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Tracking carbon footprint in French vineyards: A DEA performance assessment

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ABSTRACT

In recent years, companies have become increasingly concerned about environmental performance and the impact of their activity on the environment. Although the growing interest in sustainability, life-cycle assessment and carbon footprint analysis in literature is observed, there is still a lack of studies proposing evaluation methods to assess the performance efficiency of companies under these new constraints.

Our article furthers our knowledge in the field by providing an in-depth investigation of the operational performance of wine estates in the presence of composite indicators of carbon footprint. The calculated carbon footprint is related to vineyard practices with a major focus on pesticides, fertilizers and fuel use. We suggest in this article for the first time how to track the active ingredients in fertilizers and pesticides that contribute to carbon footprint. The methodology is based on an application of a classic radial model for an input-oriented minimization problem using data envelopment analysis.

The proposed approach is applied to 38 wine producing companies in the Bordeaux region of France to estimate technical efficiency in the presence of carbon footprint. Research results show the percentage of carbon footprint contribution in average terms, from pesticides, fertilizers and fuel. Our results confirm that the carbon footprint effect in vineyards caused by the use of fuel is more than double the impact of pesticides and fertilizers. This strong vulnerability on fuel could do matter to factors guiding farmers' choice of vineyard practices. Additionally, clear improvement targets for the firms, which are inefficient in terms of labor force, net-fixed assets, and carbon footprint, are provided for enhancing their performance. We discuss managerial implications to be put in practice, and outline the suggestions for future studies.

1. Introduction

Companies have become increasingly concerned about their environmental performance and the impact of their activities on the environment. The numerous environmental assessments are available nowadays. Life-cycle Assessment (LCA) which has existed for more than 30 years, and the carbon footprint of greenhouse gas (GHG) emission assessment, which is a recent subset of the LCA, are the two most common measurements ([JRC, 2007], [JRC, 2010]). LCA quantifies the environmental impacts associated with a product over its entire life cycle, from production of the raw materials to disposal at the end of life, and GHG assessment examines the contribution of any activity to global warming. A single unit of measurement is used in GHG analysis - a carbon dioxide equivalent (CO_2e), and a single value is obtained.

The wine industry (as well as other industries) is not innocent from contributing to climate change and global warming due to different vineyard practices namely, packaging, transportation, fermentation and energy consumption that result in carbon emissions and waste production ([Oreskes, 2004], [Thomas et al., 2004]). The analysis of carbon footprint per activity in the wine sector could help companies to identify “hot-spots” where emissions are highest in order to improve the current situation. This can be done by finding the best environmental practices implemented by companies in the sector and comparing other less performing companies to them.

Despite the fact that International Organization for Vines and

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Wines (OIV) established specific requirements for the calculations of GHG balance in wine estates [OIV, 2015], the impact of these new restrictions on companies' operational performance remains ambiguous. It is clear that carbon is not the only sustainability indicator – water consumption, efficient land use, and resource conservation also should be taken into consideration, because in some circumstances, they can be really important. Nevertheless due to the restricted use of water and low cost of electricity in France (we will give more explanations on these issues later in the article) wine growing in France could gain more benefits in terms of sustainable assessment aiming to reduce carbon footprint. Therefore in our study of French vineyards the preference is given to the GHG assessment and in particular to carbon footprint analysis with a major focus on pesticides, fertilizers, and fuel use.

For the first time in the literature, we examine the efficiency of wine estates tracking carbon footprint in vineyards. If the tools for calculating carbon footprint in the wine sector already exist (see, for example, the carbon balance method [IFV, 2011]), our approach enables the development of a measure linking an environmental analysis of carbon footprint with economic reasoning. In our research we address the operational and environmental performance of wine estates in a unified manner. We aim to measure the technical efficiency and consider further how it is affected by considering the carbon footprint. For this purpose, we introduce a new tool for environment assessment in wine estates, which will enable improvement in their environmental management and link sustainable strategies with economic performance.

This article intends to fill the gap in the literature because the selection of factors contributing to carbon footprint and affecting operational performance is seldom investigated. Some studies stress the promising potential of incorporating sustainable strategies to improve wine performance ([Berghoef and Dodds, 2013], [Christ and Burritt, 2013], [Merli et al., 2017]). However, these studies suffer from the drawback of assessing and linking economic and environmental performances in a unified manner.

