

Quality Estimation and Wine Industry Competitiveness

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Work in progress

1. Motivation

Measuring and evaluating the quality attributes of raw materials, commodities, and intermediate products is a common problem in many sectors.

Food industries, wine and grapes, milk and cheese, fruits and juices, beets or canes and sugar, beans and coffee, etc..

Other industries, chips and computers, ores and steel, steel and construction works, crude and refined oil.

2. Objectives and plan of the paper

We propose a methodology to measure the characteristics and composition of intermediate products, i.e., grapes for wine production, and we pursue two objectives:

1. we address the issue of how to measure quality attributes for intermediate goods using a **general representation of the technology**, i.e., using directional distance functions.

2. we evaluate how quality attributes **interact with quantity**. Policy reasons, e.g., self-regulation in Europe, like *appellation contrôlée* in wine.

We propose an indicator based on **directional distance functions**.

We compare firms based on the distance from the frontier along a **pre-assigned direction** which reflects the preference and needs of the buyer or downstream firm with respect to the quality attributes.

It may be the case that to be valuable to a downstream firm, the composition of the raw material has to be close to an “**ideal**” bundle of attributes preferred by the buyer.

3. Literature Review

Hedonic pricing literature;

Fixler and Zieschang (1992): using radial distance functions, the quality adjusted indexes are the product of two indexes, a quality index and a CCD-type Tornqvist productivity index;

Färe *et al.* (1992): input-oriented Malmquist productivity change index as the geometric mean of two Malmquist indexes as defined by CCD computed using linear programming;

Färe, Grosskopf and Roos (1995): extends this productivity index by incorporating attributes together with ratios of distance functions to measure the service quality of each pharmacy. They decompose

the Malmquist productivity change index into three components, quality change, technical change and efficiency change;

Jaenicke and Lengnick (1999): merge the soil science literature on soil-quality indexes with the literature on efficiency and total factor productivity indexes, and isolate a theoretically preferred soil-quality index;

Färe *et al.* (1989) extend efficiency measurement when some outputs are undesirable; notion of **weak disposability** of outputs.

4. Methodology

Here directional distance function which allows to measure firms' distance from the frontier moving along a pre-assigned direction.

We propose an **indicator**: an output aggregator expressed in difference forms, rather than in ratio forms like in the case of the Malmquist productivity index.

From the property of translation invariance in outputs, to contrast with the property of homogeneity of degree zero in outputs of the Malmquist index coming from the linear homogeneity of the output distance function à la Shephard.

Following Chambers, Chung, and Färe (1996, 1998), and Chambers (2002), we can define the **directional technology distance function** as:

$$\overline{D}_T(\mathbf{x}, y, \mathbf{s}; \mathbf{g}_x, g_y, \mathbf{g}_s) = \max\{\beta \in \mathcal{R} : (\mathbf{x} - \beta \mathbf{g}_x, y + \beta g_y, \mathbf{s} + \beta \mathbf{g}_s) \in T\},$$

$$\mathbf{g}_x \in \mathcal{R}_+^N, g_y \in \mathcal{R}_+, \mathbf{g}_s \in \mathcal{R}_+^M, (\mathbf{g}_x, g_y, \mathbf{g}_s) \neq (0^N, 0, 0^M),$$

if $(x - \beta g_x, y + \beta g_y, s + \beta g_s) \in T$ for some β and $dT(y, s, g_y, g_s) =$
 $\inf\{\delta \in \mathcal{R} : (y + \delta g_y \in \mathcal{R}_+, s + \delta g_s \in \mathcal{R}_+^M)\}$ otherwise.

Note that (g_x, g_y, g_s) is a reference vector of inputs and outputs which determines the direction over which the distance function is determined. $\overline{D}_T(x, y; g_x, g_y, g_s)$ represents the maximal translation of the input and output vector in the direction of (g_x, g_y, g_s) that keeps the translated input and output vector inside T .

As shown by Chambers, Chung, and Färe (1996), all known (radial) distance and directional distance functions can be depicted as special cases of the directional technology distance function.

Here, **directional quality distance function** with the following:

$$\overline{D}_Q(\mathbf{x}, y, \mathbf{s}; 0^N, 0, \mathbf{g}_s) = \max\{\beta \in \mathcal{R} : (\mathbf{x}, y, \mathbf{s} + \beta \mathbf{g}_s) \in T\}, \quad (1)$$

$$\mathbf{g}_s \in \mathcal{R}_+^M, \mathbf{g}_s \neq 0^M.$$

In this paper we are interested in constructing an **indicator** of quality attributes of the output. Its general purpose is that it can create a summary measure of inputs or outputs that can be used to evaluate how these aggregate quantities vary across firms (or time).

