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Exploring Firm Performance of the Wine Industry in Portugal Using a Two-Stage Efficiency Analysis

This article aims to assess the firm performance of the wine industry in Portugal. A two-stage efficiency analysis was applied to a sample of firms from the Amadeus database, where a Data Envelopment Analysis (DEA) and a fractional regression model were used to quantify efficiency and to determine the influence external environmental factors have on it. The results highlighted a dichotomy in terms of resources and strategies between small and medium-sized companies on the one hand, and large companies on the other hand. Efficient and inefficient companies differ mainly in terms of their output variables. Territorial opportunities associated with sustainability and innovation positively influence firm performance in the industry. Our findings extend knowledge relating to the relationship between efficiency, environmental context and firm strategy, and may help managers to adopt measures to improve performance and policymakers to design new policy measures.

Keywords: firm performance, accounting metrics, DEA, wine industry, fractional regression model

JEL classifications: M1, M2, C1, C6

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Introduction

For several countries in the world, the wine industry is a relevant economic activity (Maurel *et al.,* 2017; Mota *et al.,* 2021). In 2023, world production and exports were 237.4 and 99.893 million hectolitres, respectively (OIV, 2024). In 2019, the year before the Covid-19 pandemic, these figures represented a decrease of 7.9% and 6.3%, respectively.

Portugal is a significant player in the wine business (Santos *et al.,* 2018), being the 10th largest wine producer in the world with a production of 7.521 million hectolitres in 2023, and the 9th country in terms of the overall area of its vineyards (182 thousand hectares) (OIV, 2024). The wine industry has a substantial economic and social impact in the country, representing 10% of companies in the manufacturing industry and 25% of turnover. The reputation and positioning of Portuguese wines in the value chain have improved in the last decade. Nowadays, Portugal is the 8th largest exporter in the world and exports to many countries, especially France, the United Kingdom, Angola and the United States (Fragoso and Figueira, 2021).

Despite the high performance of the Portuguese wine industry, there are still some meaningful challenges. New markets have arisen due to the socioeconomic development of some emerging countries (Garcia *et al.*, 2012). The wine business is very segmented and many different products are traded, ranging from table to super-premium wines (Dollet and Diaz, 2010; Roy and Cordery, 2010). Growing internationalisation (Festa *et al.,* 2020), innovation (Pickering and Hayes, 2017) and new sustainability standards (Khan *et al.,* 2021) are just some of the further changes which the wine industry now faces (Castilho and Cortijo, 2013; Carollo *et al.,* 2022). Performance is therefore crucial to keeping the wine industry competitive in an increasingly global market (Mazzola *et al.,* 2013; Merli *et al.,* 2018).

In the literature, there are several studies on the performance of the wine industry. We highlight for instance the studies of Cisilino *et al.* (2024), Goncharuk and Lazareva (2017), Goncharuk (2017), Goncharuk (2019), Migliaccio and Tucci (2019), Camanzi *et al.* (2017), Galati *et al.* (2017) and Giuliani *et al.* (2015). However, no comprehensive study exists on the performance of the wine industry that considers internal factors and external factors from the environmental context. In addition, despite the importance of the wine industry in Portugal and its important world position in this sector, few studies in the literature address the economic performance of the Portuguese wine industry (Santos *et al.,* 2018; Rebelo *et al.,* 2018).

To address these gaps, this article aims to assess the performance of the wine companies in Portugal by determining their efficiency and their main drivers in an environmental context. A two-stage efficiency analysis was performed, where a Data Envelopment Analysis (DEA) was used to determine an efficiency score and the efficiency frontier (Coeli, 1995; Kedžo & Lukač, 2021), and a fractional regression model (FRM) (Ramalho *et al.,* 2010) was carried out to assess which environmental factors most influence the performance of the Portuguese wine firms.

This study is also an extension of the previous article of Fragoso and Figueira (2021) and further develops the theory on firm performance, highlighting the role of accounting metrics when discussing management outcomes. The two-stage DEA methodology based on production theory permits a link to be established between the conceptual vision of the resource-based view theory (Barney, 2018; Crick and Crick, 2021) and quantitative empirical research on firm performance.

