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Slack Based Revenue Inefficiency Decomposition: An Application to the French Wine sector

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Abstract. Our paper reports on the use of data envelopment analysis (DEA) to study the revenue inefficiency of the nine major wine regions in France for the period 2004-2013. We aim to track the revenue inefficiency evolution of these regions before and after the implementation of the common market organization (CMO) policies in Europe in wine sector. To accomplish our task, we use an output oriented weighted additive model of the data envelopment analysis (DEA) combining the two inputs (surface area and number of wine producers) and two output variables related to (domestic and foreign sales). The revenue decomposition relates revenue, technical, and allocative inefficiencies based on technical inefficiency measures that account for slacks. We argue that four French wine regions remain efficient after the implementation of new regulations and put forward the explanations on the possible improvements of the positions of other regions which are less efficient.

Keywords: Revenue inefficiency decomposition, Output oriented weighted additive DEA model, French wine regions, Common market organization, Wine sector.

1 Introduction

The wide range of publications on the efficiency is produced by scholars in different management fields during the last decade. The purpose of this paper is to study the efficiency in the context of wine sector.
According to **Farrell (1957)**, efficiency of a firm is composed of two components which are the technical efficiency and the allocative efficiency. Technical efficiency is defined as the ability of a firm to obtain maximal output from given inputs whereas allocative efficiency is defined as the ability of purchasing the best package of inputs given their prices and marginal productivities. A combination of these two efficiencies forms the overall economic efficiency. We can examine the overall economic efficiency using two approaches. The first is the input oriented approach which focuses on minimizing the inputs while maintaining the same level of outputs while the second is the output oriented approach which focuses on maximizing outputs while maintaining the same level of inputs. Overall cost (or revenue) efficiency is an input (or output) oriented approach of overall economic efficiency respectively.
In this study, we we aim to measure revenue efficiency of the nine major French wine regions. Revenue efficiency indicates how well a firm performs in terms of revenue relative to other firms, in the same period, for producing the same set of outputs.
The choice of French wine sector is explained by the two facts. Historically speaking, wine has been linked to France due to its leadership in quality and reputation. Wine is an important sector in France as it is the second trade surplus, and the first trade surplus among agrifood products [1]. Secondly, during the past few years, the French vine-growing areas as well as the number of winegrowers have decreased due to the shrinking profit margins and the implementation of the new Common Market Organization [2]. The French vineyard surface area has decreased by 10.91% for the 2004-2012 year period [3]. However, the production volume is considered relatively high compared to recent decrease in vineyard areas. In April 2008, the new CMO policy set multiple measures such as the grubbing-up, planting rights, national envelopes, promotion in third-country markets, crisis distillation scheme, and rural development funding to reduce production surplus, to strengthen the EU reputation of the quality wine and to increase the competitiveness of the EU

wine producers in the world market.
Moreover, this policy distinguished between the Protected designation of Origin (PDO) and the Protected Geographical Indication (PGI) where detailed rules are found in EU Regulation N 479 (OJ, 2008). This phenomenon aroused our curiosity to explore how efficient are the French wine regions before and after the implementation of new CMO policy.
Consequently, this study aims to measure and decompose revenue inefficiency of the nine major French wine regions using an output oriented weighted additive model of the data envelopment analysis.