Adapting the indicators suggested by Chambers (2002), we can define the **1-technology Luenberger quality indicator** for (x^1, y^1, s^1, s^0) by the following:

$$Q^1(s^0, s^1, y^1, x^1) = \overline{D}_Q^1(x^1, y^1, s^0; 0^N, 0, g_s) - \overline{D}_Q^1(x^1, y^1, s^1; 0^N, 0, g_s). \quad (2)$$

$Q^1(s^0, s^1, y^1, x^1)$ represents the difference between the amount that it is possible to translate s^0 and s^1 into the direction g_s and still keep both quality bundles in the output set of firm 1, i.e., we are referring to firm's 1 technology or input-output bundle (x^1, y^1) .

See figure 1.

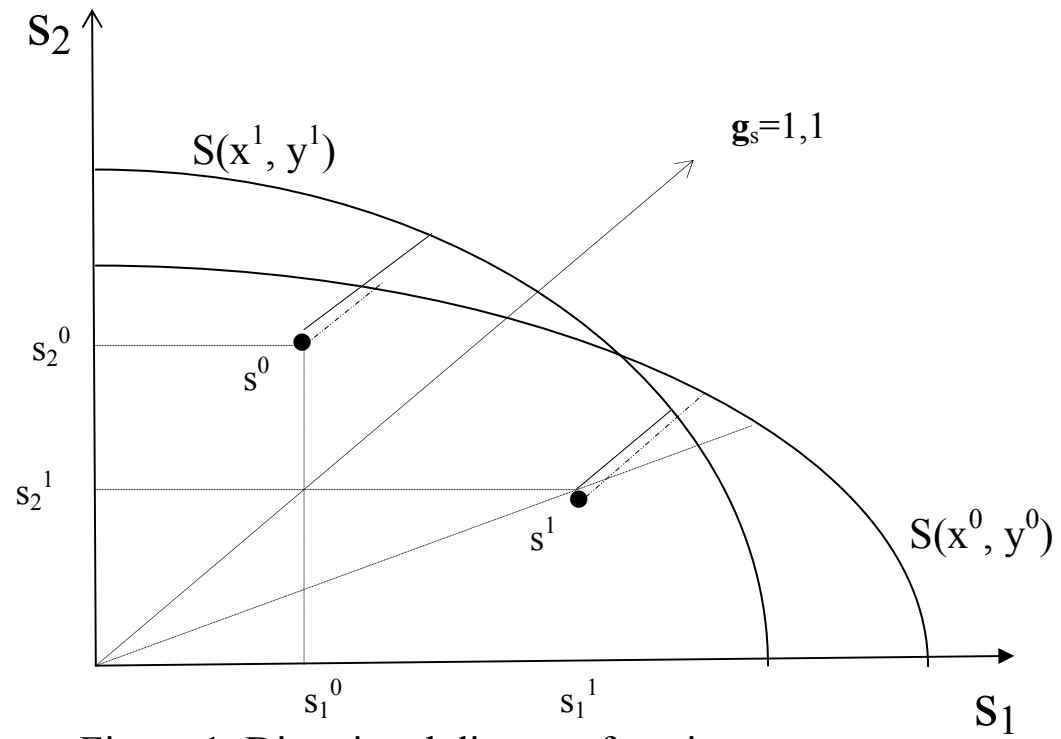


Figure 1. Directional distance function

The **0-technology Luenberger quality indicator** for (x^0, y^0, s^1, s^0) is defined by the following:

$$Q^0(\mathbf{s}^0, \mathbf{s}^1, y^0, \mathbf{x}^0) = \overline{D}_Q^0(\mathbf{x}^0, y^0, \mathbf{s}^0; 0^N, 0, \mathbf{g}_s) - \overline{D}_Q^0(\mathbf{x}^0, y^0, \mathbf{s}^1; 0^N, 0, \mathbf{g}_s). \quad (3)$$

Here we are computing the indicator from firm 0's perspective, since we consider its input-output bundle (x^0, y^0) . If $Q^0(s^0, s^1, y^0, x^0) > 0$, the quality is higher for firm 1 than firm 0, using as a reference firm 0's technology or input-output bundle (x^0, y^0) .