Consequently, this paper makes three specific contributions. First, it furnishes specific assessments to the wine industry with managerial implications for producers and policy-makers, enriching the scarce literature on firm performance in the wine industry. Second, our results reveal the impact of different value/cost drivers across wine companies. Third, from the methodological point of view, this is one of the first studies in the wine industry to have used an innovative and multidisciplinary approach, where optimisation, multivariate statistics and econometric methods are applied.

The rest of the paper is organised as follows. The second section presents the literature review. The third section describes the methodology. The fourth presents the main results. Finally, the last section presents the discussion and conclusion, as well as the paper's implications.

Literature review

Theoretical background

Firm performance may be addressed through the perspective of the resource-based view theory (Barney, 2018). According to this theory, managers can employ and combine valuable resources that are rare and non-substitutable to create competitive advantages. The resource-based theory also accounts for external factors as opposed to internal resources. Recent studies highlighted the role of stakeholders in the use of resources and capabilities to enhance performance (Barney, 2018; Leonidou *et al.,* 2020; Mussarra and Morgan, 2020; Rust, 2020; Trigo *et al.,* 2024). Thus, the influence of the employment of organisational assets on firm performance is consistent with the resource-based theory (De Massis *et al.,* 2018).

Firm performance measurement provides a benchmarking strategy (Koufteros *et al*., 2014), and allows to establish relationships between strategy and financial issues (Melnyk *et al.*, 2004). Accounting-based measures may be relevant to assess firm performance since they include profit and profitability metrics, such as return on sales and indicators of asset utilisation and return on assets (Shi and Yu, 2013).

Value creation and financial success are influenced by operational performance (Damodaran, 2012; 2006; Gelsomino *et al.,* 2016). Lambert and Pohlen (2001) describe how profit and capital-related factors might affect firm value. Generally, profit-making is related to sales growth and operational cost efficiency (Ellinger *et al.,* 2012). Capital-related factors include fixed capital efficiency (Nakajima, 1988) and working capital efficiency (Kieschnick *et al.,* 2013). Several studies highlight the relevance of working capital to financial success (Knauer and Wohrmann, 2013; Seifert *et al.,* 2013; Hahn *et al.,* 2021). Working capital establishes the links between the flow of goods, capital and information and is related to financial success and performance (Randal and Farris, 2009).

In the last two decades, many studies have measured firm performance following distinct approaches (Jagan *et al*., 2019; Estampe *et al*., 2013; Neely, 2005; Mishra and Sharma, 2014; Thakkar *et al*., 2009; Arunyanart, 2024). The Balanced Scorecard (BSC) proposed by Kaplan and Norton (1992) is one the most used approaches (Shashank and Thakkar, 2018). Mathematical approaches also are used for analysing firm performance (Hahn and Kuhn, 2012; Brandenburg, 2013; Arunyanart, 2024; Amatucci *et al.,* 2024). Within such a framework, DEA (Charnes *et al*., 1978) has been widely applied to understand the effect of inputs associated with technical efficiency and cost-efficiency on output measures (Dobos and Vörösmarty, 2018; Gallear *et al*., 2014; Peng Wong and Yew Wong, 2007). An advantage of DEA is its ability to evaluate the efficiency of a Decision-Making Unit (DMU) within a defined interest group. The disparities in efficiency explain the variations observed in productivity and overall performance (Urso *et al.,* 2018; Kraude *et al.*, 2022).

Previous studies on the performance of the wine industry

In the literature, there are few studies addressed to assess the performance of the wine industry. Mota *et al.* (2020), from a sample of 607 papers found only 23 papers addressed performance indicators in the wine industry. Some studies analysed the performance of the wine industry by using financial statements and most of these studies were accomplished in Spain and Italy.

