained from estimating eq. (21).

Using ML, once we obtain estimates of $e_i = v_i - u_i$, it is possible to obtain the information about u_i by using the conditional distribution of u_i given e_i (Jondrow *et al.*, 1982). For a Truncated normal specification, with $u_i \sim N^+(\mu, \sigma_u^2)$, and with the frontier production function defined directly in terms of the original units of production,[19] it is given by

$$f(u|e) = \frac{f(u, \varepsilon)}{f(\varepsilon)} = \frac{\exp\left\{ -\frac{(u - \mu^*)^2}{2\sigma^{*2}} \right\}}{\sqrt{2\pi}\sigma^* \left[1 - \Phi\left(-\frac{\mu^*}{\sigma^*} \right) \right]}. \quad (29)$$

Given that $f(u|e)$ is distributed as $N^+(\mu^*, \sigma^{*2})$, the mean (or the mode) can be used as a point estimate of u_i. Using the mean, given by

$$E(u_i|e_i) = \mu_i^* + \sigma^* \left[\frac{\phi\left(\frac{\mu_i^*}{\sigma^*} \right)}{\Phi\left(\frac{\mu_i^*}{\sigma^*} \right)} \right], \quad (30)$$

and noticing that we are working with the original units of production, i.e., not in log form, we can go from the point estimates of u_i to the estimates of the technical efficiency for each firm via the following

$$TE_i = \frac{\mathbf{x}_i \beta - \widehat{u}_i}{\mathbf{x}_i \beta}, \quad (31)$$

where $\widehat{u}_i$ is given by $E(u_i|e_i)$ (Battese and Coelli, 1988).

Notice however that regardless of which estimator is used, the estimates of the technical inefficiency are inconsistent and nothing can be done to overcome this problem with cross-sectional data (Kumbhakar and Lovell, 2000: 78). A possible solution to this problem comes from panel data analysis. Unfortunately, as we explain in the next sections, some of the data do not vary across years and so panel data estimation is not possible. In the next section we present the data used for the estimation and then the results of the ML estimation using a composite error model based on the truncated normal assumption of the distribution of the u_i error term.

[19] Battese and Coelli (1988, 1993, 1995) and Coelli (1996) derive the predictor for u_i and for the technical efficiency distinguishing between the case in which the production frontier is expressed either in the orignal units or in log form, e.g., Cobb-Douglas.

4.3 The data

To implement empirically the methodology presented in the previous sections we use data provided by the "Istituto Agrario di San Michele all'Adige", located near Trento, in the Northern Italian Alps. The mission of this experimental station is to investigate the best agronomic practices and varieties to match the potential of different production zones in the region and different trials are undertaken every year with this purpose.

The data we employ in this paper come from a study performed by the Istituto, on behalf of SAV, a wine cooperative, to investigate the productive potential of different varieties of grapes in the fields owned by members of the cooperative. SAV, the "Società Agricoltori Vallagarina", located in Rovereto, is a cooperative that transforms the grapes and sells the wine on behalf of members. It is a relatively small cooperative, with about 700 members and 700 ha (around 1,730 acres) of vineyards, selling on average 10,000 T. of wine every year, mostly Chardonnay (30%).

Since the late seventies, in an effort to improve the quality of its members' production, the cooperative has been investigating the different vineyards of its members, located at different locations, trying to match each production zone with the best varieties and agronomic practices. Indeed, using the information obtained in these studies, the cooperative offers consistent incentives and technical assistance to members to have their vineyards chosen and located in the areas that are the most suitable. This is an instance of the more general idea of *terroir*, that is the practice of taking advantage and highlighting the differences and peculiarities of each area in order to transmit them into the wines, so that every region may have its own specific wines, a relatively common practice in the European system of *appellation d'origine contrôllée* (AOC).

The data available for this study were collected during three years, 1994, 1995 and 1996 for a white grape variety, Chardonnay, and a red grape variety, Merlot.[20] These are not the usual experimental data, in the sense that they were not undertaken in the traditional experimental plots. Instead, the "experiments" were performed in the vineyards of the members. A sample of members was selected, and particular attention was given so to avoid those members known for using "extreme" practices, for instance too much production per ha or very high quality. Since the purpose of the experiments was to estimate the effects that the different production areas have on grape production, all farmers were provided with the standard technical assistance offered to members, and were hence suggested to follow the agronomic practices regarding labour, fertilizer, pesticides, etc. that were deemed suitable for their varieties and zone.

Therefore, vineyards located in similar areas and cultivated with the same variety were to be subject to the same agronomic practices regarding fertilizers, pesticides, labour, etc. Within every fields considered for the trials, the researchers of the Istituto could choose the trees that were the subject of all the measurement regarding pruning activities, production levels, grapes characteristics, etc. In addition, the grapes obtained were collected, analyzed and

[20] Data is available also for other varieties, but the number of observations is much smaller.

delivered to the cooperative, where they were paid like all other grapes, i.e., subject to the same remuneration scheme.

To summarize, members of the cooperative that participated in the experimental study were implementing the agronomic practices suggested by the cooperative's agronomist, and responded to the economic incentives common to all members. Indeed, their production was paid according to the schemes normally implemented by the cooperative for its members, which we describe in the following section. Given the nature of the data, as we argue in the section to follow, we find most appropriate to use a dual approach estimating a revenue function based on modified prices as we illustrate in the text. We now describe the data used in the estimation.

4.3.1 The remuneration scheme

SAV, the wine cooperative for which data are available for this study, in 1991 started to implement a remuneration scheme that together with the weight of grapes considered also sugar content, a scheme that is still in use today, even if with a partial modification.[21] Grapes are thus paid according to quantity and sugar content.

- Production per ha

The first parameter considered in the payment of grapes is the **production per ha**. Indeed, all cooperative members belong to an AOC area and thus produce grapes for appellation wines. To be eligible for AOC status,[22] however, members need to produce at most a certain amount of grapes per ha, specific for each variety and region. In the case of Merlot and Chardonnay, the two varieties under consideration, the limit in Trentino is at 150 quintals/ha.[23] In other words, all the production that is obtained in fields where the unitary yields is below 150 q/ha can be sold as AOC. If the production is above 150 q/ha, there is a downgrading of production. Indeed, if the excess production is within a 20% tolerance, corresponding to 30 q/ha, then it is only partially downgraded and awarded a (partially) lowered payment. However, if the total production per hectare is above the ceiling plus the tolerance, i.e., above 180 q/ha, then it cannot be sold as AOC and gets a more substantive downgrading and price reduction, since it can be sold only as table wine.

In the SAV cooperative, in particular, if the production of a member is within the limit of 150 q/ha, the price paid per quintal of grapes is depending only on its sugar content, as will be shown below. If production per ha, however, is above this limit, the member incurs into a penalty. Indeed, if production y is within the limit plus the 20% tolerance, that is if $150 < y \leq 180$ q/ha, then the quantity of grapes within the 150 q/ha limit is paid in full while the grapes above

[21] Before 1991, SAV used to pay only a fixed price for unit of grapes.

[22] AOC wines usually obtain higher prices compared to non-AOC or so so called "table wines". These latter receive EU market support through the transformation to alcohol for industrial use, i.e., distillation, either on a voluntary or compulsory basis.

[23] A quintal is 100 kilograms or 0.1 ton.

the limit are paid only half the sugar-related price. Moreover, if the production per ha is higher than the limit plus the tolerance, however, then the penalty is higher: *all* the production is paid only half of the price based on sugar content. To summarize, we have the following

$$R_{ij} = \begin{cases} p_j(s_{ij})\, y_{ij} & if\ y_{ij} \leq 150\ q/ha, \\ p_j(s_{ij})\, 150 + (y_{ij} - 150)\, \frac{p_j(s_{ij})}{2} & if\ 150 < y_{ij} \leq 180\ q/ha, \\ \frac{p_j(s_{ij})\, y_{ij}}{2} & if\ y_{ij} > 180\ q/ha, \end{cases} \tag{32}$$

where R_{ij} is the revenue per ha of firm i for the delivery of the grapes of variety j, $p_j(s_{ij}) = r_{ij}\, s_{ij}$ is the price received for unit of grapes, r_{ij} is the unit price of sugar for the individual member, s_{ij} is the sugar content for the individual member, and y_{ij} is the grapes production (weight) per ha.

- Sugar content

Regarding sugar content, the unit price, i.e., the Euro (Italian lira in 1994-1996) per unit of sugar content (measured in degrees Babo), is a function of sugar content delivered by a member compared to the average sugar content of all the members of the cooperative. Indeed, after all grapes are collected and transformed into wine, the cooperative computes the mean sugar content, call it $\overline{s}_j$, which is specific for each grape variety j. Each member production, i.e., her sugar content, is then compared to the cooperative mean, and receives a premium if the sugar content is above the average, or a penalty if it is below the average. More formally, the pricing scheme for sugar content can be summarized with the following

$$r_{ij} = \overline{r}_j + (s_{ij} - \overline{s}_j)\, \tau_j, \tag{33}$$

where r_{ij} is the unit price of sugar for the individual member i for the grape of variety j, $\overline{r}_j$ is the unit price of sugar when grapes have a sugar content equal to the mean of the cooperative, s_{ij} is the sugar content for the individual member i for the grape of variety j, $\overline{s}_j$ is the cooperative average sugar content for grape j, and τ_j is the premium (penalty) for unit of content above (below) the cooperative mean.

In table 1 we report the details of the remuneration scheme for Chardonnay and Merlot over the different years as established by the SAV's Board of Directors. For example, in 1994 the mean sugar content for Merlot grapes delivered by members to the cooperative was 17° Babo (column A).[24] The payment for grapes with such sugar content was 86,207 Italian Liras (column B), or 44.52 Euro (column C) per quintal of grapes, corresponding to $\overline{r_j} = 5{,}071$ Liras per degree Babo (column D). In case the sugar content of grapes was different from the mean, the premium (penalty) was 70 liras per tenth of degree Babo (or 700 liras per degree, column E).

[24] Both Babo and Brix degrees refer to the sugar content of grapes juice. 1 degree Babo is equivalent to 0.85 degree Brix.

For instance, if the sugar content of a member in 1994 for Merlot was 16.5° Babo, and hence below the cooperative mean, the amount received for each degree Babo was reduced to $r_{ij} = 5,071 - (0.5 * 700) = 4,721$ liras per degree. This would translate into a remuneration of $16.5° * 4,271 = 77,896$ liras (or 40.23 Euro) per quintal of grapes.

From table 1 it is possible to notice that SAV paid a premium for sugar content above average and imposed a penalty for sugar content below average in the period from 1991 until 1999. Starting from 2000, the scheme allowed only for penalties, i.e., a discount for sugar content below average, and the premium is not paid any longer.[25]

It is also important to notice that members of the cooperative know the pricing mechanism in advance but at the time they make production decisions - from the winter pruning up to the delivery of the grapes to the cooperative's premises - they in fact do not know exactly whether they will receive a bonus or a penalty. Indeed, this aspect depends on how all members perform. In other words, all members deliver different lots of grapes to the cooperative; the cooperative evaluates all lots of all members; for each type of grapes the cooperative finds the average sugar content and the economic value of the average sugar content; for each lot/member, the penalty or premium is finally determined. The time from harvest to the final payment received by the member is about one year, during which the cooperative produces the wines and sell them into the market. During this time period the producers receive part of the total sum that they are finally awarded for their grapes, which vary according to the market price received by the cooperative.

4.3.2 Input and output data

Given the nature and the purpose of the trials, the data that are available are mostly primal, i.e., in physical quantities. The price schedule explained above allows the computation of the revenues per ha that each member received given her production per ha and sugar content. However, no information is available regarding input prices, and on the input quantities little information can be gathered regarding agronomic practices such as the use of fertilizers, pesticides, water, etc. Indeed, as already explained, the purpose of the trials was to investigate the potential of different locations-varieties combinations in terms of yields and quality attributes. Therefore, on the input side, the data we have available was intended to describe different locations, and are the following

- altimetry,

- the number of vines per hectare, which is fixed in the short run given that vines stay planted for many years,

- the depth of the roots, a measure of the depth of usable soil, a categorical variable going from a minimum of 1 to a maximum of 3,

[25] According to the SAV agronomist, "... over the years members steadily increased sugar content up to a level that the market could not remunerate it any more...". Thus the decision to allow for a constant unit price, i.e., not a premium any more, for sugar content at or above the cooperative mean, but to give a discount for sugar content below the mean.

- the water reservoir, a measure of the water holding capacity, in the range 1-4,

- total calcium, starting from a minimum of 1 to a maximum of 5,

- skeleton, a categorical variable (1-4) for the presence of rocks in the soil,

- internal drainage, a categorical variable from 1 (bad) to 5 (too much),

- external drainage, a categorical variable from 1 (slow) to 3 (a lot).

Only few variables were more "in the control of the producers", and thus represented some choices by them, such as

- the number of buds per branch, a result of the pruning intensity,

- irrigation, a dummy for the presence of irrigation,

- cultivated, a dummy for the presence of grass or cultivated land between the vines.

Some descriptive statistics for these variables are reported in table 2A and 2B. Notice that for Chardonnay there are more observations: a total of 648 against 337 for Merlot over the three years.[26] On average, Chardonnay trials were conducted on higher fields compared to Merlot: the average height above the sea level was around 260 meters against above 200 for Merlot. The number of vines per hectare was higher for Chardonnay, around 3200, compared to 2700 for Merlot. This latter variety, however, presented more buds per branch over the years. For the roots depth, water reservoir and total calcium, there were not significant differences between the two varieties.

We also have data on weather conditions, but it is coming from a unique meteoric station, and so we have only variation over the years. As it is standard practice among practitioners, we consider this data for the last 40 days before harvest time. Since this latter is different for the two varieties,[27] we in fact have different data on weather conditions between the two varieties. The information available for weather conditions are related to the humidity and the temperature, measured as the average of the 40 days considered. In addition, rainfall, radiation, hours of sun, and temperature excursions, are all considered as the total summation over the last 40 days before harvest time (tables 2-A and 2-B).

For Chardonnay, being the pre-harvest seasons anticipated 2-3 weeks in Summer time, they were on average hotter, with more radiation, hours of sun, and higher temperature excursions. For Merlot, average humidity and rainfall were higher in 1994 and 1995 compared to Chardonnay. The year 1994 was particularly rich in rainfall for both varieties.

For the grapes obtained in the different fields, we have information on

- production per hectare,

- sugar content (measured in degree Brix),

- tartaric acid,

- malic acid,

[26] The number of observations changes among variables and across years because of missing and incomplete data.

[27] On average, harvest time was the first week of September for Chardonnay, and the third week of September for Merlot, with a lag between the two varieties of 12-18 days, depending on the year.

- potassium,
- pH,
- total acidity.

Over the period 1994-1996, Merlot grapes show higher pH but less total, tartaric and malic acidity. Potassium content is higher in Merlot than Chardonnay (tables 2-A and 2-B).

We pay a closer look at production and sugar content, since they are the two most important aspects of grapes production for our empirical implementation of the pricing scheme. Overall, Merlot is more productive in terms of both grapes production and sugar content (figures 1 and 3). Considering the production per hectare of grapes over the entire period, Merlot is statistically more productive than Chardonnay (1% significance level (s.l.)),[28] but in 1995 there were no statistically significant differences between the two varieties (figure 1). The year 1996 appears to have been the most productive year for both varieties (figure 2), with Merlot reaching an average of 22 tones per hectare (up from 14 in 1995) and Chardonnay reaching 18 tones/ha (up from 13 in 1995).

Over the period 1994-1996 and for each year considered, Merlot has statistically significant more sugar than Chardonnay (figure 3), with a significance level of 1% (except in 1994, when s.l.=5%). Opposite to the case of production per hectare seen above, however, 1996 is the year with the least sugar content (figure 4 and tables 2-A/B). In other words, in 1996 the data show a very high production of grapes but with lower sugar content: Merlot contains 19.8 degrees Brix, down from an average of 20.5 in 1995, while for Chardonnay sugar content in 1996 was 19.2° Brix, down from 19.9 in 1994.

As explained in the previous sections, we need to estimate a composite error model where some variables $\mathbf{x}$ affect the production possibilities while some variables $\mathbf{z}$ affect the technical efficiency. With this distinction in mind, we partition the available data in the following fashion: y grapes production, s sugar content in ° Brix, x_1 the number of buds per branch, x_2 total acidity, x_3 pH, x_4 tartaric acid, x_5 malic acid, x_6 potassium, z_1 altimetry, z_2 the number of vines per hectare, z_3 the water reservoir, and z_4 total calcium.[29]

4.4 The endogeneity problem

Agronomic reasons suggest that, among the set of variables that are available and can be used to estimate the production function in eq. (12), one needs to pick the set of exogenous regressors that influence the yields, among these the variables that could be endogenous, and thus a set of instruments for the endogenous variables. It is reasonable to expect that s, the quality level, is

[28] The figures 1-4 show kernel estimates. To test the differences between cultivars or years we performed the Mann-Withney test of equality of medians and the Kolmogoroff-Smirnoff test of equality of distributions. Results of the tests are reported in the kernel figures. All figures and tests were prepared using Stata 7/SE.