The choice of the technology can affect the results. Thus the **Luenberger quality indicator** is the average of $Q^1(s^0, s^1, y^1, x^1)$ and $Q^0(s^0, s^1, y^0, x^0)$:

$$Q(\mathbf{s}^0, \mathbf{s}^1, y^0, y^1, \mathbf{x}^0, \mathbf{x}^1) = \frac{1}{2} \left(Q^1(\mathbf{s}^0, \mathbf{s}^1, y^1, \mathbf{x}^1) + Q^0(\mathbf{s}^0, \mathbf{s}^1, y^0, \mathbf{x}^0) \right). \quad (4)$$

5. Activity analysis and empirical implementation

We use DEA to envelop the technology associated with a cross-section sample of firms. Referring to a VRS technology, the linear program problem to solve to compute the **directional quality distance function** for each observation k' , is the following :

$$\begin{aligned} \bar{D}_o(\mathbf{x}', y', \mathbf{s}'; 0^N, \mathbf{g}_y, \mathbf{g}_s) = \max \beta : \\ \sum_{k=1}^K z_k y_k \geq y_{k'}, \\ \sum_{k=1}^K z_k s_{km} \geq s_{k'm} + \beta \mathbf{g}_s, m = 1, \dots, M, \\ \sum_{k=1}^K z_k x_{kn} \leq x_{k'n}, n = 1, \dots, N, \\ \sum_{k=1}^K z_k = 1, k = 1, \dots, K, \end{aligned} \quad (5)$$

where g_y and g_s are the direction vectors for output and quality attributes respectively.

1. The quality indicators

To compute the quality indicator proposed, we need to use and compute four different quality directional distance functions.

The **direction vector** g_s has to be specified. One possibility is to consider the average attributes content of the grapes for the whole sample of firms, i.e., $g_s = \bar{\mathbf{s}}_m$, where $\bar{s}_m = \sum_{k=1}^K \frac{s_{km}}{K}$ and $m = 1, \dots, M$.

Another choice is the ideal composition of the good.

The choice of the **reference observation (the base)**, to have the 0-technology, allows for different options. The *average* of the observations defined by:

$$\mathbf{s}^0 = \sum_{k=1}^K \frac{S_{km}}{K}, \quad m = 1, \dots, M,$$

$$\mathbf{x}^0 = \sum_{k=1}^K \frac{x_{kn}}{K}, \quad n = 1, \dots, N,$$

$$y^0 = \sum_{k=1}^K \frac{y_k}{K}.$$

Possible drawback, it may lead to an unrealistic artificial technology, i.e., to a not feasible input/output combination.

Another possibility could be the *minimum quality* composition required by the law or by industry standards, the one that all firms should provide as a minimum requirement.

Once we obtain the results, we will look at the **distribution of the indicators** smoothed using standard normal kernel function and optimal bandwidth:

$$f(x) = \frac{1}{Kh} \sum_{j=1}^K k\left(\frac{x_j - x}{h}\right). \quad (7)$$

A more formal statistical analysis based on the kernels is the Li's nonparametric testing of closeness between two unknown distribution functions.

It tests the null that two distributions, e.g., $f(x)$ and $g(x)$, are identical, i.e., $H_0 : f(x) = g(x)$ for all x , against the alternative that they are different, that is $H_1 : f(x) \neq g(x)$ for all x .

The Li's T-statistic is asymptotically distributed as a standard normal with a critical value of 2.33 (1% significance level).

2. The quality-quantity trade off

To evaluate the trade-off between output quantity and aggregate quality, it is a natural choice to look at the **relationship between the quality indicators and the yields.**

We consider the different options used for the direction vector g_s , and show the relationship via a graphical representation using lowess smoothing, a scatterplot smoothing technique based on a locally weighted regression of a y variable - the quality indicator in our case - on an x variable, i.e., the yields.

In lowess, the regression is weighted to give the highest weight to the point and less to those that are farther away. Lowess thus tends to follow the data, because of its locality.

6. The data

We use data provided by the “Istituto Agrario di San Michele all’Adige”, located near Trento, in the Northern Italian Alps.

3 years: 1994, 1995 and 1996;

2 varieties: Chardonnay and Merlot.

On the input side, we have the following

- altimetry,
- number of vines per hectare,
- the depth of the roots, a categorical variable (1-3),
- the water reservoir, in the range 1-4,
- total calcium, 1-5,
- skeleton, a categorical variable (1-4),
- internal drainage, a categorical variable (1-5),

- external drainage, a categorical variable (1-3).

Then variables more “in the control of the producers”, 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.