2 Preliminaries

2.1 Literature review on efficiency

As we have pointed out earlier, efficiency measurement studies have been performed in different sectors, and DEA as well as other methodologies were used to assess it.
In terms of region approach we could refer to the papers of **Kamarudin et al. (2014)** and **Sufian et al. (2012)**. The first work employed data envelopment analysis to examine the revenue, profit and cost inefficiencies of Islamic and conventional banks in the Gulf Cooperative Council (GCC) countries; and the second compared the revenue efficiency levels of domestic and foreign Islamic banks in Malaysia. Results revealed that capitalization, market power, and liquidity have significant relationship with revenue efficiency. **Lovell and Pastor (1995)** used an output oriented weighted additive (WA) model to study the macroeconomic performance of OECD countries in the absence and presence of two environmental factors.
The questions of efficiency have been frequently raised in the agricultural sector. **Zaibet and Dharmapala (1999)** calculated the technical efficiency index of Jordanian government-supported horticulture using stochastic parametric frontier (SPF), CCR, and BCC DEA models. **Artukoglu et al. (2010)** investigated the technical and economic efficiency of organic and conventional olive producing farms in Turkey by using the input and output oriented CRS and VRS models. Recentlly **Atici and Podinovski (2015)** tested the trade-off approach with a Turkish agriculture data; they have compared the results with the CRS and VRS DEA models. Results revealed that the use of trade-off approach improved the discrimination of both CRS and VRS models. **Fekete et al. (2009)** examined the productivity and its elements for new agricultural EU member states using Malmquist index.

2.2 Literature review on the efficiency and the use of DEA in the wine sector

There is a lack of research studies of efficiency in wine sector. One of the first publications was the work of **Town send et. al (1998)** who provided data from the wine producing areas in Western Cape of South Africa to disclaim the inverse relationship between farm size and productivity measures. The variations of wine prices in Bordeaux by accounting for collected weather data from the closest local weather stations to each chateau have been in the focus of **Lecocq and Visser (2006)** work. **Wood et al. (2006)** used an SUR model to study the variation of secondary market prices of three icon Australian red wines. Later on, **Barros and Santos (2007)** used an output oriented technical efficiency index to compare the efficiency of cooperative and private wine enterprises in Portugal, while **Arandia and Aldanondo (2007)** compared the technical and environmental efficiencies of organic and conventional wine farms. **Henriques et al. (2009)** used panel data for the period (2000-2005) to analyze the technical efficiency of wine producing farms in Portugal, and **Fuller et al. (2014)** investigated the cost savings than can be attained from developing powdery mildew resistant grape varieties.
Vidal et al. (2013) studied the performance efficiency of the Spanish DOs wine using a bounded adjusted DEA measures **(Cooper et al. (2011b))**. **Pastor et al. (2012)** used the constant return to scale and variable return to scale bounded adjusted DEA measure to analyze the Spanish wine sector. **Aparicio et al. (2013)** used an output oriented weighted additive model to decompose revenue inefficiency. This decomposition was based on adopting technical efficiency measures that account for slacks thus providing more realistic values. This last one in particular, has inspired this study on the efficiency of the French wine regions.

2.3 Description of the DEA models

In this section we will briefly present the methodology used in **Cooper et al. (2011a)** to decompose profit inefficiency. First, let us consider n DMUs that utilize m inputs to produce s outputs. The input-output vector is denoted by (X_i, Y_j) where $j = 1, ..., n$. Moreover, we assume that $X_j = (x_{1j}, ..., x_{mj}) > 0_m$ and $Y_j = (y_{1j}, ..., y_{sj}) > 0_s$ where $j = 1, ..., n$.
The profit function denoted by Π of DMU_j is given by the following equation:

$$\Pi_j = \sum_{r=1}^{s} p_r y_{rj} - \sum_{i=1}^{m} q_i x_{ij}. \quad (1)$$

where $P = (p_1, p_2, ..., p_r)$ is the output price vector and the $Q = (q_1, q_2, ..., q_m)$ is the input price vector. We note that profit inefficiency is defined as the difference between the maximum feasible profit denoted by $\Pi(Q, P)$ and the actual profit of the evaluated DMU denoted by Π_0.
Profit inefficiency has been decomposed into technical and allocative inefficiencies since **Farrell (1957)**. However, the main problem of this decomposition was the use of technical efficiency measurements that didn't account for slacks thus leading to an overestimation of the allocative inefficiency component. We note that the allocative inefficiency is the difference between revenue inefficiency and technical inefficiency. As a result, having less value of technical inefficiency (by not accounting for slacks) tends to increase the allocative inefficiency. Therefore, **Cooper et al. (2011a)** aimed to decompose profit inefficiency through accounting for slacks in the technical inefficiency measure component i.e. having an allocative component free of slacks.
Cooper et al. (2011a) proposed a new normalized measure for the decomposition of profit inefficiency by means of a weighted additive DEA model. Using duality theory **Cooper et al. (2011a)** proved the following inequality:

$$\frac{\Pi(Q, P) - \Pi_0}{min\left[\frac{q_1}{w_1^-}, ..., \frac{q_m}{w_m^-}, ..., \frac{p_1}{w_1^+}, ..., \frac{p_s}{w_s^+}\right]} \geq WA(X_0, Y_0; W^-, W^+). \quad (2)$$

where $W^- = (w_1^-, w_2^-, ..., w_m^-)$ and $W^+ = (w_1^+, w_2^-, ..., w_s^+)$ are predefined weights that represent the relative importance of unit inputs and unit outputs, and $WA(X_0, Y_0; W^-, W^+)$ is the weighted additive DEA model which is given by:

$$\begin{aligned} WA(X_0, Y_0, W^-, W^+) := Max & \sum_{i=1}^{m} w_i^- s_{i0}^- + \sum_{r=1}^{s} w_r^+ s_{r0}^+ \\ & s.t \\ & \sum_{j=1}^{n} \lambda_{j0} x_{ij} + s_{i0}^- \leq x_{i0} \quad i = 1, ..., m \\ & \sum_{j=1}^{n} \lambda_{j0} y_{rj} - s_{r0}^+ \geq y_{r0} \quad r = 1, ..., s \\ & \sum_{j=1}^{n} \lambda_{j0} = 1 \\ & s_{i0}^- \geq 0, \quad i = 1, ..., m \\ & s_{r0}^+ \geq 0, \quad r = 1, ..., s \\ & \lambda_{j0} \geq 0, \quad j = 1, ..., n. \end{aligned} \quad (3)$$

This WA model accounts for slacks as it is shown in model (3) in which it seeks the possible input reduction and the possible output augmentation at the same time. We note that input and output oriented WA models exist, and they are found in some literature such as **Lovell et. al (1995)**, **Cooper and Pastor (1996)**, **Prieto and Zofio (2001)**, **Grifell-Tatje et al. (1998)**, and **Cook and Hababou (2001)**. Moreover, DMU_0 is said to be Pareto-Koopman efficient iff $WA(X_0, Y_0, W^-, W^+) = 0$.

As we have mentioned before, Farrell has specified two sources of profit inefficiency, which are the technical and the allocative inefficiency. Returning to inequality (2), this equality can be rendered by adding the allocative inefficiency residual component to the right side to obtain:

$$\frac{\Pi(Q,P)-\Pi_0}{min\left[\frac{q_1}{w_1^-},......,\frac{q_m}{w_m^-},.....,\frac{p_1}{w_1^+},......,\frac{p_s}{w_s^+}\right]} = WA(X_0,Y_0;W^-,W^+)+AI. \tag{4}$$

3 Methodology

In our research we adopt the methodology presented in the **Aparicio at al. (2013)** work to decompose revenue inefficiency. The idea of this decomposition is based on a study done by **Cooper et al. (2011a)** who were mainly interested in decomposing profit inefficiency.
Following the same steps as **Cooper et al. (2011a)**, **Aparicio et al. (2013)** derived a new inequality similar to inequality (2) by taking into consideration the output oriented WA model $WA(X_0,Y_0)$ that was introduced by **Lovell and Pastor (1995)**. This type of models is interested in maximizing outputs while keeping the same amount of inputs unchanged as illustrated by the following linear programming program:

$$\begin{aligned} WA(X_0,Y_0) :=& Max \sum_{r=1}^{s} \frac{s_{r0}^+}{sy_{r0}} \\ & s.t \\ & \sum_{j=1}^{n} \lambda_{j0} x_{ij} \leq x_{i0} \quad i=1,....,m \\ & \sum_{j=1}^{n} \lambda_{j0} y_{rj} = y_{r0} + s_{r0}^+ \quad r=1,....,s \\ & \sum_{j=1}^{n} \lambda_{j0} = 1 \\ & s_{r0}^+ \geq 0, \quad r=1,....,s \\ & \lambda_{j0} \geq 0, \quad j=1,....,n. \end{aligned} \tag{5}$$