[29] Notice that we have information on the depth of the roots and scheleton as well, but these two variables are actually related to the water holding capacity. Indeed, their correlation coefficients, both significant, were 0.72 and -0.69 respectively. They hence were omitted to limit collinearity problems and the number of parameters to be estimated.

endogenous. It is quite well known among practitioners, even though to the best of our knowledge not explicitly documented, that there might be a trade-off between quality and quantity and that producers, when taking their production decisions, may decide on the quantity and quality level simultaneously.

A possible instrument for the quality choice s is the lagged price that producers received for the grapes. For this reason, we need to consider the prices that producers face when making their producing decisions. In other words, we need to take into account that the cooperative under consideration is actually using a remuneration scheme which depends (already) on quality - sugar content - but also on the production level.

To give explicit consideration to the remuneration schedule faced by the producers member of the cooperative, we need to take into account that the data generating process that underlies the information available for the estimation is not the one for the usual competitive price taking behavior. In other words, producers face a downward-sloping demand curve, i.e., a non-linear pricing schedule, and thus we follow an intuition put forth by Diewert (1974) to deal with non-competitive situations using duality theory.

In addition, we want to emphasize that the price discrimination along the quantity dimension is not really a choice of the cooperative. In other words, the cooperative is not using quantity restrictions as a way to exercise monopoly power. This cooperative, like many others in the area, is operating under the AOC system, with the quantity restrictions exogenously imposed on the producers - and hence the cooperative - who want to sell their wine with the appellation. Given the exogenous quantity restrictions, the cooperative tries to maximize members' welfare providing incentives for quality to capture consumers' willingness to pay for quality wines.[30] In addition, we are considering Merlot and Chardonnay, two varieties that are pretty common in many other places in the world and so have plenty of substitutes.[31]

Moreover, to deal with the price being dependent on the quality level, and to be consistent with the theoretical part of this study, we would use a restricted revenue function where we represent the optimal quantity choice given the quality choices of a representative member with the following

$$\begin{aligned} R(p(s,y),\mathbf{x},s,\theta) &= \sup_y \left\{ p(s,y)\, y : \ y \in P(\mathbf{x},s,\theta) \right\}, \\ &= p(s,y^*)\, y^*, \end{aligned} \tag{34}$$

where y^* is the optimal choice for grapes production, and $p(s,y)$ is the price received for unit of grapes, which depends on s, the sugar content for the indi-

[30] In the discussions with the cooperatives' management in Trentino, it emerged that their interest is in devising an incentive scheme to pay for quality (not only sugar content). They never mentioned or discussed the need for quantity restrictions or the like.

[31] Different may be the case with local varieties, common in the Trentino region as well, but which we not consider here. The choice of quantity restrictions by the AOC governing body, however, could be seen as a way to restrict output, but we think this is a different matter from the one modeled in this study, in which the output restriction could be seen as an imperfect way to obtain higher quality from producers.

vidual member, and recognizes that in our empirical setting it is also depending on y, the grapes production.

To deal with non-competitive situations using duality theory, Diewert (1974) argues that when the output set is closed and convex and if the pricing schedule is differentiable at y^*, the objective function in eq. (34) can be linearized with respect to y around the observed production choice vector y^*. This linearized version will be tangent to the production surface at y^*, i.e., it will be a supporting hyperplane to the convex output set when the producer is monopolistically optimizing, or more specifically for our case, when facing a non-linear pricing schedule. It is then possible to apply the well known duality results and employ the usual econometric techniques. In other words, we have the following

$$\begin{aligned} \sup_y \{\widetilde{p}\, y : \ y \in P(\mathbf{x}, s, \theta)\} &\equiv \widetilde{R}(\widetilde{p}, \mathbf{x}, s, \theta), \\ &= \widetilde{p}\, R(1, \mathbf{x}, s, \theta), \end{aligned} \tag{35}$$

where $\widetilde{p} = p(s, y^*) + p'(s, y^*)\, y^*$ is the marginal revenue[32] of the producer for her choice of output level, $\widetilde{R}(\widetilde{p}, \mathbf{x}, s, \theta)$ is the producer's true (restricted) revenue function, and $R(1, \mathbf{x}, s, \theta)$ is the producer's (restricted) production function. Notice that the second line of eq. (35) above comes from the linear homogeneity in prices of the (restricted) revenue function.

The estimation of the restricted revenue function can proceed as usual, i.e., either estimate the revenue function or the revenue function together with the supply equations derived by using Hotelling's lemma, replacing the observed price by the appropriate marginal prices (Diewert, 1982). In our case, the price schedule that each member faces represents her demand schedule and hence it is exogenous allowing the dual estimation of the revenue function.[33]

Referring to the price schedule facing each producer and represented in eq. (32), notice that the pricing rule is not everywhere differentiable. We thus consider piecewise differentiability and consider a pricing rule that is almost everywhere differentiable. In particular, consider that only at $y = 150$ q/ha it is not differentiable, but the right and left derivatives do exist.[34] The marginal revenue schedule for the producers is the following[35]

$$\widetilde{p}_{ij} = \begin{cases} p_j(s_{ij}, y_{ij}) & if\ y_{ij} \leq 150\ q/ha, \\ \frac{p_j(s_{ij}, y_{ij})}{2} & if\ y_{ij} > 150\ q/ha. \end{cases}$$

[32] Diewert (1974 and 1982) actually calls it the *marginal price or shadow price* of output.

[33] In suggesting this approach for a monopolist, Diewert noticed that from an empirical point of view its drawback is that the slope of the demand curve facing the monopolist must be known to the outside observers of the market. In our setting, however we have the knowledge of the demand curve, i.e., the pricing schedule, that each firm is facing so that the appropriate marginal prices can be calculated. To the best of our knowledge, this approach originally suggested in Diewert (1974) has never been applied.

[34] However, in the actual dataset used for this study no observation was found at exactly 150 q/ha.

[35] See appendix 2 for the derivation.

For the information on the prices $p_j(s_{ij}, y_{ij})$, one could assume that producers have perfect foresight. Indeed, one could postulate that besides the "mechanics" of the pricing scheme producers know also the mean sugar content for the cooperative, $\overline{s}_j$, and the unit price of sugar for grapes with a mean sugar content, $\overline{r}_j$. In addition, it could be assumed that each member does not behave strategically with respect to the group and that she cannot influence the group mean.[36]

To conclude, to take into account the endogeneity problem of sugar content one could instrument it using the lagged price. Indeed, if s_{jt} is the optimal choice of firm j at time t, a possible instrument could be $\widetilde{p}(s_{jt-1}, y_{jt-1})$, the marginal price received by firm j at time $t-1$ for producing quality s_{jt-1} and production level y_{jt-1}. One may argue that producers' decisions are related to prices they received the previous year, but which are predetermined.[37] Using this instrument it is possible to take into account the endogeneity problem using the General Method on Moments with a composite error model (Olson, Schmidt, and Waldman, 1980).

5 Results

5.1 Estimation and technical efficiency

We report first the results of the ML estimation of the composite error model in eq. (28) for the **pooled data**, i.e., for both cultivars and for the three years considered (table 3A). Notice that quite few of the coefficients are significant, including that on the sugar coefficient which is negative and significant at the 10% s.l. Two of the coefficients of the explanatory variables for the inefficiency term, the **z**'s, appear significant. At the bottom of the table we report the estimates of the variance for both error components, σ_v^2 and σ_u^2, which shows a clear predominance of the variability for the symmetric component σ_v^2.

We also report the estimates of the technical inefficiency expressed in original units, that is $\widehat{u}_i$ calculated by eq. (30), in table 4. Notice that since we are using the production data in the original units, i.e., not in log form, the values reported are expressed in terms of reduced production. Thus the most inefficient unit is almost 32 quintals of grapes less efficient than the frontier. To cast the results on the technical inefficiency in terms more familiar for the reader, that is in percentage form, we report also the estimates of eq. (31) in table 4. Notice that the average efficiency is about 91%, with the most inefficient producer being only 75%-efficient compared to the producers on the frontier.

[36] In models of moral hazard and relative performance, it is common to exclude the individual performance from the computation of the mean to which she is benchmarked to (see, e.g., Bogetoft, 1995). Here we do not have all the observations that would be needed to compute the group's mean. In addition, notice that here we do not model a moral hazard problem.

[37] In fact, as we explained earlier, producers receive the final payment of grapes delivered in the year $t-1$ to the cooperative at around the harvest time of year t. The possible problem with this price, however, is that it could influence also the choice of production level.

We calculate (and report) the values in original units since $\widehat{\theta}_i = -\widehat{u}_i$ and hence we can estimate the optimal quality choices in eq. (15), in particular the second term in the right hand side. Indeed, we also report the results for the estimation of the "correction factor"[38] for the demand parameters, i.e., for the first part of the right hand side of eq. (15), and that takes into account the production technology and producers' heterogeneity. Notice that on average this factor has a value of -15.4° Brix, going from a minimum of -15.9 to a maximum of -14.9. Considering that on average the sugar content actually chosen by the producers in the sample is about 20° Brix, it means that the correction factor is about 75-80% of the actual choices, with a difference between the most and the least efficient producer of the order of 5-6%.

We estimate also the **pooled data with dummies** for the year and the cultivar (second set of columns, table 3A). The dummies for both years and the cultivar are indeed significant. Notice also that some of the results are different. First of all, more explanatory variables, i.e., the **x**'s, are now significant. Three of the coefficients on the **z**'s, the variables explaining the inefficiency, are now negative and significant. In addition, the symmetric component σ_v^2 is much lower, while slightly higher appears the asymmetric one, σ_u^2.

Of particular interest are the results on $\widehat{u}_i$, the inefficiency term in the original units. The mean value is now higher, around 47 quintals, going from around zero to almost 126 quintals. Thus taking into account the heterogeneity across years and cultivars sensibly decreases the technical efficiency of the producers under consideration. This translates into a slightly bigger correction factor in eq. (15) - its average value is about -15.8° Brix - but more importantly with more variability, going from -17.5 to -12.9 ° Brix (table 4). In terms of technical efficiency, this corresponds to about 83% of mean technical efficiency, going from a minimum of 49% to 100% (table 4).

Comparing across the two specifications, with and without dummies, we can indeed see the differences by looking at the distributions of the efficiency scores, i.e., their kernels (see figure 5). The figure on the left shows the model with no dummies for the years and cultivar, while the one on the right is estimated with those dummies. As can be seen, the model without the dummies has a distribution with a mode above 0.9 and it is not very dispersed. On the contrary, the model with the dummies has a mode around 0.8 and it is more dispersed. Moreover, notice that the efficiency score for Chardonnay[39] appears bimodal in both model specifications. In figure 6 we report the efficiency distribution across years (again for both model specifications, with and without dummies). As in the previous figure, the major difference is between the model with and

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[38] We refer to the following expression appearing in eq. (15), which we label *correction factor*: $CF = \frac{\widehat{\beta}_0 + \sum_l^L \sum_j^L \widehat{\beta}_{lj}\overline{x}_l\overline{x}_j + \sum_l^L \widehat{\beta}_l\overline{x}_l + \widehat{\theta}}{2\left(\sum_l^L \widehat{\beta}_{sl}\overline{x}_l + \widehat{\beta}_s\right)}$, where $\widehat{\beta}$ is the estimated coefficient and $\overline{x}$ is the mean of the variable across observations.

[39] Notice that we estimate the pooled sample for both cultivars and all years, thus imposing the same common technology frontier, but we actually show the results distinguishing for the two different cultivars (in figure 5) or the different years (figure 6).

without dummies, where in this latter the mean technical efficiency is higher and less dispersed.

We perform the same analysis, that is estimating the technology and the technical efficiency, after dividing the pooled data into the two cultivars, Chardonnay and Merlot. We report first the results of **Chardonnay**, starting with the model in eq. (21) - see table 3A, last columns - and then including also the dummies for the years (table 3B, first column). Although the data available allow for more observations than Merlot, the estimation of the model for Chardonnay appears more problematic. Indeed, when using the model without the dummies for the years, convergence could not be obtained.[40]

However, when estimating the model **Chardonnay with dummies** for the year, results appear quite similar to the pooled sample, even though fewer **x**'s variables appear significant. Among the **z**'s, vines density and water reservoir appear negative and significant. Technical efficiency results are quite similar to the pooled sample with dummies model: rather low (on average 82%), leading to a correction factor slightly bigger (-15.8) and more dispersed (from -17.7 to -11.9 ° Brix). In figure 7 we report the distribution of the technical efficiency scores for Chardonnay with both model specifications, with the already explained caveats for the results of the model without dummies.

Considering **Merlot**, in the estimation without the dummies for the years, none of the explanatory variables for the inefficiency term **z**'s are significant (table 3B). The inefficiency term in original units, $\widehat{u}_i$, is quite low (around 15.6 q), corresponding to an average technical efficiency of around 92%. However, the correction factor is quite similar to the values already seen, that is an average of -15.2 ° Brix, and with a limited range, going from -15.7 to -14.7 ° Brix (table 4).

When estimating **Merlot with dummies** for the years, fewer of the explanatory variables **x**'s are significant, even though the 1996 dummy is significant at the 5% level. Of the **z**'s variables affecting the inefficiency term, only the density of vines is significant and negative (table 3B). The inefficiency is now larger, reaching an average of 23.4 quintals of grapes, corresponding to a mean technical efficiency of about 89%. The correction factor is slightly bigger, about -15.6 ° Brix, going from -16.32 to -14.9 ° Brix. In figure 8 we report the technical efficiency score distributions for Merlot across the years and for the two model specifications. The distributions appear rather similar between the two specifications, with 1996 having the highest efficiency and 1995 the lowest.

5.2 The optimal quality choices

In this section we report the results of the simulation for the optimal quality choice, that is $s(\theta)$ of eq. (15). For this simulation we need an estimate of the

[40] It appears that the Hessian matrix is singular and thus not invertible impeding the classical Newton-Raphson optimization algorithm to find a solution to the maximum likelihood problem. To derive the standard errors a generalized inverse (produced by dropping one or more rows/columns) is used instead for the variance covariance matrix. This explains why the standard errors for the **z**'s variables for Chardonnay are missing (table 3A, last column).

demand parameters a and b. To make the simulated quality choices comparable to the choices actually made by the producers in the SAV cooperative from which the data were originated,[41] for the value of b we use the value of sugar (euro per degree Brix) that was associated with the average content for the specific year and cultivar, as can be inferred from table 1 discussed earlier.[42] Using the pricing scheme actually implemented we obtain also some starting values for a needed to calibrate the simulation.[43]

We report the different cases for the parameters a and b in table 5. For each variety, we take the values of a and b that can be inferred from the payments made by the SAV cooperative (table 1) in those years. We calculate the average across years of the parameter - either $\overline{a}$ or $\overline{b}$ - and then create two other different values for each parameter by adding and subtracting 50%.[44] In this fashion we can construct 3x3=9 cases, reported in table 5. We thus report the 9 different cases resulting from the different combinations of the values for parameters a and b. We also report the same cases for the pooled data sample, where we take the average of Chardonnay and Merlot mean parameter values and then add/subtract 50%. Notice that for all samples, *case 5* has exactly the parameter values that can be inferred from table 1 (actually the mean across years).

In tables 6A and 6B we report the results for the quality choices, comparing the actual choices and those simulated with the 9 cases explained above, again distinguishing for the pooled, Chardonnay and Merlot samples. In all samples, we can notice similar results. First of all, in almost all instances the average value of the simulated optimal choices of sugar is higher than the actual choices. In *case 5*, when the parameter values for a and b are similar to those obtained from the payments made by the cooperative, the simulated quality choices are somewhat around 50% higher than the actual choices. The closest simulation to

[41] Notice also that even if useful for comparison purposes, this is just an approximation. The average sugar value obtained in this fashion indeed is calculated from the total revenues for the wines produced (for each variety) minus the costs born by the cooperative to transform the grapes and selling the wines, divided by the total sugar content produced by all members. We also refer here only to a subset of the members, those for which valid experimental production data is available.