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

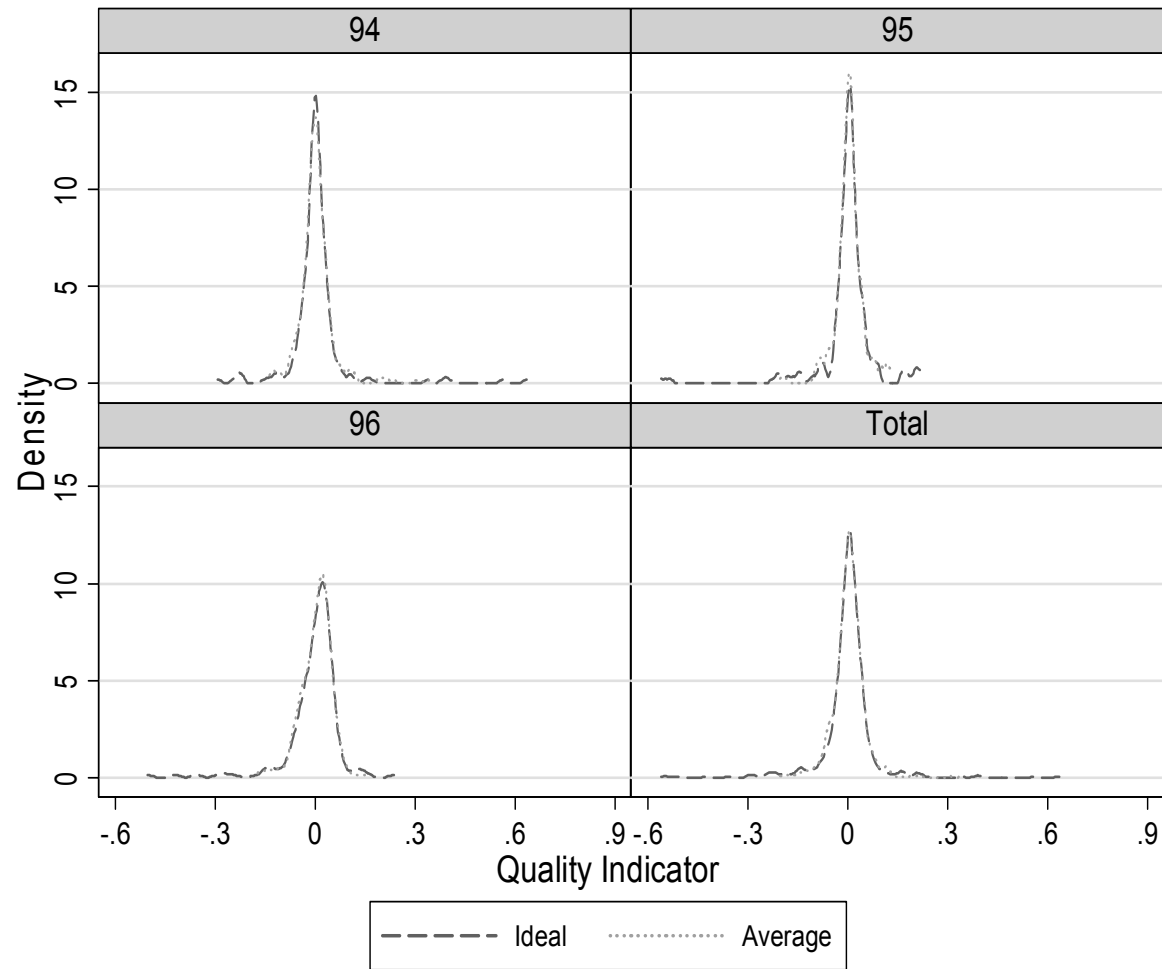
- production per hectare,
- sugar content (measured in degree Brix),
- tartaric acid,
- malic acid,
- potassium,
- pH,
- total acidity.

Variable	Unit of measure
Altimetry	mt.
Vines per hectare	no.
Buds per branch	no.
Water holding capacity	1-4
Total calcium	1-5
Grapes production per ha	0.1 t./ha
Sugar content	°Brix
Total acidity	gr./l.
pH	1-14
Tartaric acidity	gr./l.
Malic acidity	gr./l.
Potassium content	gr./l.