As we can notice, to get this output oriented version of the WA model we choose $W^- = (0,0,......,0) = 0_m$ and $W^+ = (\frac{1}{sy_{10}},\frac{1}{sy_{20}},......,\frac{1}{sy_{s0}})$. The main properties of this model is that obtaining an optimal value of zero means that the assessed DMU_0 is Pareto-Koopman efficient otherwise it is inefficient. Moreover, it is units and translation invariant. We note that the WA models are always units invariant, but it is not the case for translation invariance. In case, the input and output slack weights are positive then the WA model is translation invariant (see, **Lovell et Pastor (1995)**).
After introducing the output oriented WA model, **Aparicio et al. (2013)** derived a similar inequality to that of **Cooper et al. (2011a)** as shown in the following inequality:

$$\frac{R(P,X_0)-R_0}{min[p_1 sy_{10},.....,p_s sy_{s0}]} \geq WA(X_0,Y_0). \tag{6}$$

Again, this inequality in rendered by adding the allocative inefficiency component to get the following equation similar to (4) :

$$\frac{R(P,X_0)-R_0}{min[p_1 sy_{10},.....,p_s sy_{s0}]} = WA(X_0,Y_0)+AI. \tag{7}$$

It is worth noting that the revenue inefficiency is greater or equal to zero in which obtaining a zero value means that the assessed DMU has acheived the maximum feasible revenue i.e $R(Q,P)=R_0$.
This approach allows to establish a dual correspondence between the revenue function and the output oriented weighted additive models. Hence, the revenue inefficiency decomposition overcame the decomposi-

tion gap between the optimal and actual revenue by adopting technical efficiency measures that account for all sources of inefficiencies.

4 Research scenario

In this study, we consider the nine major French regions as follows: Alsace, Beaujolais, Bordeaux, Bourgogne, Champagne, Languedoc-Roussillon, Loire, Provence, and Rhone. Moreover, we take into account two input and output variables. The data used in this study for the time period 2004-2013 is provided from the following three sources: FranceAgriMer, Conseil Interprofessionnel du Vin de Bordeaux (CIVB), and Comite Interprofessionnel du vin de Champagne (CIVC). The input variables are surface area (hectares) and number of winegrowers whereas the output variables are the volume of the AOC domestic sales in supermarket and hypermarkets and all wine foreign sales (hl). The revenue inefficiency is calculated using the output oriented weighted additive model with the aid of DEA excel Solver developed by **Zhu (2009)**.

5 Empirical analysis and results

The analysis carried out is based on tracking the evolution of revenue inefficiency for the years 2004, 2007, 2010 and 2013. We choose a three-year difference period as we believe that three years are sufficient to have a preliminary vision of the impact of CMO on revenue inefficiency. Then, we investigate the results after additional three years to have a period of six years to examine the trend of revenue inefficiency. The analysis performed has an evident advantage reflected in accounting for all sources of technical inefficiencies, thus leading to improving the discrimination power of our model. The results of the study are illustrated in table 1, 2, 3 and 4 as shown below.

Table 1: Revenue inefficieny, technical inefficiency and allocative inefficiency of the regions for year 2004

Wine regions	Revenue inefficiency	Technical inefficiency	Allocative ineffficiency
ALSACE	17.93	0	17.93
BEAUJOLAIS	21.14	0	21.14
BORDEAUX	1	0	1
BOURGOGNE	9.76	0.92	8.84
CHAMPAGNE	0.00	0.00	0.00
LANGUEDOC - ROUSSILLON	12.67	2.33	10.33
LOIRE	9.59	1.34	8.25
PROVENCE	102.8	9.8	93.01
RHONE	6.02	1.18	4.84

Table 2: Revenue inefficieny, technical inefficiency and allocative inefficiency of the regions for year 2007