[42] In table 1 in fact the values refer to degrees Babo. The b value obtained in this fashion is 3.05, 4.79 and 4.91 Euro/degree Babo for Chardonnay respectively for 1994, 1995, 1996; and 2.62, 3.51 and 4.75 for Merlot in the same years. Similar values were obtained in a hedonic study of red grapes in the nearby province of Verona. Perali (1996) estimates the marginal price for the quality charactersitics of the grapes (Corvina, Rondinella and Molinara) used for Bardolino, a red wine produced in Verona that is usually is not aged but drank quite young. Using data for the period 1983-1993, he reports that the marginal price for sugar content was about 2.65 Euro per ° Babo at 1993 constant prices.

[43] Given the sugar content of grapes and the pricing scheme of the SAV cooperative, we calculate the unit price of the grapes as a function of sugar content. We then calculate the vertical intercept by interpolation to find an estimate of a. We obtain values in the range $a \in [-128, -94]$: for Chardonnay, -102, -121 and -122 respectively in 1994, 1995 and 1996; for Merlot, -105, -94 and -128 in the same years.

[44] For instance, the average value of a across years for Chardonnay is $\overline{a} = -115$ and so we obtain:
$a_1 = -(115 * 50\%) = -58;$
$a_2 = \overline{a} = -115;$
$a_3 = -(115 * 150\%) = -173.$

the actual choices is the one with the parameters of *case 9*, where the average of the optimal quality choices is around that of the actual choices. This is a result common to all samples and model specifications.

In addition, in all cases the simulated quality has lower variability than the actual quality choices. This is an expected result, since in the simulation we "take away" the variability coming from the symmetric error component σ_v^2, while we are left only with the asymmetric component σ_u^2 via the estimate of the technical efficiency, $\widehat{\theta}$, that enters the correction factor in eq. (15).

A clearer picture of the results can be formed by looking at the distribution of the actual and simulated quality choices. In figures 9-10-11 we report the kernel estimates of the distributions for the actual choices, those of *case 5* (with parameter values similar to those inferred from the actual payments to the producers), those of *case 9* (with sugar level similar to the actual choices), and those of *case 1*.

In the pooled and Chardonnay samples we can observe that the distributions of the simulated choices with the specification without dummies are much less dispersed than those of the actual choices, while in the model with the dummies the distributions have quite the same dispersion. Notice also that the distributions of *case 9* are quite overlapping with those of the actual choices. In the case of Merlot, on the other hand, both model specifications lead to the simulated choices distribution that are considerably less dispersed than those of the actual choices.

Summarizing, the optimal quality choices derived in the theoretical and empirical part of the paper - although quite sensitive to the choice of the demand parameters used to calibrate the simulation - appear higher and often less variable across producers than the choices actually made. Using the demand parameters that can be inferred from the pricing scheme used by the SAV cooperative actually leads to simulated choices that are on average 50% higher than the actual choices. On the other hand, to obtain quality levels comparable to the actual ones, one needs to start from an inverse demand for quality that shows higher willingness to pay for quality (*case 9*).

Although this result might be related to a wrong calibration of the simulation,[45] notice that over the period under consideration (from 1991, when the pricing scheme for sugar was introduced, to 2003, the last year for which data is available) the average sugar content in the cooperative in fact increased quite consistently over time, as can be seen from table 1. This may show that the cooperative wanted to increase the sugar content provided by the members and to obtain it they might have decided to pay a price higher than the market to set producers' deliveries to a higher quality equilibria. In other words, the cooperative may have induced farmers to produce grapes with more sugar content using higher than the market prices for a transition period. Indeed, as we will see shortly, the cooperative lowered the premium for above average

[45] As explained earlier, there could some selection bias in the use of only the subsample of members for which production data is available. Or simply the way we infer the demand parameters a and b from the actual payments made by the cooperative could be just imprecise.

quality starting in 2000, presumably when it reached some sort of steady state equilibrium more in line with market demand conditions.

5.3 The pricing scheme

In this section we report the results of the optimal pricing rule obtained by eq. (17)[46]. We obtain results that appear quite symmetrical to those obtained for the optimal quality choices. Indeed, with almost no exceptions, we obtain price levels that are lower that those received with the actual mechanisms implemented by the SAV cooperative (table 7A and 7B). In particular, in *case 5* (where the demand parameter values appear closer to those inferred from table 1 of the payments made by the cooperative), the average price received for quintal of grapes would be 10% or less than the actual price received. To obtain prices that are comparable to those actually obtained we need to consider *case 9*, which again would be consistent with a more optimistic evaluation of the demand for quality and hence consumers' willingness to pay for sugar content (or alcohol content, for that matter).

For a better understanding of the results, we plot the pricing schemes - the actual and the simulated ones - as a function of sugar content (figures 12-13-14). The comparison with the actual pricing rule used in the SAV cooperative is indeed quite interesting, showing that the pricing scheme derived in this study using the same demand parameters (*case 5*) indeed results quite different from the one adopted by the cooperative. Notice in particular that in the actual pricing mechanism the level of prices paid by the cooperative is much higher than that emerging from the simulation using similar demand parameters. This result is quite common in all samples and model specifications, even though it is easier to see in the model with dummies where the dispersion is greater.

Paying higher prices is equivalent to having an enhanced slope of the pricing schedule, and a steeper pricing schedule has more "incentive power", in the sense that paying a higher unit price for sugar induces higher sugar production by members. As we explained in the previous section, this may be due to the poor demand information we based our simulation upon. Or it could signal that to increase the quality delivery of members the cooperative initially offered a relatively high price for sugar.

Indeed, starting from the year 2000, the cooperative under consideration reduced the prices for sugar, in particular deciding that only the penalty for sugar content below the group's average was to be enforced, while the premium for above average sugar production was not paid any longer. This may mean that the actual pricing schedule implemented in 1994-1996 was in fact too steep, i.e., too high, for the market demand and thus the actual willingness to pay for sugar, i.e., alcohol content.[47] On the other hand, the fact that the "penalty" part of the pricing scheme is still enforced may be due to the requirements - in

[46] Th same results would be obtained using eq. (18).

[47] Another possible explanation is that the market demand may have changed in the meantime.

the form of the minimum quality standard in terms of sugar content - needed in order to qualify as AOC grapes.

As a last piece of evidence regarding the pricing scheme, we report its relationship with the technical efficiency scores (figure 15). As can be seen, the simulated price paid (*case 9*) appears increasing with the efficiency level,[48] especially in the model with the dummies. On the other hand, the actual price paid is decreasing with the efficiency level.[49]

6 Concluding remarks

In this study we derive the optimal quality choices and the pricing mechanism for quality for a group of producers and we implement them empirically. First, we derive the theoretical pricing scheme using a simple model for a group of producers that needs to decide on how to pay for quality, i.e., sugar, in grapes production. We find that the optimal quality choices depend on the efficiency level of farmers and on the trade-off between quality and quantity. In addition, the optimal pricing scheme simply "reflects" market demand willingness to pay for quality. Being the pricing scheme dependent on technology parameters, we then estimate the production technology using a stochastic production frontier that takes into account producers' heterogeneity. We then simulate the optimal quality choices and pricing schedule, and compare them to those actually made by a group of producers for which we are able to estimate the production technology.

A critical piece of information needed for the implementation of the theoretical pricing scheme is the estimation of the technology. In this study we use a primal approach, i.e., a restricted production function estimation based on a stochastic production frontier and thus an error composite model, because we can rely on quasi-experimental data for which input prices are not available. This approach, however, may suffer from endogeneity problems. Given data availability, dual approaches - either based on profit or revenue function estimation - could be implemented, probably attenuating the endogeneity problem.

Another important piece of information, needed for actually implementing the optimal contract, is the estimation of market demand for the quality attributes of the product or commodity under consideration. In this study we consider grapes for wine production and we infer some market demand information from payments actually made by the cooperative under investigation. Although this information may not be the ideal one for empirical implementation purposes, we are able to derive a pricing scheme and show that in fact the cooperative seems to be paying the sugar content more than what we can predict from the market information we have available. This difference may be due to the poor market demand data we use, or may be related to some missing

[48] This is because the simulated quality choices are increasing with the efficiency level. This result is not reported here but available on request.

[49] For clarity's purposes we do not show all the observations for the actual choices but only their linear regression fit.

aspects of the analysis.

Indeed, the paper makes some simplifying assumptions. We do not assume any informational asymmetry between the group's management and producers. This may be realistic in some settings, while in others it may be questionable. In addition, the actual pricing mechanism observed for the set of producers analyzed in this study is a relative performance scheme in which each individual producer is given a premium (penalty) if she is producing more (less) sugar than the group's average. Relative performance schemes are usually explained as a mechanism to transfer the common risk from producers when there are problems of hidden action, an informational asymmetry which is not modeled here but that could be quite relevant in many settings given also the uncertainty due to changing weather conditions.

The paper also does not model the group's aversion for inequality or the concern that each and every member may need to obtain a certain minimum return from her grapes. It can be argued that different pricing mechanisms can have rather different distributional impacts, and to the extent that cooperatives and other producer groups may have some concern for equity in addition to efficiency, this could be quite an important aspect that could explain the actual remuneration choices with different incentive power used by cooperatives and producer's groups.

It is reasonable to expect that the higher is the "power" of the pricing schedule, the greater is the inequality among the members of the group in terms of price received per unit of grapes. In other words, the pricing mechanism should serve to increase efficiency, i.e., to reflect market demand and enhance production from more efficient producers, but it has also an impact on the income distribution across the members of the producers' group. To the extent that greater efficiency may imply greater inequality in returns to members, an inequality averse group may choose a less powerful pricing scheme. In the paper we just mention some of these implications of different pricing schemes, but we believe that this topic deserves a much more thorough investigation.

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8 Appendixes

8.1 Appendix 1

A survey among the wine-cooperatives in the North-East of Italy was conducted in 1998-99. Among other things, the cooperatives were asked about the relative importance given to the possible objectives pursued by their management. We report here the results in decreasing order of importance. For each possible answer, the interviewed person in the cooperative (either the CEO or the Chairman of the Board of Directors), could give a ranking from 1 (low importance) to 7 (very important). Here are the results.

Objective n=65	Mean	St. dev.	Min	Max	# max
Equal treatment for all	6.8	0.5	2	7	53
Sure market outlet	6.3	1.7	1	7	51
Income/price enhancement	5.8	1.6	1	7	34
Quality enhancement	5.5	1	1	7	30
Management professionality	5.2	1.7	1	7	17
Local development	5.1	1.6	1	7	10
Cooperative values	4.9	1.6	1	7	11
Treatment based on quality	4.4	2.5	1	7	26
Price stabilization	4	1.8	1	7	2
Services to members	3.9	1.8	1	7	6
Increase bargaining power	3.8	2.1	1	7	4
Feeling of ownership	3.7	1.9	1	7	7
Members' training	3.6	2.1	1	7	4
Members' involvement	3.4	1.6	1	7	2
Members' social networking	3.3	1.9	1	7	4
Members' cost savings	2.3	1.8	1	7	3

The most important objective for the cooperatives interviewed is the fact that members should be treated equally, probably a response which could be motivated by the management's fear of being accused of discriminating among members. This answer obtains a score of 6.8 out of 7, and 53 cooperatives out of 65 indicated it with the highest mark of importance. The second objective indicated is for the cooperative to represent a secure market outlet for members' supply. It receives an average score of 6.3, and 51 cooperatives out of 65 give the maximum importance. The objective of price and income enhancement is seen very important by 34 out 65 cooperatives and its average score is 5.8. The quality enhancement of members' products is on average getting a score of 5.5, receiving the highest importance from 30 cooperatives.

8.2 Appendix 2

Starting from equation (32) we can derive the expression for the marginal price $\widetilde{p} = p(s, y^*) + p'(s, y^*)\, y$ by noting the following

$$p_{ij} = \begin{cases} p_j(s_{ij}, y_{ij}) & if\ y_{ij} \leq 150\ q/ha, \\ \frac{p_j(s_{ij},y_{ij})}{2} \frac{(150+y_{ij})}{y_{ij}} & if\ 150 < y_{ij} \leq 180\ q/ha, \\ \frac{p_j(s_{ij},y_{ij})}{2} & if\ y_{ij} > 180\ q/ha, \end{cases}$$

and

$$p'_{ij} = \begin{cases} 0 & if\ y_{ij} \leq 150\ q/ha, \\ \frac{-75\ p_j(s_{ij},y_{ij})}{y_{ij}^2} & if\ 150 < y_{ij} \leq 180\ q/ha, \\ 0 & if\ y_{ij} > 180\ q/ha. \end{cases}$$

So we have

$$\widetilde{p}_{ij} = \begin{cases} p_j(s_{ij}, y_{ij}) & if\ y_{ij} \leq 150\ q/ha, \\ \frac{p_j(s_{ij},y_{ij})}{2} & if\ 150 < y_{ij} \leq 180\ q/ha, \\ \frac{p_j(s_{ij},y_{ij})}{2} & if\ y_{ij} > 180\ q/ha. \end{cases}$$

Table 1. Pricing schedule for sugar content, SAV

MERLOT A.O.C.						
	Type					***Premium***
Year	***Degree***	***Degree***	***£./q***	***€./q***	***£./ °B***	***£./G° +/-***
		A	***B***	***C***	***D***	***E***
1991	Babo	16.50	73,079	37.74	4,429	+/- 70
1992	Babo	16.00	56,304	29.08	3,519	+/- 70
1993	Babo	16.00	48,240	24.91	3,015	+/- 50
1994	Babo	17.00	86,207	44.52	5,071	+/- 70
1995	Babo	17.40	153,294	79.17	6,800	+/- 70
1996	Babo	17.00	156,400	80.77	9,200	+/- 90
1997	Babo	17.10	178,883	92.39	10,461	+/- 120
1998	Babo	17.40	162,180	83.76	9,321	+/- 120
1999	Babo	18.00	216,810	111.97	12,045	+/-200
2000	Brix	21.50	235,010	121.37	10,931	-200
					€.	***€./G° +/-***
2001	Brix	21.00	229,196	118.37	5.64	-0.100
2002	Brix	20.50	226,563	117.01	5.708	-0.105
2003	Brix	22.70	199,455	103.01	4.538	-0.130

CHARDONNAY A.O.C.						
	Type					***Premium***
Year	***Degree***	***Degree***	***£./q***	***€./q***	***£./ °B***	***£./G° +/-***
		A	***B***	***C***	***D***	***E***
1991	Babo	16.70	128,306	66.26	7,683	+/- 90
1992	Babo	16.00	75,392	38.94	4,712	+/- 70
1993	Babo	16.50	57,503	29.70	3,485	+/- 50
1994	Babo	17.50	103,513	53.46	5,915	+/- 70
1995	Babo	17.20	159,616	82.43	9,280	+/- 90
1996	Babo	16.50	156,750	80.95	9,500	+/- 90
1997	Babo	16.90	168,476	87.01	9,969	+/- 120
1998	Babo	17.40	145,800	75.30	8,379	+/- 120
1999	Babo	18.00	188,100	97.15	10,450	+/- 200
2000	Brix	21.50	202,210	104.43	9,405	-150
					€.	***€./G° +/-***
2001	Brix	21.50	245,916	127.00	5.91	-0.080
2002	Brix	20.50	242,131	125.05	6.10	-0.085
2003	Brix	21.90	222,707	115.02	5.252	-0.080