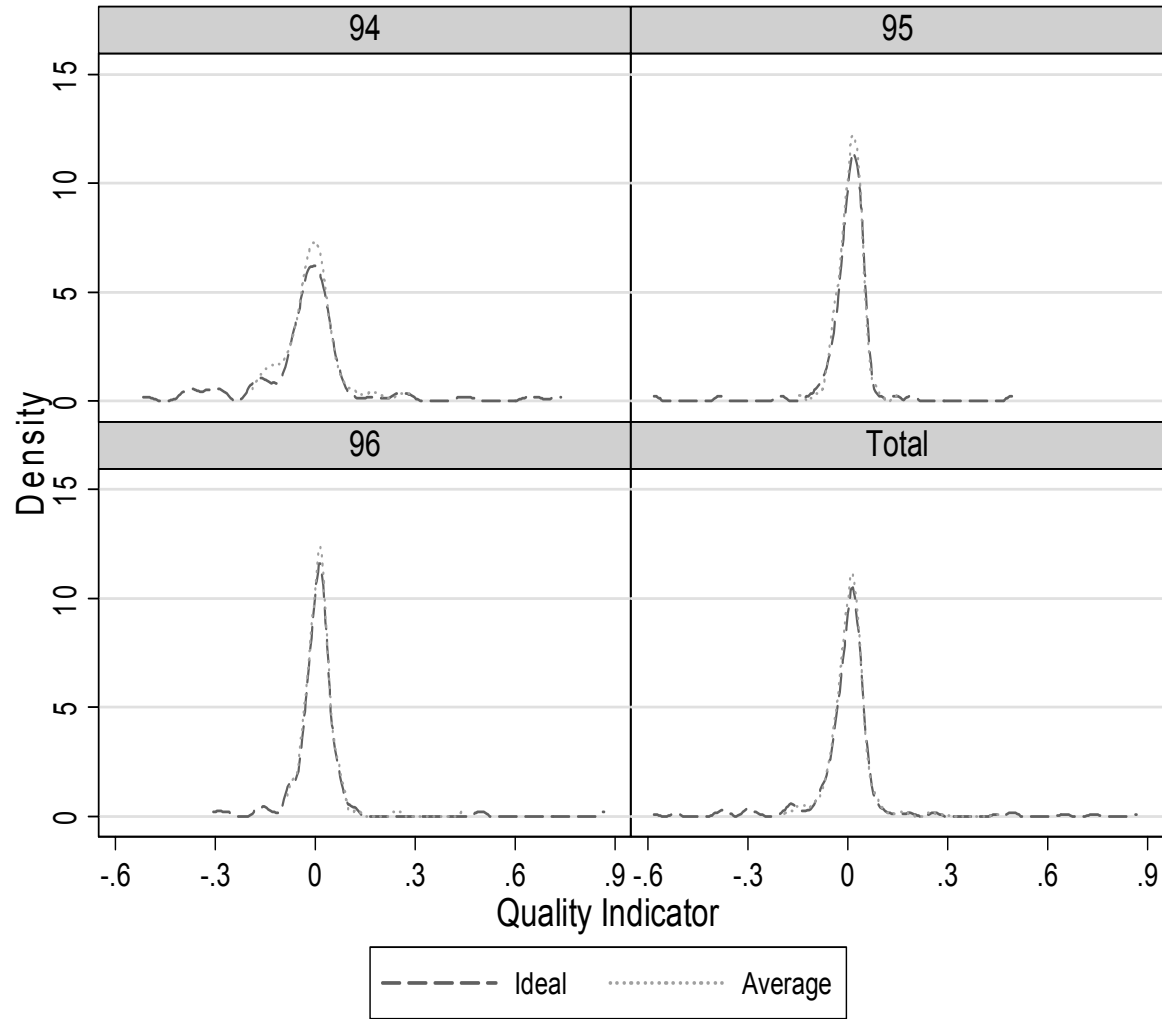
7. Results

Table 4. Luenberger Quality Indicators

	No. obs.	Mean	St. dev.	Min	Max
Chardonnay					
Average					
1994	214	0.004	0.056	-0.137	0.349
1995	187	0.005	0.044	-0.216	0.130
1996	213	0.004	0.047	-0.173	0.164
Ideal					
1994	214	0.006	0.091	-0.292	0.636
1995	187	0.000	0.085	-0.559	0.217
1996	213	-0.003	0.079	-0.503	0.238
Merlot					
Average					
1994	78	-0.011	0.082	-0.188	0.286
1995	127	0.008	0.037	-0.145	0.151
1996	120	0.014	0.058	-0.083	0.451
Ideal					
1994	78	-0.018	0.181	-0.517	0.739
1995	127	0.005	0.088	-0.581	0.494
1996	120	0.011	0.108	-0.306	0.869