Sellers-Rubio (2010) studied the efficiency of wineries in Spain applying profitability and productive measures in a DEA approach. Vásquez-Rowe *et al.* (2012), determined the operational efficiency of 40 winemaking farms in Rias Baixas, Spain by combining life cycle assessment and DEA. Castillo and Cortijo (2013) found that the profitability of wine firms in Castilha-La-Mancha, Spain was influenced by the ownership structure, in which large firms perform best, and in terms of capital structure, internal funding is more advantageous than external funding. Aparicio *et al.* (2013), identified revenue, technical and allocative inefficiencies in Spanish protected designations of origin with an output-oriented version of the weighted additive model. Garcia-Alcaraz *et al.* (2017) concluded that human resources are a source of economic performance. Arimany-Serrat and Ferras-Noguer (2019), analysed economic and financial indicators of wine companies in Catalonia, La Rioja and Languedoc-Roussillon from 2008 to 2013, and concluded that large firms with an export tradition perform best in economic and financial terms.

Gallucci and D'Amato (2013), studied the relationship between family power and performance in Italian companies. Chinnici *et al.* (2013), used data from the balance sheet to determine the performance of Sicilian wine producers and found that operational aspects can affect both performance and efficiency. Camanzi *et al.* (2017), Galati *et al.* (2017), and Giuliani *et al.* (2015) emphasise the remarkable performance and efficiency of the wine industry in Italy.

Sellers and Alampi-Sottini (2016), from a sample of 723 wineries in Italy showed that the size has a positive influence on the economic performance. Migliaccio and Tucci (2019) analysed the balance sheet of wine companies in Italy to investigate the dynamics of the income's wine producers from 2008 to 2017.

Liu and Lv (2010) analysed 22 wineries in China and determined the productive efficiency and the influencing factors. Couderc and Marchini (2011) highlighted the relationship between governance, performance and commercial strategies based on financial statements. Lazareva (2015) determined the efficiency of 11 wineries in Ukraine and detected ineffectiveness in small businesses. Goncharuk and Lazareva (2017) study the differences in economic performance between Ukrainian and foreign wineries. Goncharuk (2017) compares the efficiency of Ukrainian and German winemaking. More recently, Goncharuk (2019) analysed the main determinants of winemaking performance in Ukraine.

Toth and Gal (2014) employed a two-stage model to identify the factors of inefficiency among key wine-producing countries between 1995-2007. Galluzzo (2014) found that certified wine producers with protected designation of origin are less efficient than other producers, a finding which can be attributed to lower levels of agrarian capital and labour force.

In Portugal, Barros e Santos (2007) conducted a study revealing that wine cooperatives are more efficient than private companies. Souza Henriques *et al.* (2009) assessed the technical efficiency of a sample of wine producers in the Portuguese region of Alentejo. Santos *et al.* (2018) and Rebelo *et al.* (2018) are other studies that addressed the performance of the wine industry in Portugal.

In recent years, several studies have examined firm performance in relation to sustainability and innovation. Trigo *et al.* (2024) propose a holistic framework to assess and monitor sustainability and management efforts. Amatucci *et al.* (2024) apply a DEA model to measure and decompose the efficiency of innovation systems in the wine industry. Martínez-Falcó *et al.* (2024) analyse the impact of green ambidexterity innovation on the sustainable performance of Spanish wineries by using a structural equations model. Montalvo-Falcón *et al.* (2023) also use structural equations to assess the impact of green human resource management on the economic, social and environmental performance of Spanish wineries. Cisilino *et al.* (2024) estimate technical efficiency in Italian grape farming using a Stochastic Frontier Analysis (SFA).

As previously stated, there are few studies on firm performance of the wine industry, such studies being still scarcer in the case of the Portuguese wine industry. Furthermore, the influence of environmental factors on the firm performance of the wine industry has been scarcely studied. This article therefore assesses the firm performance of the wine industry in Portugal by focusing on financial variables from the income statement and balance sheet and uses a two-stage efficiency analysis based on DEA (Moutinho *et al.*, 2018) and FRM (Ramalho *et al.,* 2010; Moutinho *et al.,* 2020; Silva *et al.,* 2022) to provide guidelines for a future action plan.

Methodology

Based on the resource-based view theory we proposed a performance evaluation model developed in two stages. Firstly, we applied the DEA, to quantify the efficiency scores of each DMU. Then, an FRM was implemented to determine which environmental factors most influence the efficiency scores.