Wine regions	Revenue inefficiency	Technical inefficiency	Allocative ineffficiency
ALSACE	20.56	0	20.56
BEAUJOLAIS	28.41	0	28.41
BORDEAUX	1.27	0	1.27
BOURGOGNE	11.12	0	11.12
CHAMPAGNE	0.00	0.00	0.00
LANGUEDOC - ROUSSILLON	17.19	2.83	14.37
LOIRE	9.56	1.29	8.27
PROVENCE	97.6	9.03	88.57
RHONE	6.57	1.22	5.36

Table 3: Revenue inefficieny, technical inefficiency and allocative inefficiency of the regions for year 2010

Wine regions	Revenue inefficiency	Technical inefficiency	Allocative ineffficiency
ALSACE	19.37	0	19.37
BEAUJOLAIS	26.75	0	26.75
BORDEAUX	0.94	0	0.94
BOURGOGNE	9.4	0	9.4
CHAMPAGNE	0.00	0.00	0.00
LANGUEDOC - ROUSSILLON	16.83	2.82	14
LOIRE	10.73	1.82	8.92
PROVENCE	57.36	6.74	50.62
RHONE	5.84	0.97	4.871

Table 4: Revenue inefficieny, technical inefficiency and allocative inefficiency of the regions for year 2013

Wine regions	Revenue inefficiency	Technical inefficiency	Allocative ineffficiency
ALSACE	20.09	0	20.09
BEAUJOLAIS	26.9	0	26.9
BORDEAUX	0.71	0	0.71
BOURGOGNE	8.2	0	8.2
CHAMPAGNE	0.00	0.00	0.00
LANGUEDOC - ROUSSILLON	13.8	3.23	10.57
LOIRE	10.48	1.5	8.98
PROVENCE	27.27	3.83	23.44
RHONE	4.26	1.04	3.22

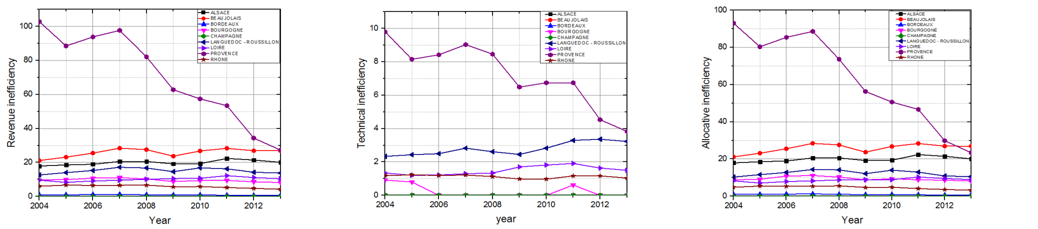
According to the obtained results, we separate these regions into four groups. First group, consists of regions that exhibit a steady evolution before and after the implementation of CMO. Second group, consists of regions that exhibit an increase in revenue inefficiency before the implementation of CMO and then a decrease in revenue inefficiency after the implementation of CMO. Third group, consists of regions that exhibit a decrease in revenue inefficiency for all years. Fourth group, consists of regions that exhibit various fluctuations over the years.

To begin with, Champagne is the only region that belong to group one as its revenue inefficiency was zero for all years. Group two consists of Bordeaux, Bourgogne, Languedoc-Roussillon, and Rhone. This group reflects positive aspects of the CMO policy in those regions as we witness a decrease in revenue inefficiency after the implementation of CMO. The revenue inefficiency of each of these regions has decreased by 44%, 26%, 20%, and 35% for the 2007-2013 period. Moreover, we can see that Bordeaux and Bourgogne had been technically efficient for all years. However, their source of revenue inefficiency was due to allocative inefficiency only. In 2013, the allocative inefficiency of Bordeaux reached its minimum value of 0.71 to assure that it is on the right track to be revenue efficient.