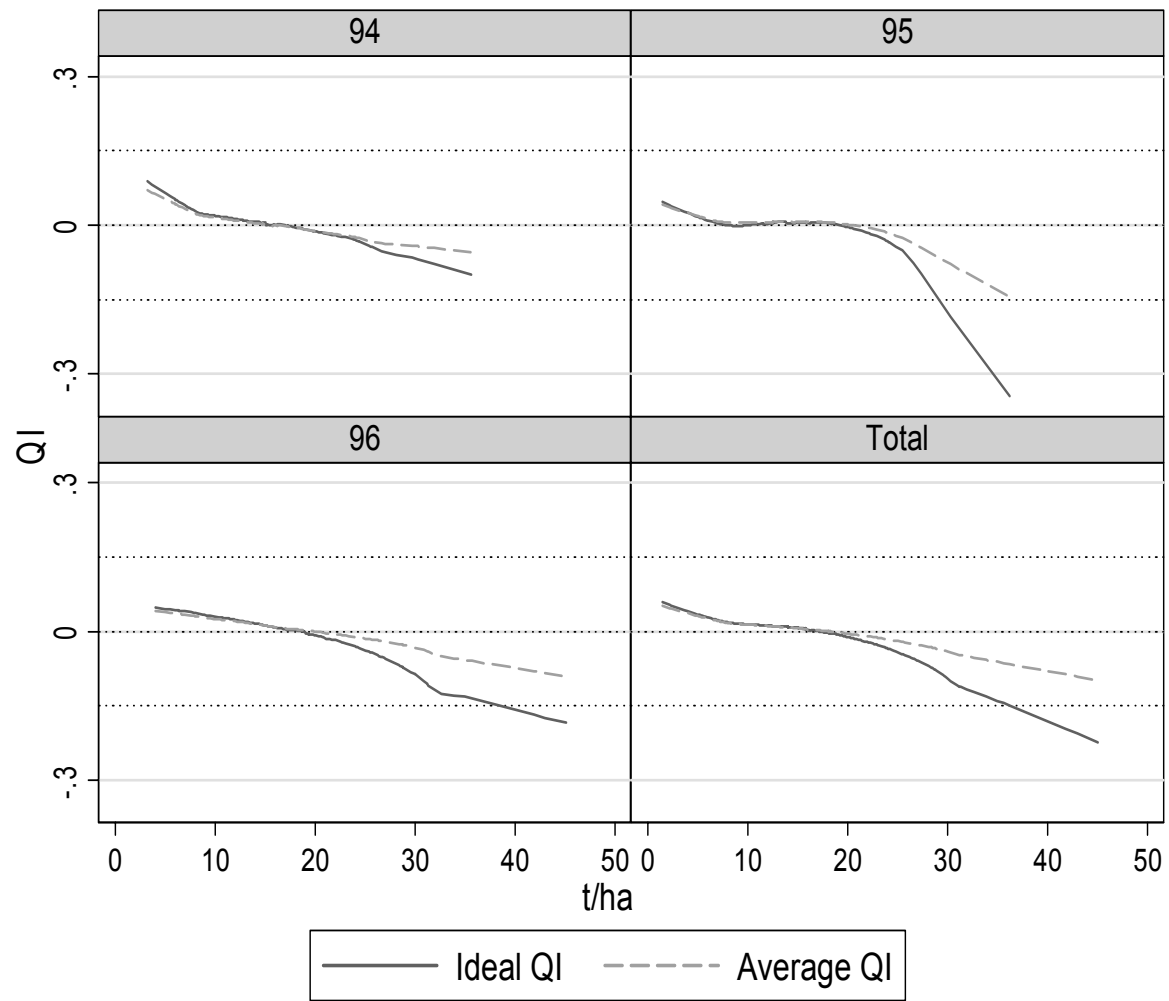
Distributions of Quality Indicators – Chardonnay



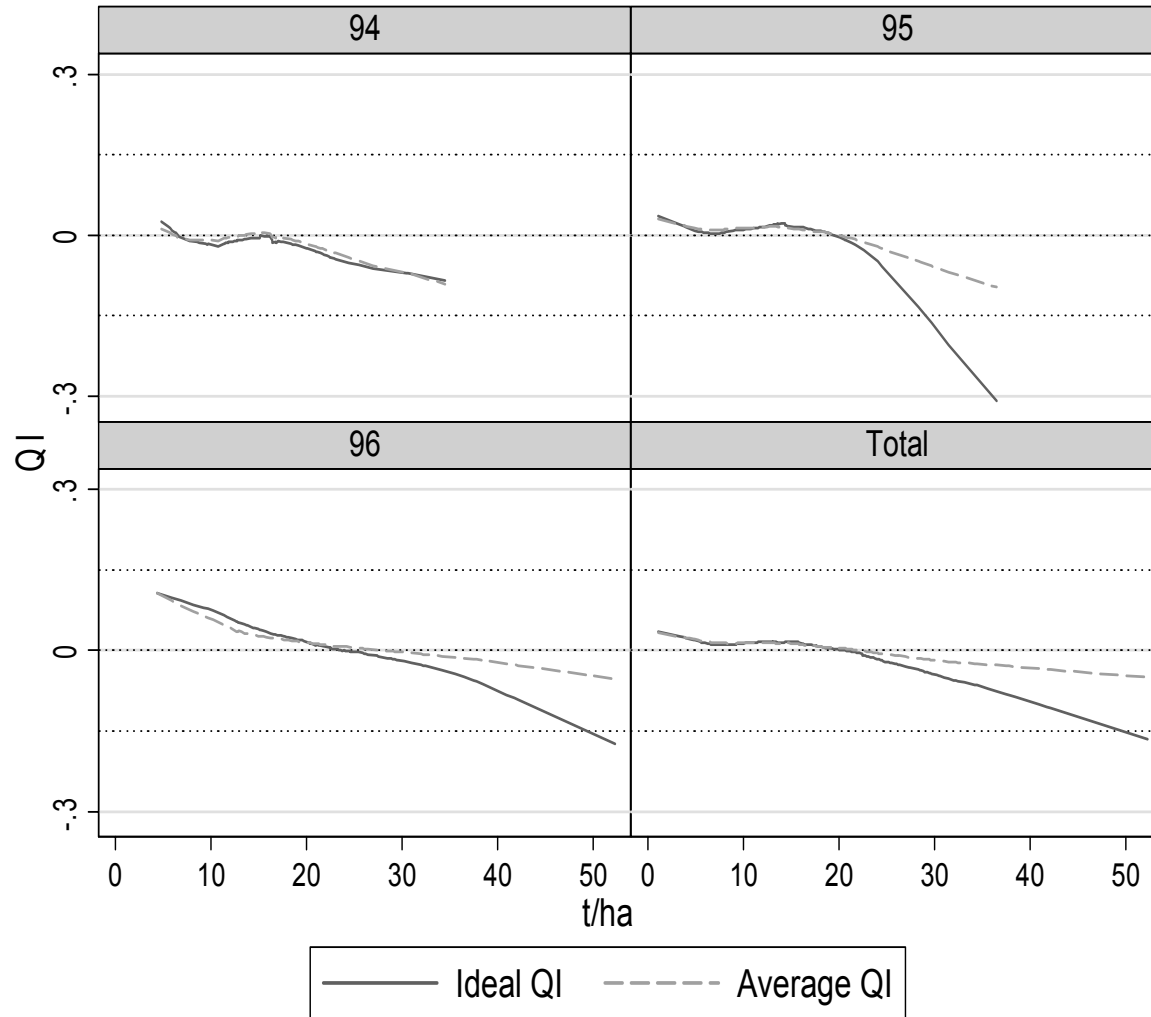
Distributions of Quality Indicators – Merlot