Table 2-A. Inputs and Outputs - CHARDONNAY

	Unit of	1994					1995					1996				
Variable	measure	n	Mean	St. dev.	Min	Max	n	Mean	St. dev.	Min	Max	n	Mean	St. dev.	Min	Max
Altimetry (z_1)	mt.	236	262.691	94.899	170	500	187	259.037	90.614	180	500	213	260.282	91.2022	180	500
Vines per hectare (z_2)	no.	236	3146.74	774.709	1500	5000	187	3193.69	789.8	1500	5000	213	3175.78	778.318	1500	5000
Buds per branch (x_1)	no.	236	23.6186	6.73943	10	42	187	27.016	8.5857	9	62	213	31.216	11.0769	8	89
Roots depth°	1-3	236	2.41525	0.85379	1	3	187	2.31016	0.8921	1	3	213	2.40845	0.85082	1	3
Water holding capacity° (z_3)	1-4	236	2.29661	1.02155	1	4	187	2.18182	1.0102	1	4	213	2.29578	1.0149	1	4
Total calcium° (z_4)	1-5	236	3.3517	1.13702	1	5	187	3.44385	1.1643	1	5	213	3.3662	1.14397	1	5
Scheleton°	1-4	236	2.62288	0.87868	1	4	187	2.6738	0.8893	1	4	213	2.6338	0.86176	1	4
Internal Drainage°	1-5	236	3.5678	0.92234	1	5	187	3.6631	0.8544	1	5	213	3.57747	0.86867	1	5
External Drainage°	1-3	236	2.76271	0.50828	1	3	187	2.78075	0.4864	1	3	213	2.77465	0.48166	1	3
Irrigated°	0-1	236	0.69915	0.4596	0	1	187	0.70053	0.4593	0	1	213	0.69014	0.46352	0	1
Cultivated°	0-1	236	0.03814	0.19193	0	1	187	0.04813	0.2146	0	1	213	0.04225	0.20164	0	1
Grapes production per ha	0.1 t./ha	236	146.575	60.1179	32	356.7	187	134.017	57.001	14.8	362.1	213	182.048	73.6158	40	451
Sugar content (s)	°Brix	236	19.8953	1.36064	15.7	25.4	187	19.5631	1.3703	13.2	22.8	213	19.2305	1.01501	16.2	21.7
Total acidity (x_2)	gr./l.	236	8.54907	1.65822	5.6	16.07	187	10.5664	1.8004	6.75	15.54	213	11.868	1.4524	8.4	16.98
pH (x_3)	1-14	236	3.15936	0.13824	2.81	3.65	187	3.17316	0.1081	2.89	3.44	213	3.20653	0.12002	2.9	3.63
Tartaric acidity (x_4)	gr./l.	214	6.52911	0.80975	3.62	8.88	187	7.86604	0.8516	5.91	10.01	213	7.09977	0.55282	5.62	9.02
Malic acidity (x_5)	gr./l.	214	3.96332	1.50448	0.86	9.5	187	5.64155	1.5179	2.65	9.99	213	5.73709	1.05352	3.36	8.07
Potassium content (x_6)	gr./l.	214	1.4779	0.19796	0.78	2.34	187	1.62155	0.2116	1.02	2.26	213	1.69648	0.17594	1.15	2.04
Mean humidity*	%	-	58.0	-	-	-	-	62.0	-	-	-	-	67.4	-	-	-
Mean temperature*	°C	-	22.6	-	-	-	-	20.1	-	-	-	-	19.7	-	-	-
Rainfall**	mm.	-	172.2	-	-	-	-	61.7	-	-	-	-	124.6	-	-	-
Radiation**	cal./sqcm.	-	14045.0	-	-	-	-	11824.0	-	-	-	-	10927.0	-	-	-
Sun hours**	no.	-	321.7	-	-	-	-	266.4	-	-	-	-	253.7	-	-	-
Temperature excursion**	°C	-	593.4	-	-	-	-	534.3	-	-	-	-	509.9	-	-	-

° Categorical variable

* Average conditions for the last 40 days before harvest

** Summation for the last 40 days before harvest

Table 2-B. Inputs and Outputs - MERLOT

	Unit of	1994					1995					1996				
Variable	measure	n	Mean	St. dev.	Min	Max	n	Mean	St. dev.	Min	Max	n	Mean	St. dev.	Min	Max
Altimetry (z_1)	mt.	81	209.7531	65.1148	180	450	129	203.488	53.5118	180	450	120	203.25	55.0655	180	450
Vines per hectare (z_2)	no.	81	2727.778	703.207	1500	4100	129	2701.16	644.855	1800	4100	120	2650	621.465	1800	4100
Buds per branch (x_1)	no.	81	30.01235	8.48601	7	58	129	28.8527	9.54193	12	61	120	37.6	14.4347	16	97
Roots depth°	1-3	81	2.320988	0.9464	1	3	129	2.51163	0.82079	1	3	120	2.525	0.80922	1	3
Water holding capacity° (z_3)	1-4	81	2.481481	1.22588	1	4	129	2.74419	1.12694	1	4	120	2.775	1.11115	1	4
Total calcium° (z_4)	1-5	81	3.345679	1.37077	1	5	129	3.51163	1.23185	1	5	120	3.425	1.28771	1	5
Scheleton°	1-4	81	2.283951	1.0516	1	4	129	2.32558	1.00904	1	4	120	2.275	1.02869	1	4
Internal Drainage°	1-5	81	3.333333	1.04881	1	5	129	3.23256	1.05706	1	5	120	3.175	1.02623	1	5
External Drainage°	1-3	81	2.567901	0.56873	1	3	129	2.55814	0.58506	1	3	120	2.55	0.59196	1	3
Irrigated°	0-1	81	0.493827	0.50308	0	1	129	0.53488	0.50073	0	1	120	0.5	0.5021	0	1
Cultivated°	0-1	81	0.111111	0.31623	0	1	129	0.06977	0.25575	0	1	120	0.05	0.21886	0	1
Grapes production per ha	0.1 t./ha	81	158.3259	63.5073	48.6	345	129	140.542	64.8205	11	364.9	120	220.678	83.6854	44	522.9
Sugar content (s)	°Brix	81	20.15309	1.46791	17	24.6	129	20.4868	1.67777	13.5	23.9	120	19.8208	1.28108	16.3	22.5
Total acidity (x_2)	gr./l.	81	6.331235	1.53496	4.29	11.91	129	9.59643	2.45448	4.95	17.74	120	8.72508	1.03875	6.49	14.37
pH (x_3)	1-14	81	3.584074	0.18372	3.05	3.95	129	3.35	0.13976	3.13	3.89	120	3.45225	0.47033	3.15	8.4
Tartaric acidity (x_4)	gr./l.	78	6.393333	1.00574	4.27	9.93	127	7.33811	0.92698	3.71	9.78	120	5.41617	0.69614	2.77	7.21
Malic acidity (x_5)	gr./l.	78	2.800128	1.22178	1.2	6.36	127	3.9215	1.11098	1.67	8.02	120	3.68808	0.69927	2.07	6.88
Potassium content (x_6)	gr./l.	78	1.784231	0.24385	1.06	2.51	128	1.73242	0.17144	1.15	2.26	120	1.9225	0.1572	1.5	2.34
Mean humidity*	%	-	63.0	-	-	-	-	68.5	-	-	-	-	65.5	-	-	-
Mean temperature*	°C	-	20.7	-	-	-	-	17.6	-	-	-	-	17.1	-	-	-
Rainfall**	mm.	-	274.9	-	-	-	-	89.2	-	-	-	-	83.0	-	-	-
Radiation**	cal./sqcm.	-	12349.0	-	-	-	-	9439.0	-	-	-	-	9470.0	-	-	-
Sun hours**	no.	-	281.7	-	-	-	-	214.9	-	-	-	-	220.0	-	-	-
Temperature excursion**	°C	-	549.2	-	-	-	-	477.0	-	-	-	-	504.9	-	-	-

° Categorical variable

* Average conditions for the last 40 days before harvest

** Summation for the last 40 days before harvest

Table 3A. Estimation results of stochastic frontier

Sample ->	**Pooled data**		**Pooled + dummies**		**Chardonnay**	
Variable	Coeff.	P>|z|	Coeff.	P>|z|	Coeff.	P>|z|
Buds per branch (x_1)	3.88	0.54	10.36	0.07	-10.15	0.26
Total acidity (x_2)	-94.03	0.08	-95.57	0.04	38.63	0.64
pH (x_3)	-551.08	0.15	-638.92	0.06	325.67	0.73
Tartaric acidity (x_4)	-83.34	0.31	-96.35	0.19	119.21	0.42
Malic acidity (x_5)	61.79	0.42	73.99	0.29	-49.15	0.70
Potassium content (x_6)	534.41	0.09	230.49	0.40	197.15	0.67
x1x1	0.01	0.47	-0.03	0.06	0.02	0.45
x2x2	0.52	0.77	1.84	0.25	-2.36	0.37
x3x3	12.73	0.49	8.86	0.59	-96.76	0.73
x4x4	-8.80	0.01	-8.19	0.01	-20.36	0.00
x5x5	-4.06	0.20	4.27	0.14	-5.21	0.28
x6x6	39.75	0.55	22.90	0.69	-2.50	0.98
x1x2	-0.02	0.95	-0.34	0.33	0.69	0.21
x1x3	3.18	0.39	-0.16	0.96	12.94	0.02
x1x4	-0.66	0.16	-0.19	0.64	-1.79	0.03
x1x5	-0.03	0.95	0.17	0.71	1.00	0.18
x1x6	-1.82	0.50	-0.91	0.70	-13.85	0.00
x2x3	52.58	0.07	54.20	0.03	-4.70	0.92
x2x4	0.72	0.85	5.11	0.12	-7.80	0.20
x2x5	0.14	0.97	-9.27	0.01	3.30	0.60
x2x6	-13.02	0.53	7.64	0.67	2.53	0.93
x3x4	55.36	0.20	31.11	0.41	-44.78	0.60
x3x5	-57.57	0.23	-56.80	0.18	-26.99	0.71
x3x6	-152.16	0.27	-67.97	0.58	-72.98	0.78
x4x5	13.64	0.01	9.49	0.04	22.53	0.01
x4x6	-55.27	0.06	-29.45	0.25	6.41	0.89
x5x6	2.11	0.94	-10.42	0.69	8.31	0.84
x1s	-0.14	0.44	-0.11	0.50	0.12	0.65
x2s	0.54	0.66	-0.88	0.41	0.13	0.95
x3s	14.76	0.34	20.57	0.13	9.34	0.68
x4s	3.21	0.08	4.03	0.01	4.46	0.10
x5s	0.05	0.98	1.07	0.50	0.14	0.96
x6s	-3.82	0.70	-2.90	0.74	0.05	1.00
Sugar content (s)	-79.30	0.09	-96.97	0.02	-81.44	0.25
1995			-12.28	0.04		
1996			25.08	0.00		
Chardonnay			-21.90	0.00		
Constant	2073.11	0.07	2664.05	0.01	8.19	1.00
Altimetry (z_1)	0.04	0.27	0.02	0.69	0.03	.
Vines per hectare (z_2)	-0.01	0.01	-0.05	0.00	0.00	.
Water holding capacity (z_3)	4.71	0.04	-6.51	0.00	-0.07	.
Total calcium (z_4)	2.34	0.24	-5.14	0.01	-0.07	.
Constant	15.37	0.52	220.35	0.00	1.03	.
sigma_u2	0.00		1.74		0.00	
sigma_v2	3384.38		2566.59		3158.65	

Table 3B. Estimation results of stochastic frontier (cont.ed)

Sample ->	**Chardonnay + dummies**		**Merlot**		**Merlot + dummies**	
Variable	Coeff.	P>|z|	Coeff.	P>|z|	Coeff.	P>|z|
Buds per branch (x_1)	7.29	0.34	26.03	0.06	22.73	0.10
Total acidity (x_2)	88.96	0.20	-73.91	0.49	-156.22	0.15
pH (x_3)	1075.48	0.18	-732.94	0.38	-956.06	0.23
Tartaric acidity (x_4)	10.91	0.93	-227.64	0.12	-178.39	0.22
Malic acidity (x_5)	-114.12	0.27	172.14	0.37	224.17	0.23
Potassium content (x_6)	194.92	0.61	30.63	0.97	-190.05	0.80
x1x1	-0.02	0.31	-0.06	0.11	-0.06	0.07
x2x2	-2.65	0.22	-1.89	0.51	1.41	0.64
x3x3	-290.16	0.21	35.76	0.21	5.27	0.86
x4x4	-15.61	0.00	-2.73	0.55	-2.15	0.63
x5x5	-0.82	0.84	-13.99	0.11	-7.06	0.43
x6x6	45.80	0.53	-29.73	0.80	-68.67	0.55
x1x2	-0.29	0.53	-0.62	0.35	-0.55	0.40
x1x3	6.23	0.17	-11.04	0.13	-9.49	0.18
x1x4	-1.49	0.03	1.10	0.09	0.98	0.13
x1x5	0.78	0.20	-0.66	0.47	-0.57	0.53
x1x6	-7.38	0.02	9.06	0.05	8.40	0.06
x2x3	-0.92	0.98	13.46	0.80	45.51	0.39
x2x4	-2.13	0.67	8.53	0.14	7.66	0.18
x2x5	0.83	0.88	1.65	0.82	-5.07	0.50
x2x6	-0.58	0.98	27.83	0.46	26.93	0.46
x3x4	-1.03	0.99	101.34	0.13	59.54	0.38
x3x5	-6.16	0.92	-21.57	0.83	-65.50	0.51
x3x6	-175.10	0.42	61.98	0.85	220.57	0.50
x4x5	16.21	0.02	11.24	0.17	11.53	0.15
x4x6	-12.37	0.75	-94.18	0.02	-57.55	0.17
x5x6	6.86	0.84	-41.56	0.41	-40.58	0.41
x1s	-0.05	0.80	-0.49	0.07	-0.42	0.12
x2s	-3.05	0.07	0.82	0.69	1.38	0.49
x3s	-3.37	0.86	14.15	0.62	27.42	0.32
x4s	4.96	0.03	3.62	0.22	3.51	0.23
x5s	2.98	0.19	-4.36	0.21	-3.07	0.37
x6s	6.01	0.59	3.62	0.84	-2.07	0.91
Sugar content (s)	-29.55	0.61	-70.19	0.46	-115.63	0.22
1995	-24.13	0.00			-0.07	1.00
1996	13.34	0.11			35.35	0.03
Chardonnay						
Constant	-1551.26	0.37	2759.97	0.35	3892.24	0.17
Altimetry (z_1)	0.03	0.38	0.12	0.15	0.07	0.36
Vines per hectare (z_2)	-0.06	0.00	-0.01	0.17	-0.02	0.02
Water holding capacity (z_3)	-4.34	0.07	3.79	0.34	0.63	0.87
Total calcium (z_4)	-1.12	0.59	1.61	0.62	-0.63	0.85
Constant	240.20	0.00	1.46	0.97	52.10	0.14
sigma_u2	1.99		0.01		0.00	
sigma_v2	2107.73		3163.94		3003.11	

Table 4. Technical efficiency results and correction factors

Sample	Variable	Unit of measure	# Obs	Mean	Std. Dev.	Min	Max
Pooled	u_i	q	927	16.15	7.80	1.96	31.42
	TE_i	%	927	0.91	0.04	0.75	0.99
	Corr. Factor	° Brix	927	-15.43	0.28	-15.94	-14.88
Pooled with dummies							
	u_i	q	939	46.61	33.14	0.06	125.64
	TE_i	%	939	0.83	0.10	0.49	1.00
	Corr. Factor	° Brix	939	-15.79	1.22	-17.51	-12.87
Chardonnay							
	u_i	q	473	2.62	1.88	0.00	8.42
	TE_i	%	473	0.98	0.06	-0.26	1.00
	Corr. Factor	° Brix	473	-15.01	0.06	-15.10	-14.81
Chardonnay with dummies							
	u_i	q	614	50.23	39.32	0.07	149.83
	TE_i	%	614	0.82	0.11	0.51	1.00
	Corr. Factor	° Brix	614	-15.80	1.53	-17.74	-11.93
Merlot							
	u_i	q	313	15.61	6.66	0.32	31.21
	TE_i	%	313	0.92	0.04	0.73	1.00
	Corr. Factor	° Brix	313	-15.20	0.21	-15.68	-14.72
Merlot with dummies							
	u_i	q	319	23.39	9.46	0.00	44.60
	TE_i	%	319	0.89	0.05	0.71	1.00
	Corr. Factor	° Brix	319	-15.55	0.31	-16.32	-14.85

Table 5. Demand parameter values for the simulations

Samples ->	**Poo led**		**Chard onnay**		**Mer lot**	
	a	*b*	*a*	*b*	*a*	*b*
Cases:						
Case 1	-168	1.97	-173	2.13	-164	1.82
Case 2	-168	3.94	-173	4.25	-164	3.63
Case 3	-168	5.91	-173	6.38	-164	5.45
Case 4	-112	1.97	-115	2.13	-109	1.82
Case 5	-112	3.94	-115	4.25	-109	3.63
Case 6	-112	5.91	-115	6.38	-109	5.45
Case 7	-56	1.97	-58	2.13	-55	1.82
Case 8	-56	3.94	-58	4.25	-55	3.63
Case 9	-56	5.91	-58	6.38	-55	5.45