Group three consists only of Provence. We can see that the revenue inefficiency of Provence had been in a continuous decrease before and after the implementation of CMO. It is really worth to mention that Provence had witnessed a sharp decrease in revenue inefficiency accounting for 73% decrease for the 2004-2013 period. This may doubt that the regulations of the CMO policy might not be the reason behind such decrease; as Provence had witnessed a decrease in revenue ineffciency even before the implementation of revenue inefficiency. For this reason, we calculated the decrease in revenue inefficiency for the following three periods: 2004-2007, 2007-2010 and 2010-2013. Results revealed that revenue inefficiency decreased by 5% only for the first period, however it decreased by 41% and 52% for the remaining periods respectively. This certainly reflects the success of the CMO policy in Provence region. Moreover, this huge success in Provence performance was reflected in decreasing both of its components; the technical and the allocative inefficiencies.

Finally, group four consists of Alsace, Beaujolais, and Loire in which this group had witnessed various fluctuations over the years. It is good to notice that Alsace and Beaujolais had been technically efficient for all years; this demonstrates that their revenue inefficiency is due to allocative inefficiency only. To explain these various fluctuations, we calculate the percentage change of revenue inefficiency of Alsace, Beaujolais, and Loire for the following three periods: 2004-2007, 2007-2010 and 2010-2013. Regarding the first period, we have detected an increase in revenue inefficiency by 15% and 34% for Alsace and Beaujolais respectively. On the other hand, Loire has witnessed no change in revenue inefficiency thus accounting for 0%. Regarding the second period, we have detected an increase in revenue inefficiency by

6% for Alsace and Beaujolais, and 12% for Loire. Regarding the third period, we have detected an increase by 4% and 1% for Alsace and Beaujolais respectively, however Loire has witnessed a decrease in revenue inefficiency by 2%. We believe that these results are not sufficient to demonstrate whether the CMO policy has worked for these regions or not. Additional years are certainly required to track the trend of the revenue inefficiency of these regions, as well as the other regions to investigate the overall impact of the CMO policy.



(a) Evolution of revenue inefficiency (b) Evolution of technical inefficiency (c) Evolution of allocative inefficiency

Figure 1: Evolution of the revenue, allocative and technical inefficiencies for the 2004-2013 period

As for the technical inefficiency, the figures indicated above consist of the results of each year for the 2004-2013 period. Alsace, Beaujolais, Bordeaux and Champagne were technically efficient for the whole 2004-2013 period. Bourgogne had been technically efficient for all years except 2004, 2005 and 2011. The average percentage of allocative inefficiencies of Languedoc-Roussillon, Loire, Provence, and Rhone are 82%, 85%, 89%and 80% respectively for the 2004-2013 period. It is really worth noting that the average allocative inefficiency for all regions except Champagne exceeds 80%. Thus, we can conclude that the revenue inefficiency obtained for these regions is mainly due to allocative inefficiency. Hence, it is really important that winemakers reconsider pricing issues and consumer preferences to reduce the allocative inefficiency. At last, we can say that the CMO policy has succeeded in 78% of the French wine regions.

6 Conclusion

In this paper, we have studied the revenue inefficiency of the nine major French wine regions for the 2004-2013 period. Results revealed that Champagne was the only revenue efficient region for the years 2004, 2007, 2010 and 2013. Moreover, we have seen that the revenue inefficiency have decreased after the implementation of CMO policy mainly for Bordeaux, Bourgogne, Languedoc-Roussillon, Rhone, and Provence. Hence we can say that the CMO policy has succeeded in 78% of the French wine regions. Various fluctuations in revenue inefficiency were detected for Alsace, Beaujolais, and Loire. This indicates that additional years are required to study the revenue inefficiency of those regions as well as the others to determine whether the CMO policy has succeeded to fulfill its objectives or not.
Our study is the first in which revenue inefficiency have been measured and decomposed for the major French wine regions. In addition, we have adopted an output oriented weighted additive model that accounts for all sources of technical inefficiencies. Thus, more realistic values were obtained. At last, we would like to point out that this study can be extended in the future to include more detailed analysis of the French wine sector. For example, a detailed study for a certain region could be done examining the revenue, technical and allocative inefficiencies for its local wineries. It would be really interesting to consider Provence as a case study to explain the strategies used to decrease revenue inefficiency.

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