Table 3. Li's tests for returns to scale & direction vectors

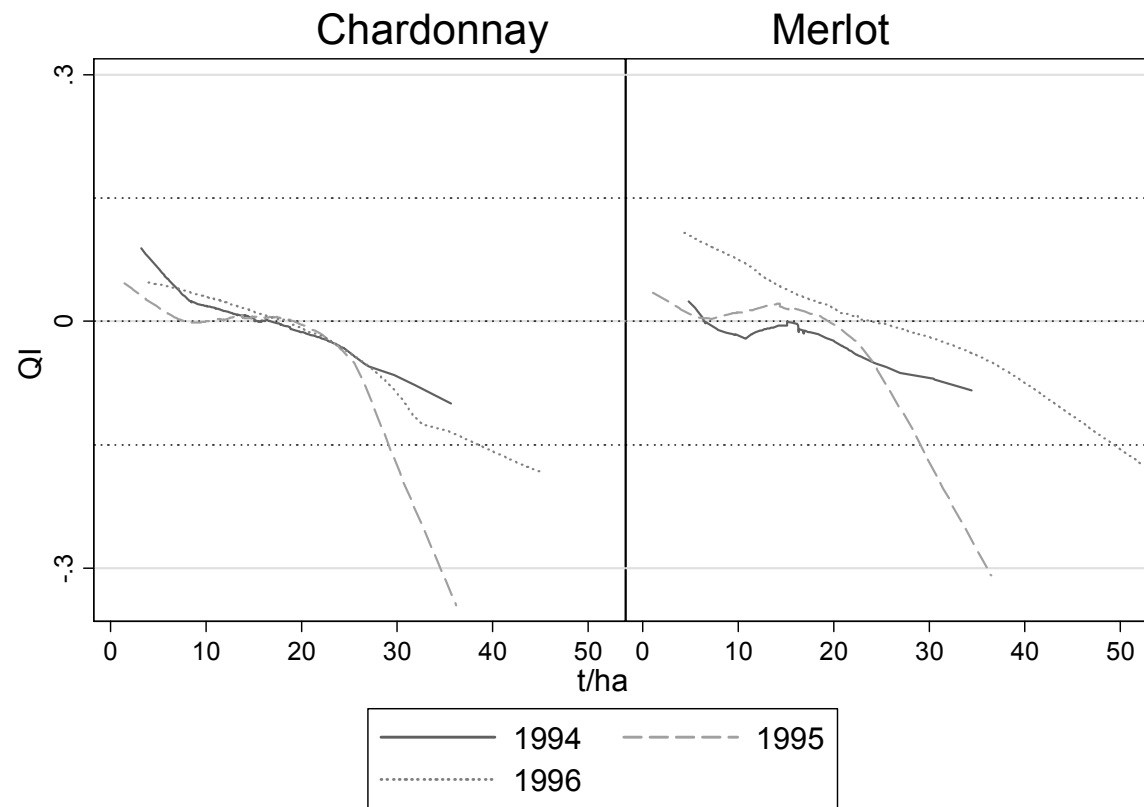
	CRS vs VRS	Ideal vs Average
Chardonnay		
1994	0.0319	0.1382
1995	0.0068	0.0783
1996	0.0018	0.0242
All	0.0325	0.1424
Merlot		
1994	--	0.2653
1995	0.0058	0.0661
1996	--	0.0167
All	0.0735	0.2170