Table 6A. Estimated and actual quality choices

Sample	Variable	# Obs	Mean	Std. Dev.	Min	Max
Pooled						
	Actual choices	966	19.78	1.40	13.20	25.40
	Case 1	927	58.07	0.28	57.52	58.58
	Case 2	927	36.75	0.28	36.20	37.26
	Case 3	927	29.65	0.28	29.10	30.16
	Case 4	927	43.86	0.28	43.31	44.37
	Case 5	927	29.65	0.28	29.10	30.16
	Case 6	927	24.91	0.28	24.36	25.42
	Case 7	927	29.65	0.28	29.10	30.16
	Case 8	927	22.54	0.28	21.99	23.05
	Case 9	927	20.17	0.28	19.62	20.68
Pooled with dummies						
	Actual choices	966	19.78	1.40	13.20	25.40
	Case 1	939	58.43	1.22	55.51	60.15
	Case 2	939	37.11	1.22	34.19	38.83
	Case 3	939	30.00	1.22	27.09	31.72
	Case 4	939	44.22	1.22	41.30	45.93
	Case 5	939	30.00	1.22	27.09	31.72
	Case 6	939	25.27	1.22	22.35	26.98
	Case 7	939	30.00	1.22	27.09	31.72
	Case 8	939	22.90	1.22	19.98	24.61
	Case 9	939	20.53	1.22	17.61	22.24
Chardonnay						
	Actual choices	636	19.58	1.29	13.20	25.40
	Case 1	473	55.62	0.06	55.42	55.71
	Case 2	473	35.36	0.06	35.16	35.45
	Case 3	473	28.56	0.06	28.37	28.65
	Case 4	473	42.00	0.06	41.80	42.09
	Case 5	473	28.54	0.06	28.34	28.63
	Case 6	473	24.02	0.06	23.82	24.11
	Case 7	473	28.62	0.06	28.42	28.71
	Case 8	473	21.83	0.06	21.63	21.92
	Case 9	473	19.55	0.06	19.35	19.64

Table 6B. Estimated and actual quality choices (cont.ed)

Sample	Variable	# Obs	Mean	Std. Dev.	Min	Max
Chardonnay with dummies						
	Actual choices	636	19.58	1.29	13.20	25.40
	Case 1	614	56.41	1.53	52.54	58.35
	Case 2	614	36.15	1.53	32.28	38.10
	Case 3	614	29.35	1.53	25.49	31.30
	Case 4	614	42.79	1.53	38.93	44.74
	Case 5	614	29.33	1.53	25.46	31.27
	Case 6	614	24.81	1.53	20.94	26.76
	Case 7	614	29.41	1.53	25.55	31.36
	Case 8	614	22.62	1.53	18.75	24.57
	Case 9	614	20.34	1.53	16.48	22.29
Merlot						
	Actual choices	330	20.16	1.52	13.50	24.60
	Case 1	313	60.26	0.21	59.78	60.73
	Case 2	313	37.79	0.21	37.31	38.27
	Case 3	313	30.25	0.21	29.77	30.72
	Case 4	313	45.15	0.21	44.67	45.62
	Case 5	313	30.22	0.21	29.73	30.69
	Case 6	313	25.20	0.21	24.72	25.68
	Case 7	313	30.31	0.21	29.83	30.79
	Case 8	313	22.78	0.21	22.30	23.25
	Case 9	313	20.25	0.21	19.77	20.72
Merlot with dummies						
	Actual choices	330	20.16	1.52	13.50	24.60
	Case 1	319	60.60	0.31	59.91	61.37
	Case 2	319	38.14	0.31	37.44	38.91
	Case 3	319	30.60	0.31	29.90	31.36
	Case 4	319	45.49	0.31	44.80	46.26
	Case 5	319	30.56	0.31	29.87	31.33
	Case 6	319	25.55	0.31	24.85	26.32
	Case 7	319	30.66	0.31	29.96	31.43
	Case 8	319	23.13	0.31	22.43	23.89
	Case 9	319	20.60	0.31	19.90	21.36

Table 7A. Estimated and actual pricing schemes

Sample	Variable	# Obs	Mean	Std. Dev.	Min	Max
Pooled						
	Actual pricing	966	64.55	13.97	12.25	132.03
	Case 1	927	-53.59	0.55	-54.68	-52.59
	Case 2	927	-23.19	1.11	-25.35	-21.18
	Case 3	927	7.22	1.66	3.97	10.23
	Case 4	927	-25.59	0.55	-26.68	-24.59
	Case 5	927	4.81	1.11	2.65	6.82
	Case 6	927	35.22	1.66	31.97	38.23
	Case 7	927	2.41	0.55	1.32	3.41
	Case 8	927	32.81	1.11	30.65	34.82
	Case 9	927	63.22	1.66	59.97	66.23
Pooled with dummies						
	Actual pricing	966	64.55	13.97	12.25	132.03
	Case 1	939	-52.89	2.41	-58.64	-49.51
	Case 2	939	-21.79	4.82	-33.27	-15.02
	Case 3	939	9.32	7.22	-7.91	19.47
	Case 4	939	-24.89	2.41	-30.64	-21.51
	Case 5	939	6.21	4.82	-5.27	12.98
	Case 6	939	37.32	7.22	20.09	47.47
	Case 7	939	3.11	2.41	-2.64	6.49
	Case 8	939	34.21	4.82	22.73	40.98
	Case 9	939	65.32	7.22	48.09	75.47
Chardonnay						
	Actual pricing	636	67.62	13.63	14.05	141.69
	Case 1	473	-54.54	0.14	-54.96	-54.35
	Case 2	473	-22.72	0.27	-23.57	-22.34
	Case 3	473	9.24	0.41	7.97	9.81
	Case 4	473	-25.54	0.14	-25.96	-25.35
	Case 5	473	6.28	0.27	5.43	6.66
	Case 6	473	38.24	0.41	36.97	38.81
	Case 7	473	2.96	0.14	2.54	3.15
	Case 8	473	34.78	0.27	33.93	35.16
	Case 9	473	66.74	0.41	65.47	67.31

Table 7B. Estimated and actual pricing schemes

Sample	Variable	# Obs	Mean	Std. Dev.	Min	Max
Chardonnay with dummies						
	Actual pricing	636	67.62	13.63	14.05	141.69
	Case 1	614	-52.85	3.25	-61.09	-48.71
	Case 2	614	-19.36	6.49	-35.80	-11.09
	Case 3	614	14.28	9.74	-10.38	26.70
	Case 4	614	-23.85	3.25	-32.09	-19.71
	Case 5	614	9.64	6.49	-6.80	17.91
	Case 6	614	43.28	9.74	18.62	55.70
	Case 7	614	4.65	3.25	-3.59	8.79
	Case 8	614	38.14	6.49	21.70	46.41
	Case 9	614	71.78	9.74	47.12	84.20
Merlot						
	Actual pricing	330	62.90	14.48	11.01	112.90
	Case 1	313	-54.33	0.38	-55.21	-53.46
	Case 2	313	-26.81	0.75	-28.56	-25.09
	Case 3	313	0.87	1.13	-1.77	3.45
	Case 4	313	-26.83	0.38	-27.71	-25.96
	Case 5	313	0.69	0.75	-1.06	2.41
	Case 6	313	28.37	1.13	25.73	30.95
	Case 7	313	0.17	0.38	-0.71	1.04
	Case 8	313	27.69	0.75	25.94	29.42
	Case 9	313	55.37	1.13	52.73	57.95
Merlot with dummies						
	Actual pricing	330	62.90	14.48	11.01	112.90
	Case 1	319	-53.70	0.56	-54.97	-52.30
	Case 2	319	-25.55	1.13	-28.08	-22.77
	Case 3	319	2.75	1.69	-1.05	6.93
	Case 4	319	-26.20	0.56	-27.47	-24.80
	Case 5	319	1.95	1.13	-0.58	4.73
	Case 6	319	30.25	1.69	26.45	34.43
	Case 7	319	0.80	0.56	-0.47	2.20
	Case 8	319	28.95	1.13	26.42	31.73
	Case 9	319	57.25	1.69	53.45	61.43