Evaluating environmental performance alone is not sufficient from a managerial point of view because the economic and environmental performances are jointly executed. Thus, the importance of our study lies in assessing the performance of wine companies in the presence of environmental factors. In such a framework, managers will have a clearer picture of the global performance of the company and the possibility of implementing sustainable strategies that are in harmony with their economic performance. We bridge our contributions mainly with [Christ and Burritt, 2013] study, in which the authors used an integrative literature review to examine the key areas of environmental concerns in the global wine industry. The review revealed a lack of quantitative environmental data to investigate current practices and described their impact on economic and environmental performances.

However, different studies have shown that ignoring undesirable outputs such as carbon emission or waste products, may produce misleading results in assessing performance efficiency ([Färe et al., 1989]; [Lovell et al., 1995]). Our article aims to make a contribution to the literature on the evaluation of performance efficiency accounting for environmental factors. The method of data envelopment analysis (DEA) is used as a form of a classic radial model for an input-oriented minimization problem to examine the impact of composite indicators (CI) of carbon footprint emissions on the operational performance of French wine estates.

Overall we know very little about the contribution of the active ingredients in fertilizers and pesticides to the carbon footprint in addition with fuel use. In this article we address this issue and suggest for the first time how to track these active ingredients in vineyards. The objective of the study is therefore to examine the performance efficiency while accounting for carbon footprint and establishing, if necessary, the targets for eventual efficiency improvement in decision-making units (DMUs), wine farms in our case. We implement the proposed approach to 38 French wine estates in the Bordeaux region to track carbon footprint and investigate its impact on the estates' technical efficiency. The Bordeaux region is the first wine producing region in France to introduce a system of environmental management (SME) that aims to certify sustainable practices in all wine companies. The objective of the SEM certification is to significantly restrict, and even forbid in the future the use of chemical crop protection products [Abellan, 2017].

The remainder of this article is organized as follows: We first provide an overview of the relevant literature in Section 2. We then turn our attention in Section 3 to the situation in the French wine sector that aims to enhance sustainability and environmental aspects of wine growing. We explain in Section 4 the proposed DEA methodology and the data-collection process with a specific emphasis on the calculations of the active ingredients contributing to the carbon footprint of a vineyard. We then present findings in Section 5 and discuss the results of this study. Finally, in Section 6 we summarize the contributions of the article, present the managerial implications, and outline directions for further research.

2. Related studies: literature review

The abundant literature on performance efficiency and sustainability covers multiple fields though is quite heterogeneous. We focus in the first part of this section on research that sheds light on agricultural sustainability. Then, we present the studies that deal with carbon footprint and LCA in the wine sector. Finally, we recall the research papers that assess performance efficiency of firms with and without accounting for environmental factors.

2.1. Sustainability in agricultural studies

Initially, [Schaller, 1993] addressed the reasons for a growing interest in agricultural sustainability and the frequent debate issues related to the profitability and adequacy of food production from sustainable systems. [Tilman, 1999] studied the increase in food production and its environmental costs, mainly the rates of nitrogen and phosphorus fertilization. [De Koeijer et al., 2002] studied agricultural sustainability of the Dutch sugar beets using DEA where sustainability was quantified based on pesticides figures. [Pretty et al., 2003] studied the impact of sustainable-based projects on food poverty mainly in Africa, Asia and Latin America. Results revealed that the adoption and spread of more agriculturally sustainable practices increases food production and reduces poverty. [Saunders et al., 2006] argued that organic practices are more responsible for carbon emission than the number of miles that food travels. [Sofo et al., 2014] tested two different management practices on soil microbial composition and metabolic diversity. Results revealed that implementing sustainable practices can improve soil functionality and productivity. [Adomako and Ampadu, 2015] reviewed the impact of agricultural practices on environmental sustainability in Ghana.

The calculation of carbon footprint and the use of LCA to assess environmental impact is the focus of several recent researches in agricultural sector. [Clavreul et al., 2017] studied the relative importance of inter-year and intra-year variability of carbon footprint in tomato production. [Perrin et al., 2017] used LCA method to study the environmental impacts of urban farming in Benin with major results focusing on nitrogen emission from irrigation and use of fertilizers and insecticide. [Chiriacò et al., 2017] investigated the