DEA model

The DEA was proposed by Charnes *et al.* (1978) to measure efficiency among several DMUs with multiple inputs and outputs. However, the idea of using a Production Possibility Frontier (PPF) as a benchmark of efficient DMU emerged long before with Farrell (1957). To build the PPF, DEA uses a nonparametric linear programming model. For a given dataset of inputs and outputs, the efficiency scores are estimated for all DMUs. The efficient DMUs have a score equal to 1, while the inefficient DMUs have scores lower than 1, such scores being measures of efficiency relative to the production frontier (Coelli *et al.,* 2005).

Besides using multiple inputs and outputs, the nonparametric frontier can be built with input or output orientations and different returns to scale (Moutinho *et al.*, 2018). The multiple inputs and the multiple outputs are the multiple criteria, where inputs are preferred to be as small as possible and outputs as big as possible. In the input-oriented models, the objective is to determine the optimal use of inputs: in other words, the minimum quantity of inputs that allows producing a given quantity of outputs. In the output-oriented models, the objective is to maximise the outputs for a given quantity of inputs. In general, the former models are addressed to managerial and operational problems and the latter models to planning and strategy (Cullinane *et al.,* 2006; Nong, 2023). In the CRS model, an increase in inputs leads to a proportional rise in outputs. It is used to derive the production frontier and calculate the value of the Total Technical Efficiency (TTE). Banker *et al.* (1984) adjusted the assumption of the CRS model into VRS, allowing that increments in inputs bring decreasing or increasing returns to scale in outputs. In the VRS model, the TTE of the CRS model is divided into pure efficiency and scale efficiency.

Several studies use DEA to benchmark and assess performance based on financial and non-financial variables (Jain *et al.,* 2011; Gold *et al.,* 2017; Telles *et al.,* 2020). Some studies limit their analyses to a single industry to control sectorial effects (Peng Wong and Yew Wong, 2007; Saranga, 2009; Saranga and Moses, 2010).

DEA has been applied to assess relative efficiency using accounting data (Harrison and Rouse, 2016). For instance, Smith (1990) used a DEA to assess the financial statement data of pharmaceutical manufacturers. Day *et al.* (1995) used financial and operational data to assess efficiency. Feroz *et al.* (2003) using a DEA approach analysed the financial statements of oil and gas companies. Joo *et al.* (2011), with a similar approach, assessed the performance of retail firms using annual report data.

In this paper, we followed the input-oriented approach and the BCC model (Banker *et al.*, 1984) with variable returns to scale since it can deal with negative values. The model formulation, based on Kedžo & Lukač (2021), is presented as follows:

$$\min\theta_0 = -\varepsilon\,(\sum_{i=1}^{I} s_{io}^{-} + \sum_{r=1}^{R} s_{ro}^{+}) \tag{1}$$

s.t.

$$\theta_0 x_{i0} = \sum_{j=1}^{J} x_{ij}\lambda_j + s_{i0}^{-}, \quad \forall\, i \in I \tag{2}$$

$$y_{r0} = \sum_{j=1}^{J} y_{rj}\lambda_j + s_{r0}^{+}, \quad \forall\, r \in R \tag{3}$$

$$\sum_{j=1}^{J} \lambda_j = 1 \tag{4}$$

$$\lambda_j, s_i, s_r \geq 0 \tag{5}$$

where, j=1 to J DMUs; i=1 to I inputs; r=1 to R outputs x_{ij} is a vector of inputs, y_{ij} is a vector of outputs, ε is a small "non-Archimedeon" quantity, s_r^+ and s_i^- are positive slack variables, θ is the efficiency score, and λ_j are the weights of inputs and outputs in each DMU_j.

Econometric model

Some previous studies have developed efficiency approaches in two stages. Wagner (2005) analysed relationships between economic and environmental variables in European industry. Moutinho *et al.* (2018) used quantile regressions to find the determinants of efficiency. Wasiaturrahma *et al.* (2020) determined the efficiency scores of rural banks in Indonesia and estimated the factors that influence those scores using a panel Tobit regression. Silva *et al.* (2022) by using a DEA and FRM assessed how socio-economic conditions influence entrepreneurship in 18 European countries.