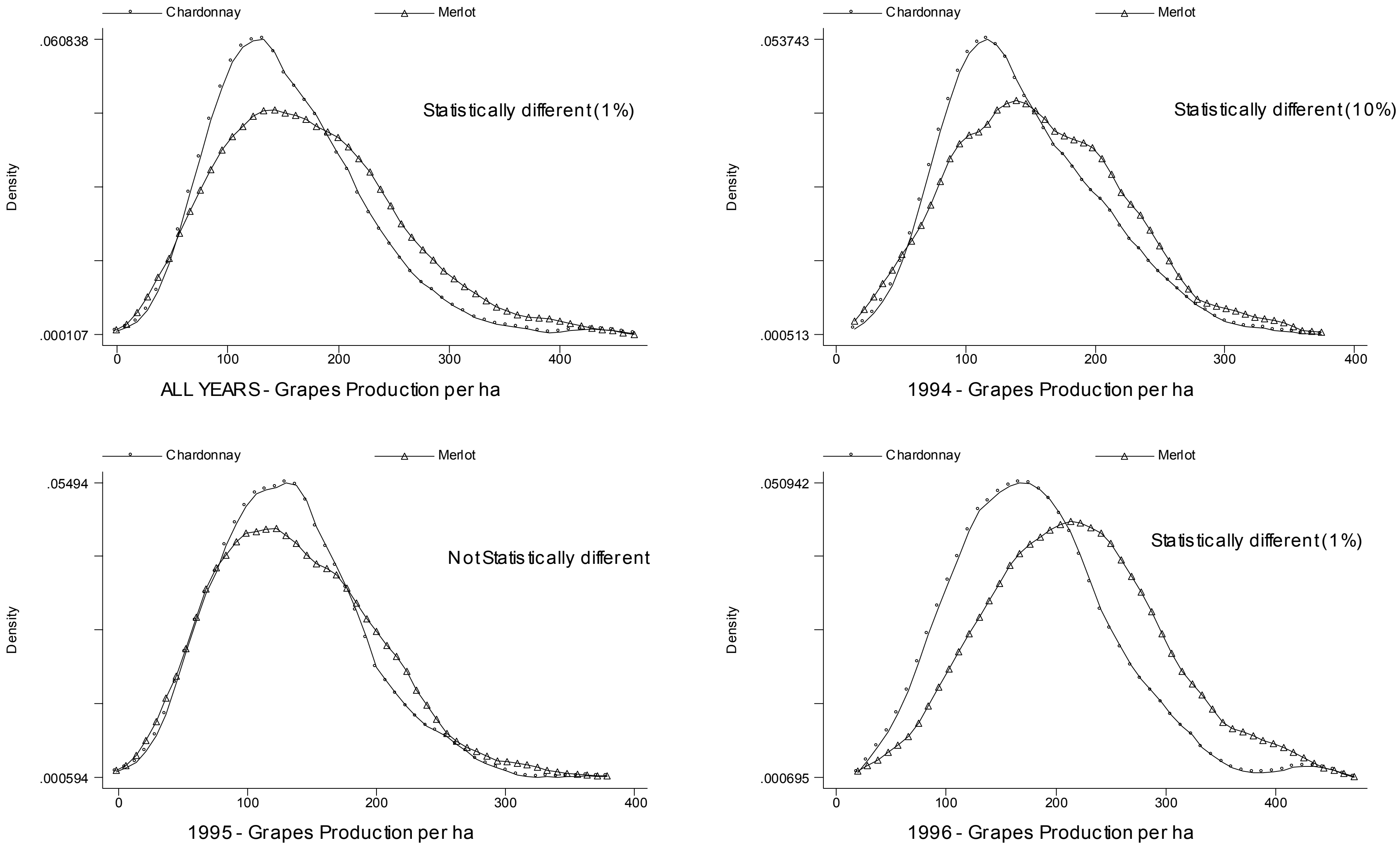


Figure 1. Grapes production per hectare in different years

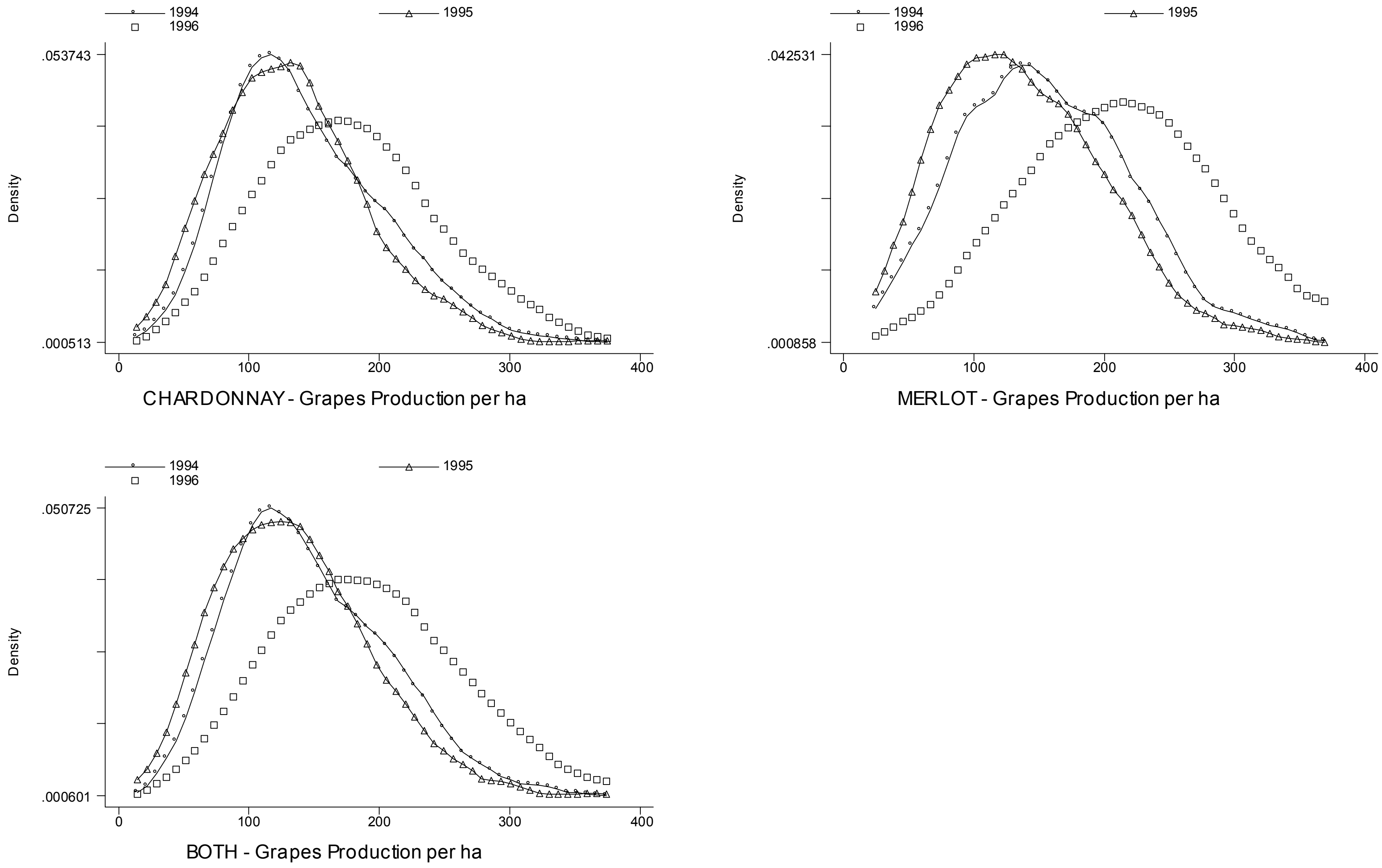


Figure 2. Grapes production per hectare

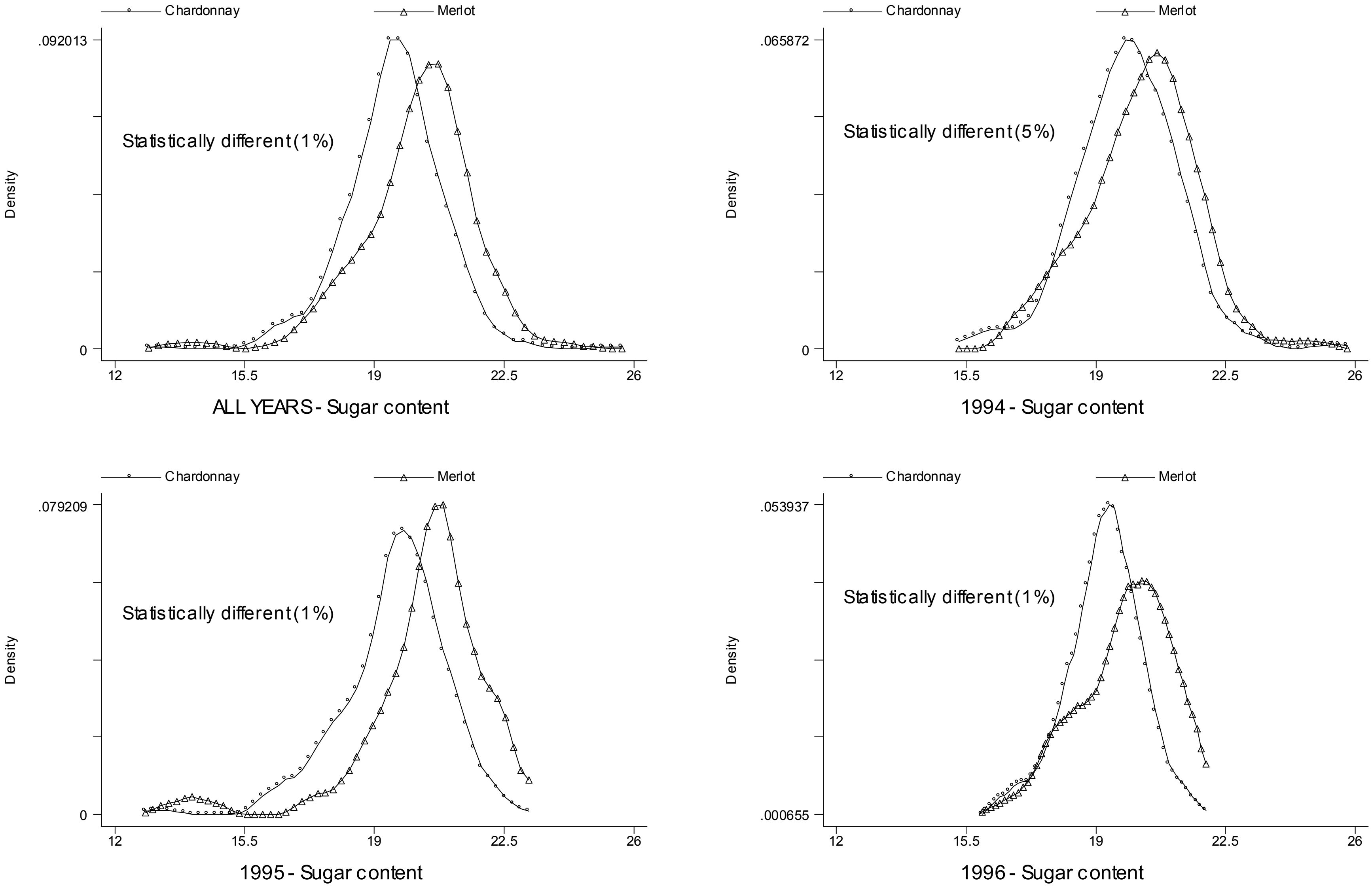


Figure 3. Sugar content in different years

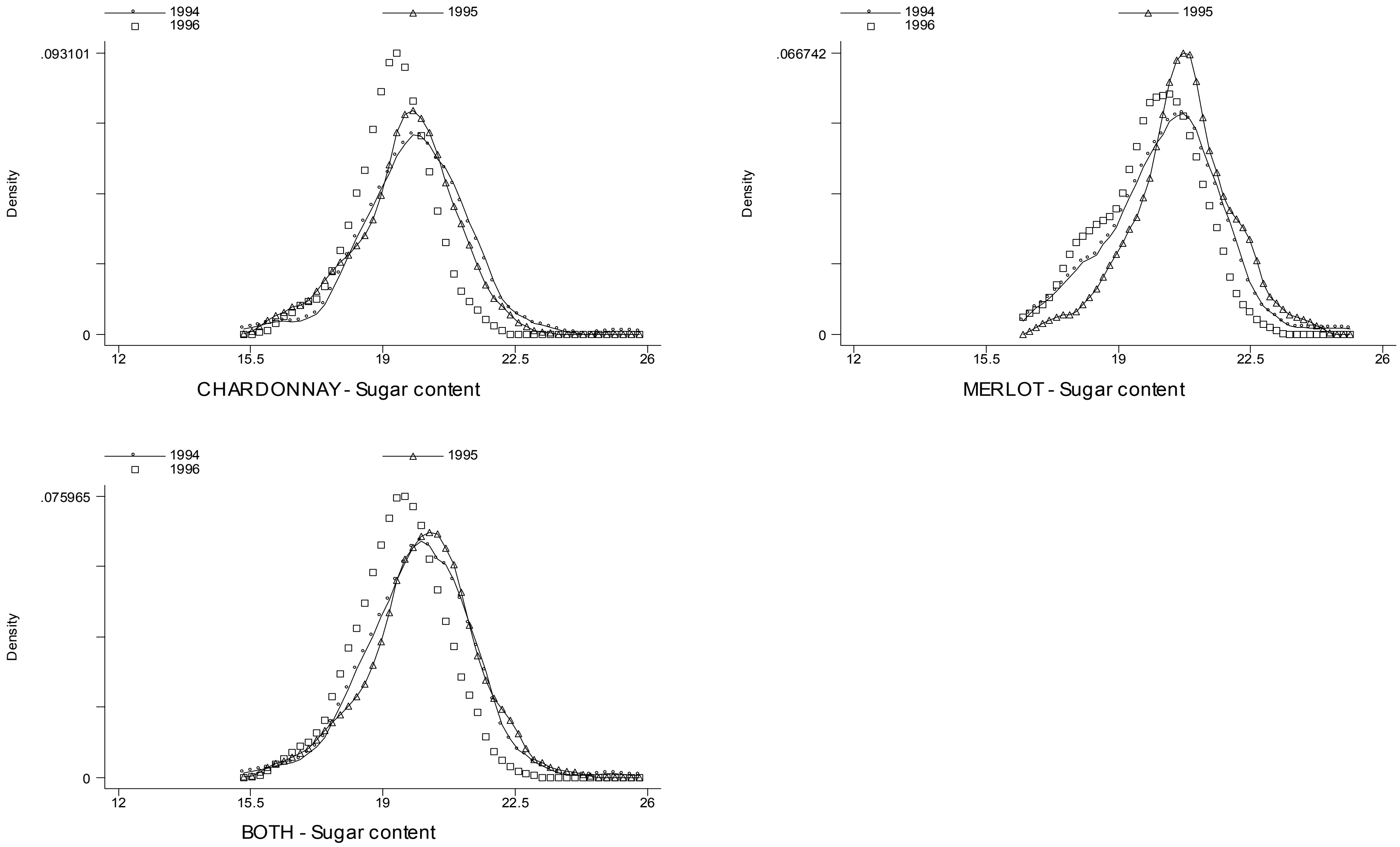


Figure 4. Sugar content

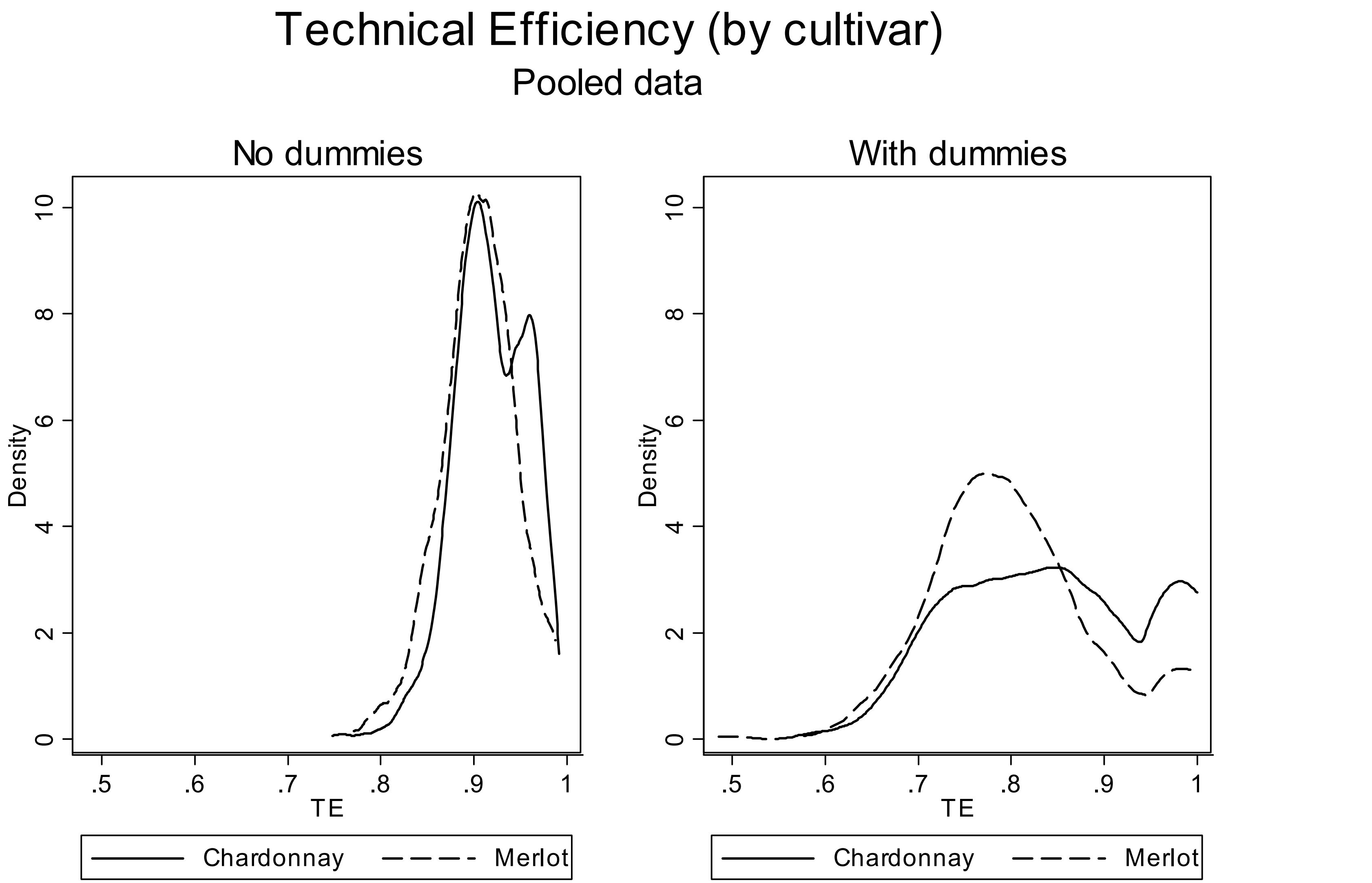

Technical Efficiency (by cultivar)
Pooled data
No dummies
With dummies
Density
TE
0
2
4
6
8
10
.5
.6
.7
.8
.9
1
Chardonnay
Merlot

Figure 5

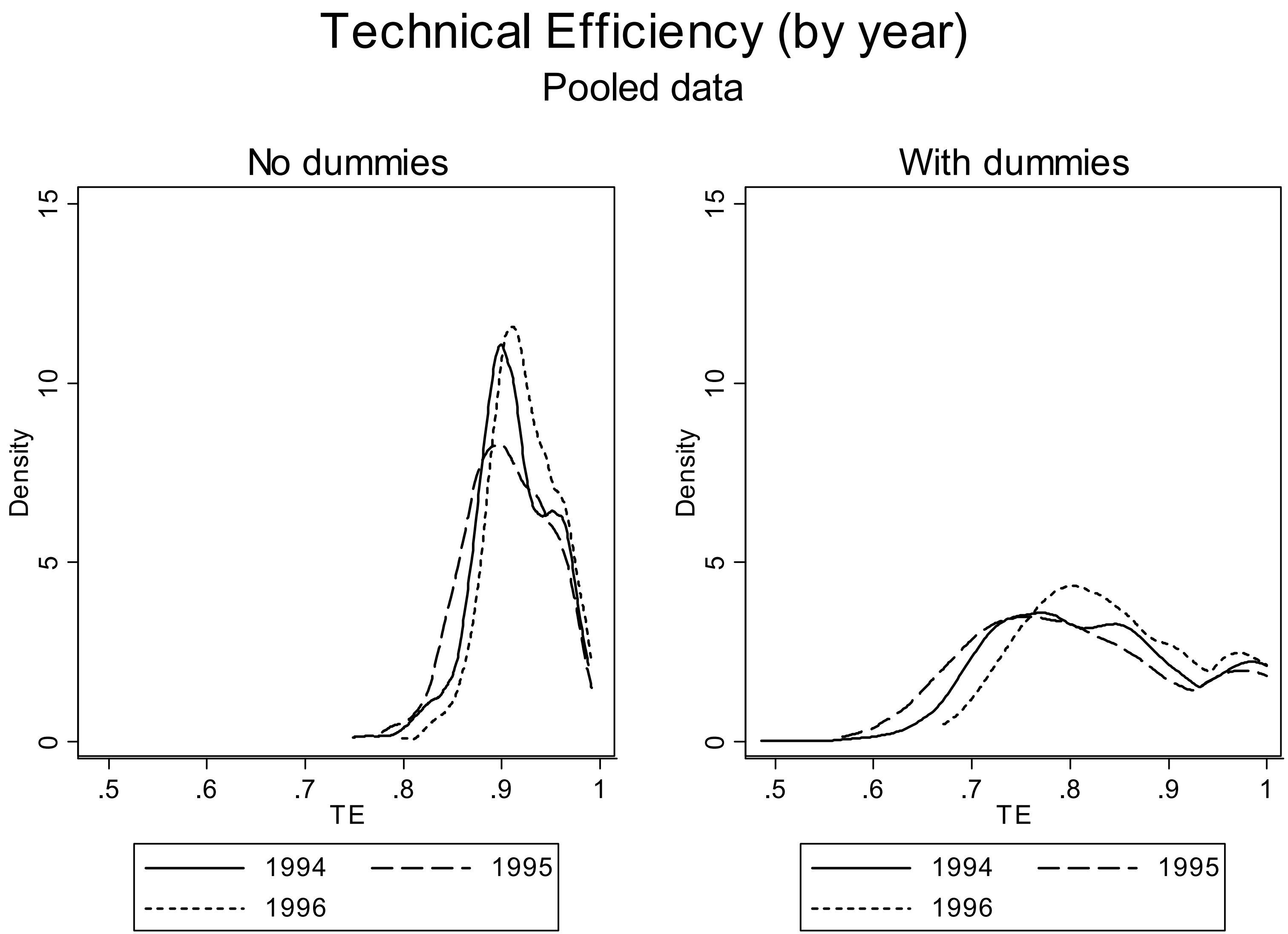

Technical Efficiency (by year)
Pooled data
No dummies
With dummies
Density
15
10
5
0
.5
.6
.7
.8
.9
1
TE
1994
1995
1996