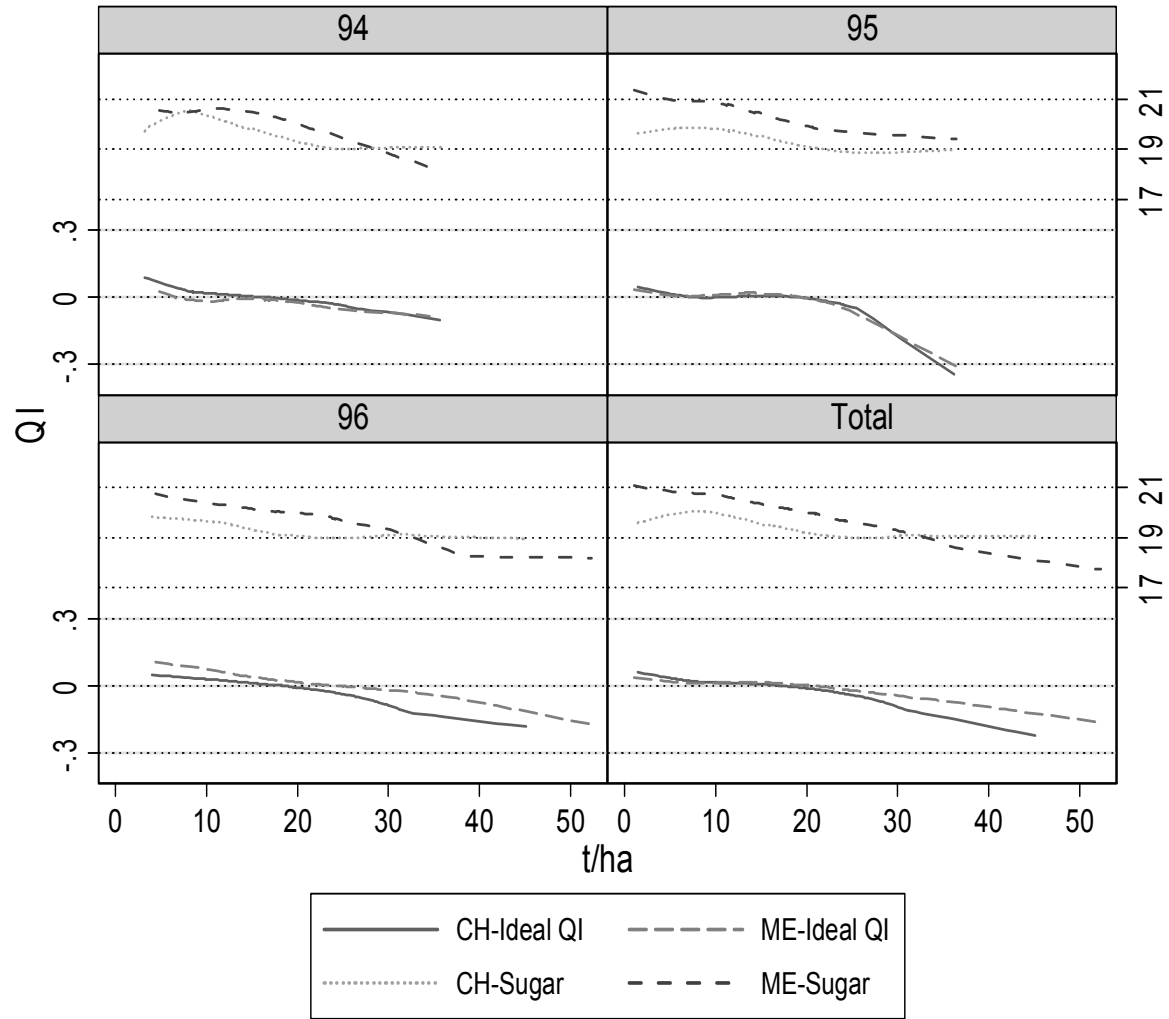
Tradeoff of Yields versus Quality Indicators - Chardonnay



Tradeoff of Yields versus Quality Indicators - Merlot



Tradeoff of Yields versus Ideal Quality Indicator - By Years



Comparison of Tradeoffs: Sugar and Ideal QI versus Yields

8. Concluding Remarks

Quality is important → need to be able to understand what market wants.

Here 2 different measures of aggregate quality, to be compared with the standard practice of using only sugar content.

They seem similar, but they show different results when compared with respect to the yields.

How to use a more limited set of variables? How to give incentives to producers? Calculate the shadow prices of yields and quality attributes.

How to take equity issues into consideration?