Figure 6

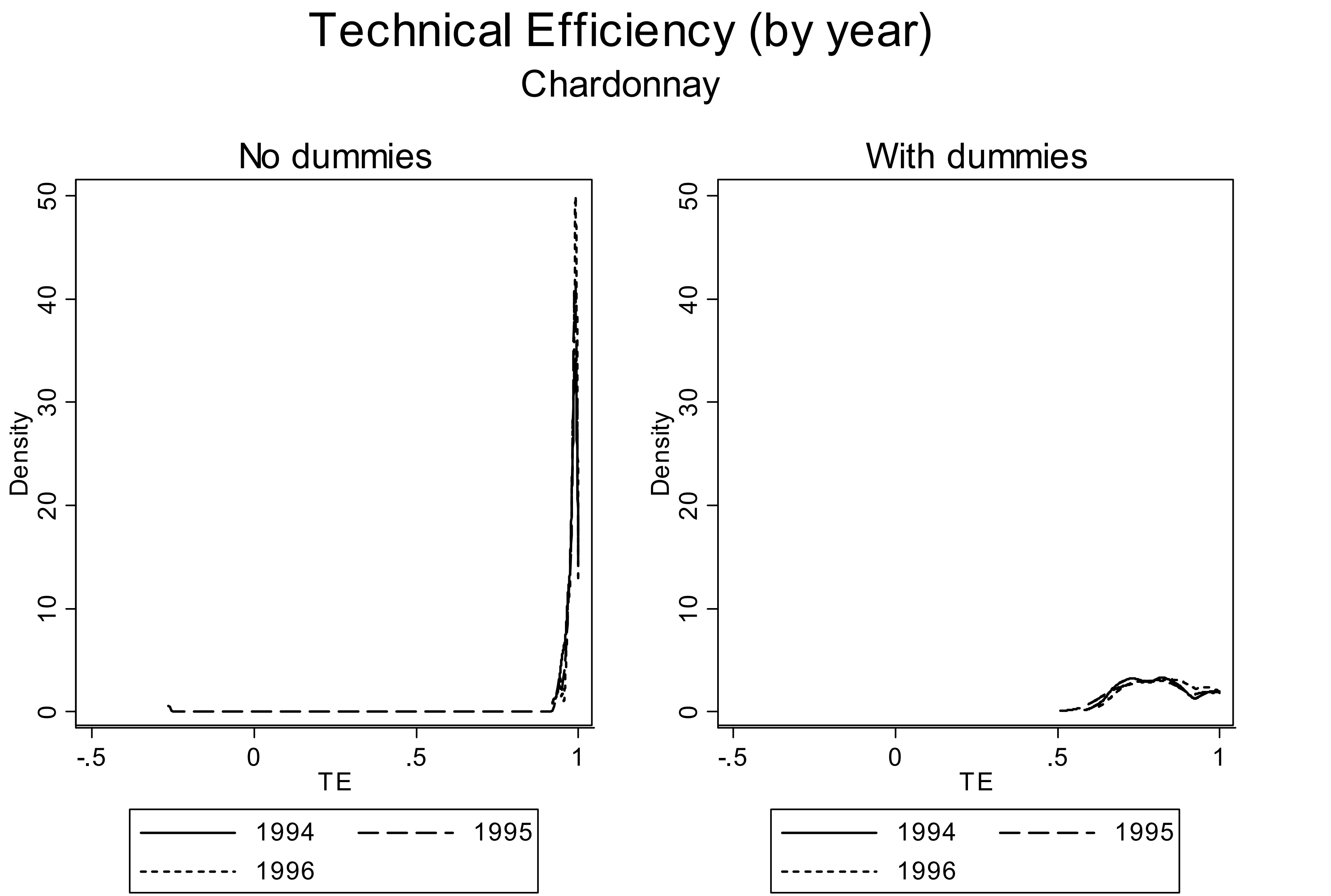
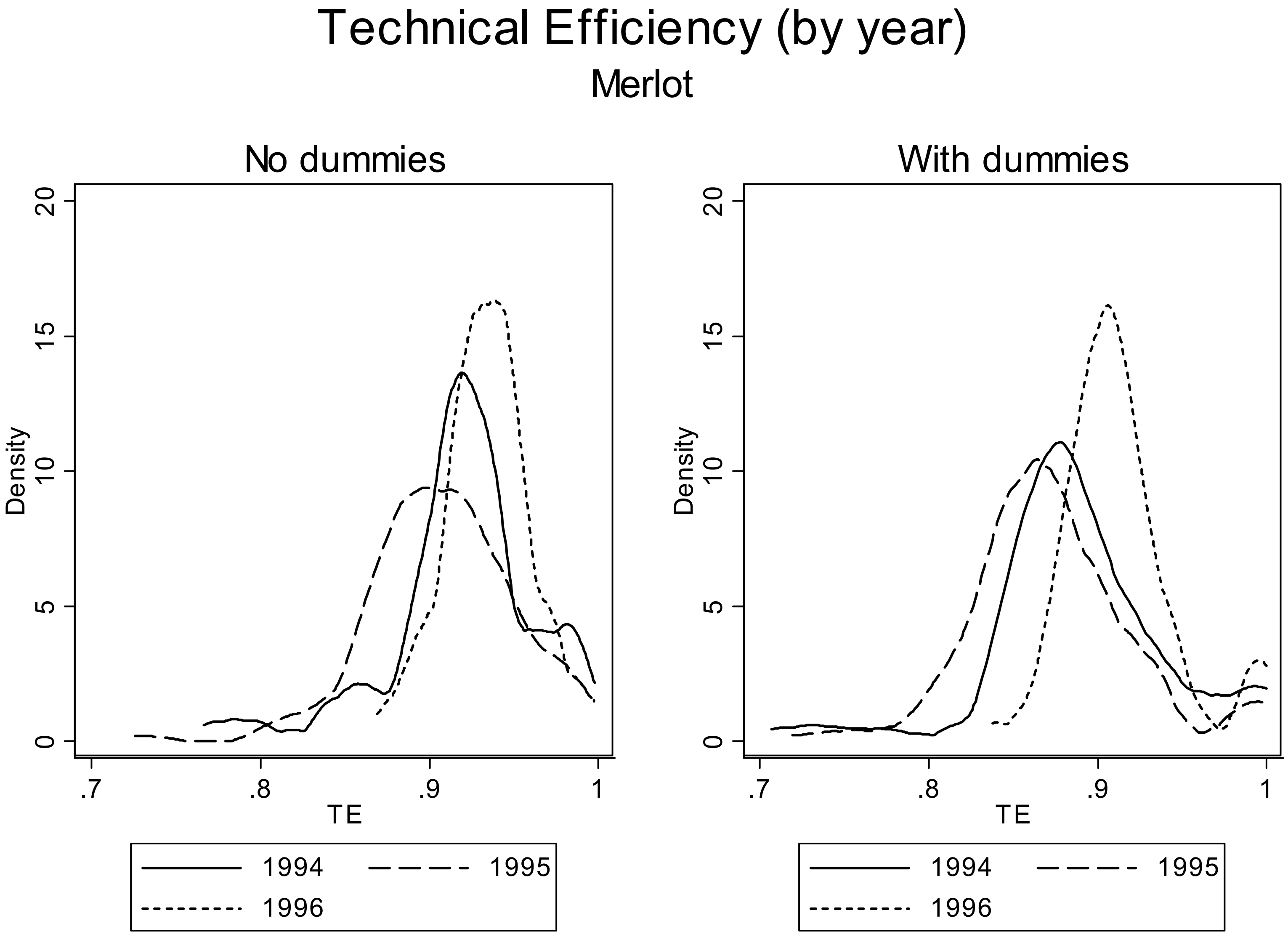

Technical Efficiency (by year)
Chardonnay
No dummies
With dummies
Density
0
10
20
30
40
50
-.5
0
.5
1
TE
1994
1995
1996

Figure 7



Technical Efficiency (by year)
Merlot
No dummies
With dummies
Density
TE
0
5
10
15
20
.7
.8
.9
1
1994
1995
1996

Figure 8

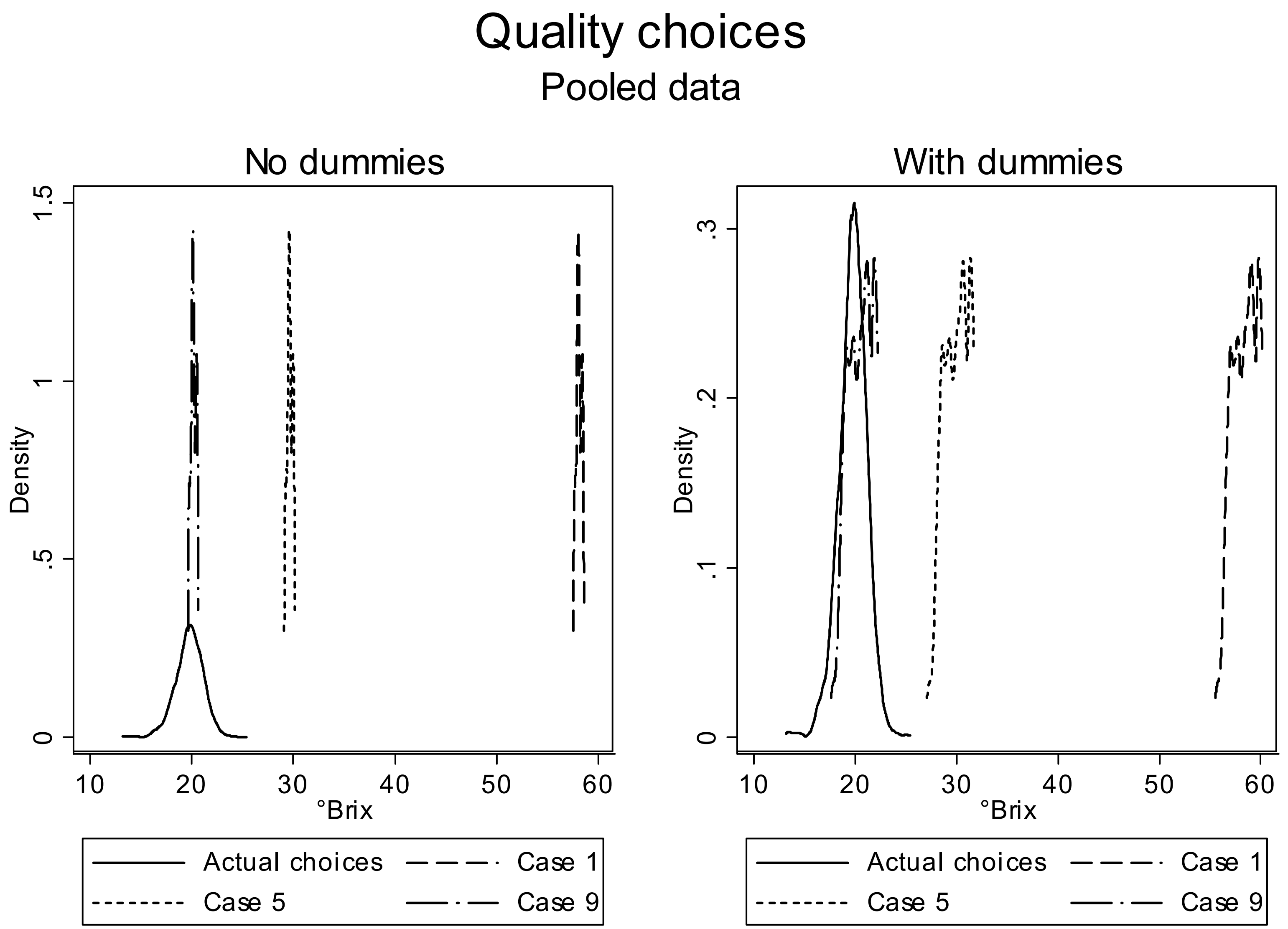
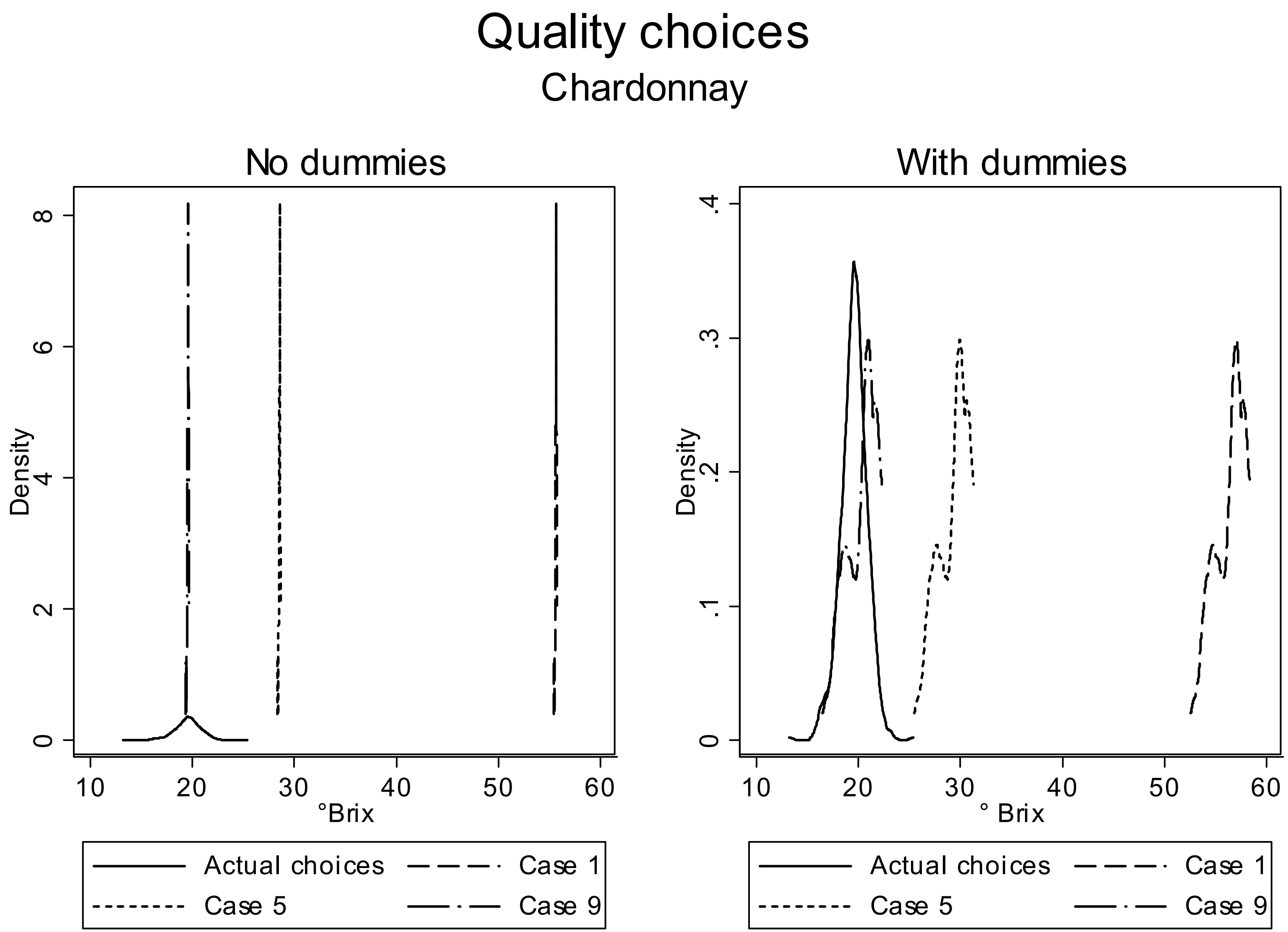
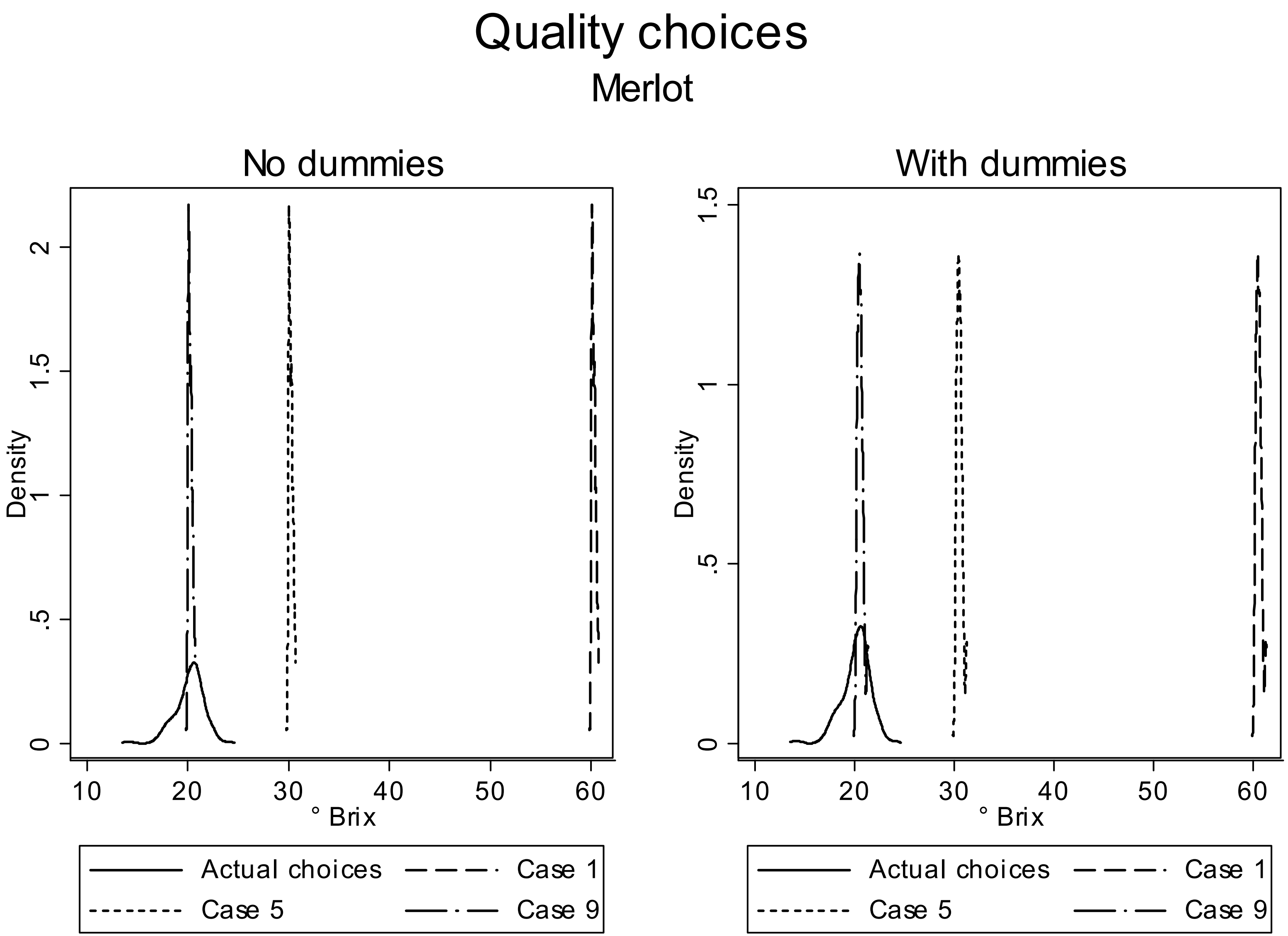

Quality choices
Pooled data
No dummies
With dummies
Density
°Brix
0
.5
1
1.5
.1
.2
.3
10
20
30
40
50
60
Actual choices
Case 1
Case 5
Case 9

Figure 9



Quality choices
Chardonnay
No dummies
With dummies
Density
0
2
4
6
8
0
.1
.2
.3
.4
10
20
30
40
50
60
°Brix
° Brix
Actual choices
Case 1
Case 5
Case 9

Figure 10



Quality choices
Merlot
No dummies
With dummies
Density
° Brix
0
.5
1
1.5
2
10
20
30
40
50
60
Actual choices
Case 1
Case 5
Case 9

Figure 11

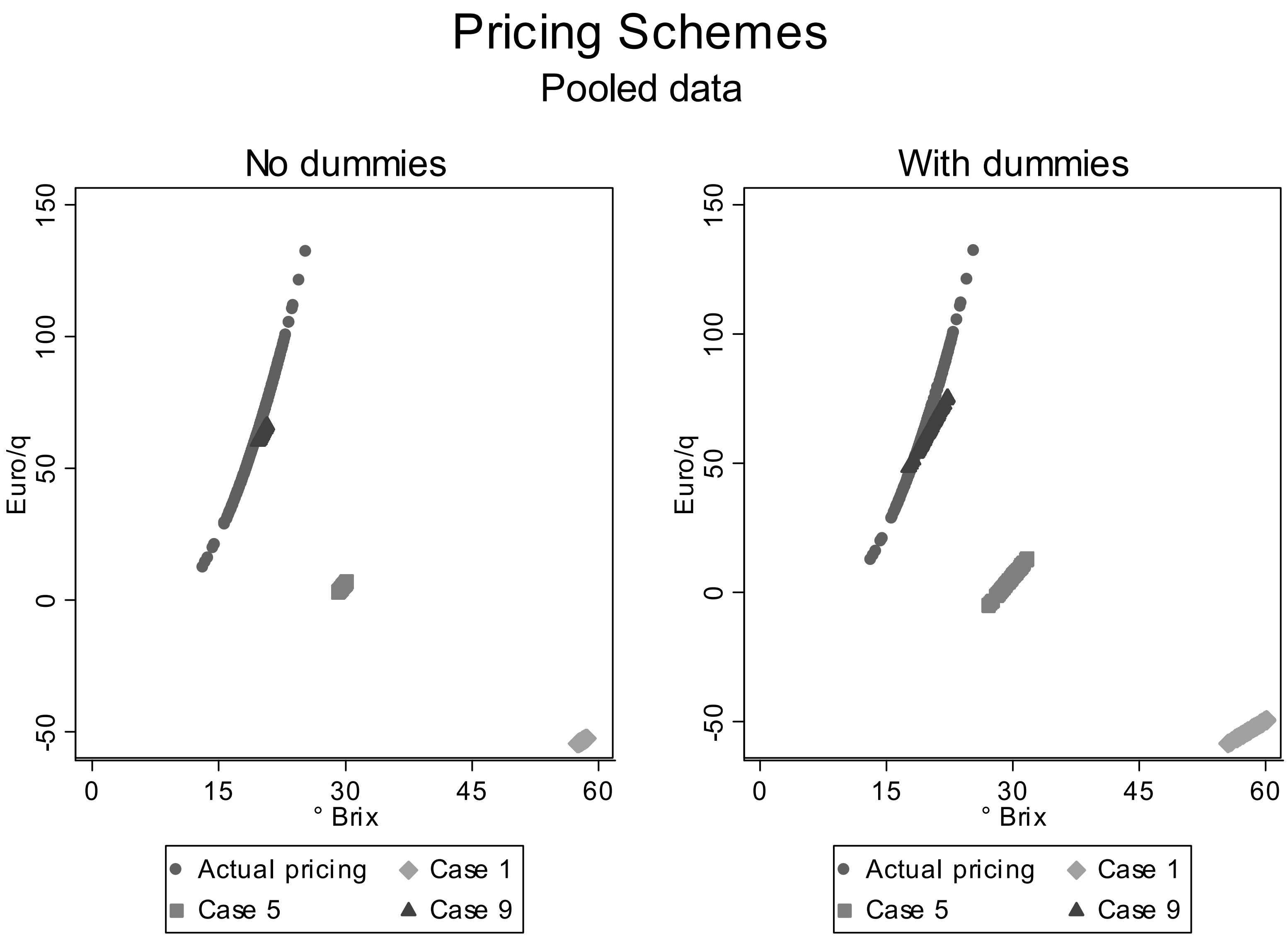

Pricing Schemes
Pooled data
No dummies
With dummies
Euro/q
-50
0
50
100
150
0
15
30
45
60
° Brix
Actual pricing
Case 1
Case 5
Case 9

Figure 12

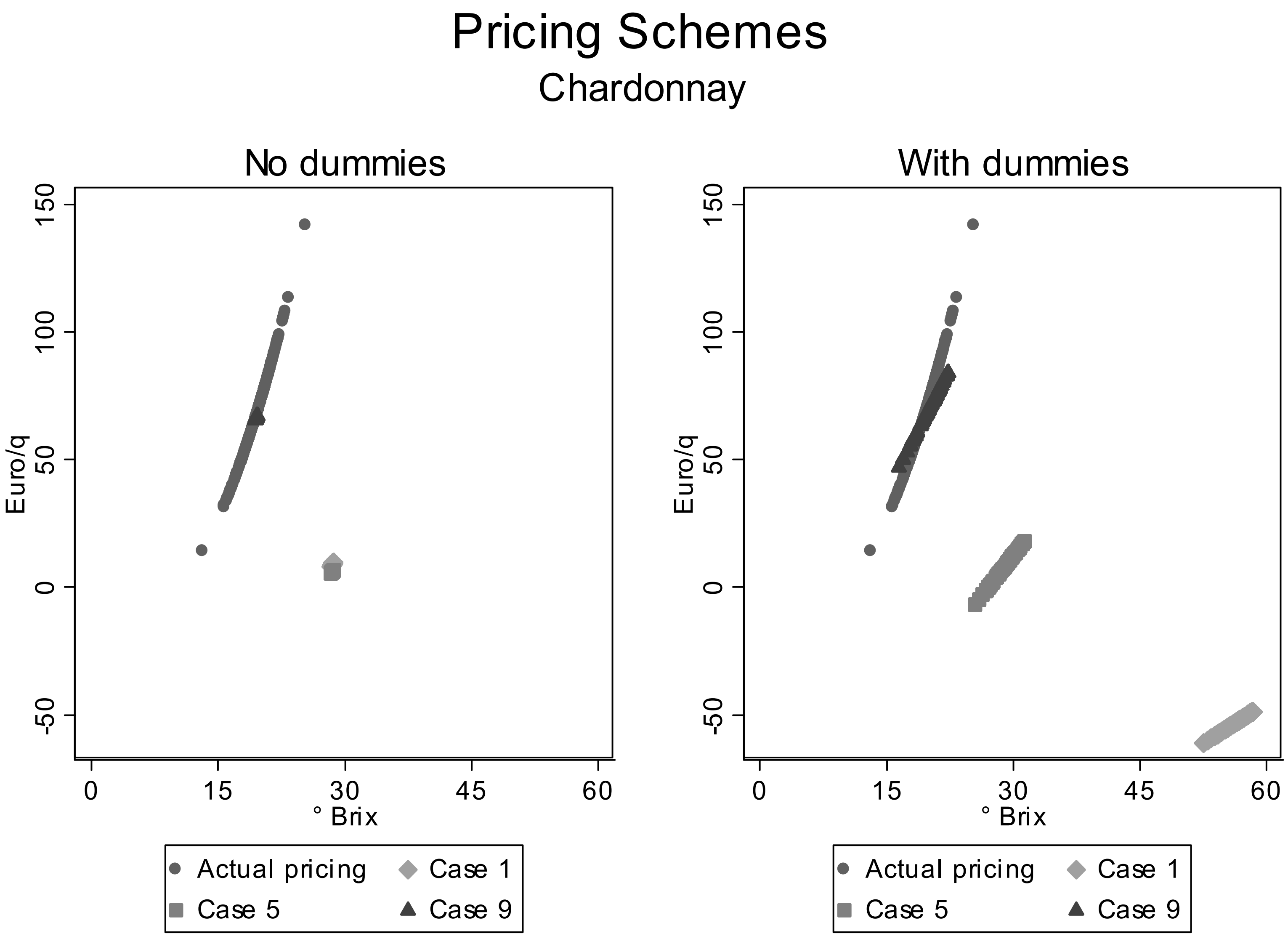

Pricing Schemes
Chardonnay
No dummies
With dummies
Euro/q
150
100
50
0
-50
0
15
30
45
60
° Brix
Actual pricing
Case 1
Case 5
Case 9

Figure 13

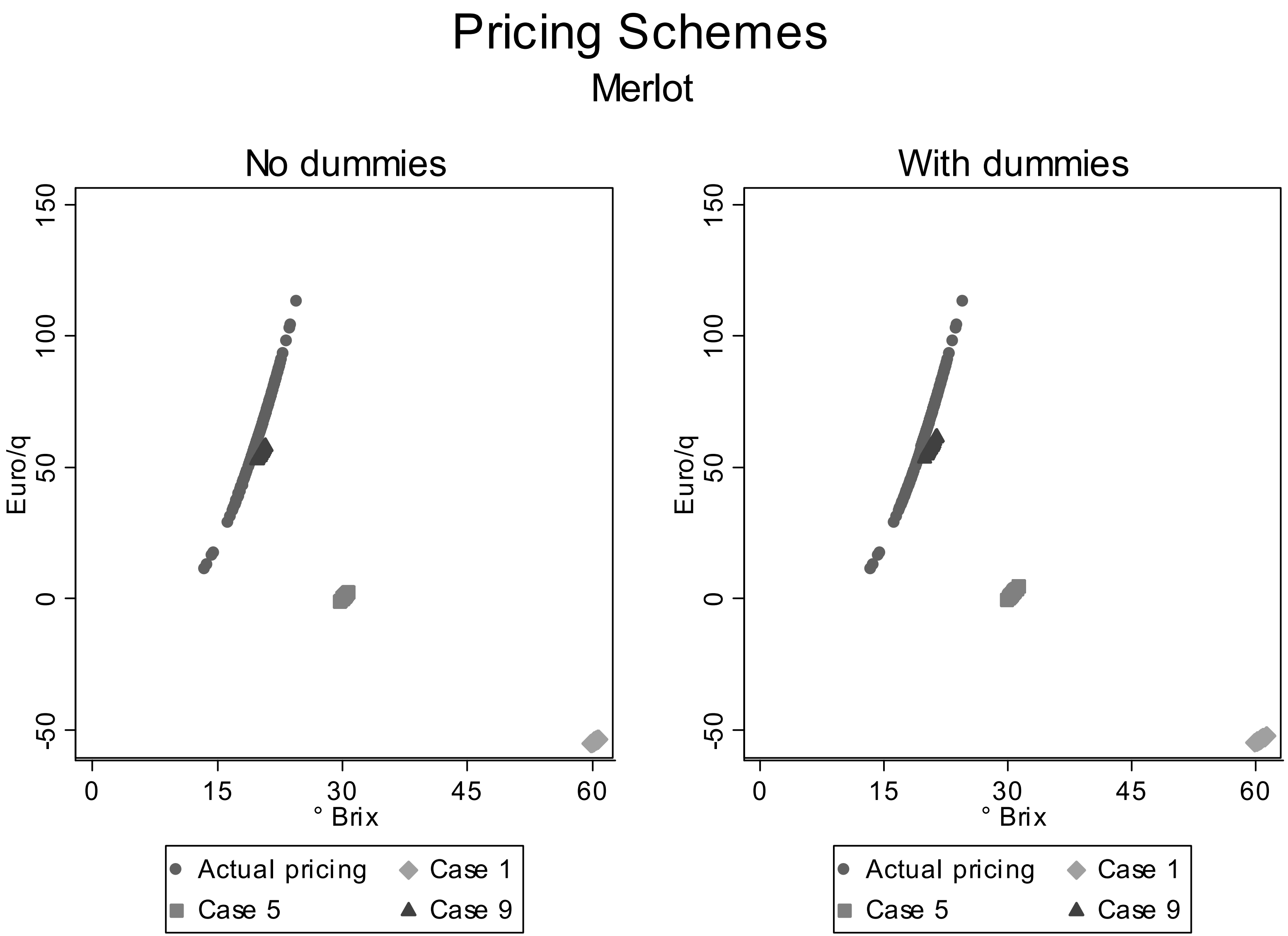

Pricing Schemes
Merlot
No dummies
With dummies
Euro/q
150
100
50
0
-50
0
15
30
45
60
° Brix
Actual pricing
Case 1
Case 5
Case 9

Figure 14

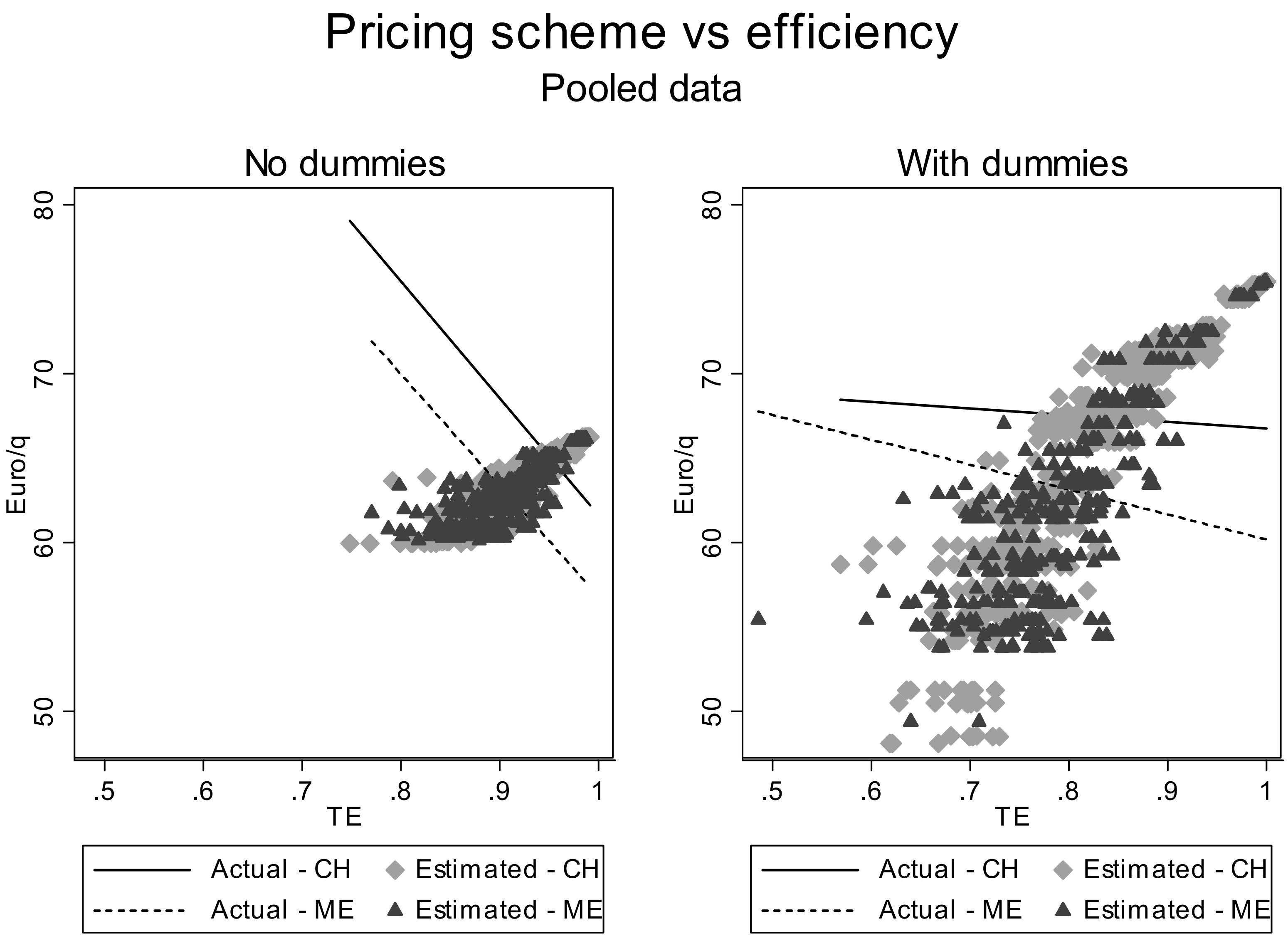

Pricing scheme vs efficiency
Pooled data
No dummies
With dummies
Euro/q
80
70
60
50
.5
.6
.7
.8
.9
1
TE
Actual - CH
Actual - ME
Estimated - CH
Estimated - ME

Figure 15