Among the most used estimation methods in the second stage of efficiency analyses are the Ordinary Least Squares (Wooldridge, 2012; Davidson and MacKinnon, 1993), because this method is intuitive and simple to apply (Gujarati and Porter, 2008; Gujarati, 2003), and Tobit's regression models (Raheli *et al.*, 2017). However, as the DEA scores have values between 0 and 1, these models do not predict well the dependent variable. In light of this, a valuable alternative is the use of FRM (Ramalho *et al*., 2010; Moutinho *et al.,* 2020; Silva *et al.,* 2022).

Therefore, after obtaining the efficiency scores, an FRM was developed to find the environmental factors influencing efficiency. FRM requires the assumption of a functional form for the conditional mean of predicted values of efficiency scores (Raheli *et al.*, 2017). Papke and Wooldridge (1996) suggest as functional forms, any cumulative distribution, such as the logit and probit forms or the loglog and complementary loglog (cloglog) specifications. To detect the most suitable specification of functional forms, we used the RESET test (Ramsey, 1969) and the P-test (Davidson and MacKinnon, 1993).

Data source and variables

The following sub-sections describe briefly the data source that was used to perform the analyses, and the input and output variables applied in the DEA, as well as the external variables used in the econometric analysis.

For the DEA a sample of Portuguese wine companies was used, obtained from the Amadeus database. The sample includes data from 2017 for companies classified in NACE code 1102 – *Wine-production from grapes*. Initially, the sample was composed of 847 companies, which according to INE (2018) represented 80% of the wine companies in Portugal. Then, the companies were checked in terms of the main product supplied and excluded all that do not have wine as a main product. As we only considered the companies for which the Amadeus database provides complete data from the balance sheet and income statement, the final sample was reduced to 382 companies, representing 36% of the Portuguese wine companies.

The companies of our sample cover all the Portuguese territory of the main country. Each company corresponds to one DMU, and they were classified according to the twelve Portuguese demarcated wine-producing regions, and in a second step were aggregated into the following five regions: North, Centre, Lisbon & Tejo, Setúbal, and Alentejo & Algarve.

For the econometric analysis were used regional data from the Statistics of Portugal for the year 2020. These data are from several statistical projects covering different areas of the external environment, such as territory, population, agricultural production, and innovation and research. The territory includes data relative to climate, protected areas, the surface of counties and infrastructures. To characterise the population, we used population density, population growth rate, ageing index, renewal index and the rate of graduates with higher education. For agricultural production, we gathered data about farm size, agricultural productivity, percentage of irrigation area, percentage of single farmers, age and labour force. Innovation and research encompass data relative to the weight of expenses with R&D on the Gross Domestic Product (GDP), averages expenses with R&D per DMU, percentage of people working in R&D, and percentage of households with computers, and with internet access.

Input and output variables

Asset utilisation and profitability are key drivers of manufacturing firms' performance that may be influenced by Supply Chain Management (SCM) since sales revenue and operational costs are affected by customer-service levels supplied and resource productivity (Shi and Yu, 2013). Operational costs are often used as a measure of efficiency, and fixed assets are associated with asset deployment, capacity and utilisation.

Efficient utilisation of resources can be obtained by reducing the safety stocks, collecting accounts receivable quickly and delaying accounts payable (Lamber and Pohlen, 2001). Cash-flow is also an important measure of firm performance, related to its internal perspective.

Thus, profitability and asset utilisation can be decomposed into earns and turns. They are two strategic levers to increase transaction values by lowering operating costs and increasing transaction frequency by reducing cycle times and hence working-in-progress inventories (Hahn *et al.,* 2021).

Therefore, based on Chopra and Meindle (2016) and Christopher (2011), we have considered in the DEA as input variables Operational costs, Inventory and Fixed assets, and as output variables Sales revenue, Operational profit and Cash-flow. These variables provide a financial bottom line perspective, highlighting the influence of cashflow on decision making, as well as resource utilisation (Fixed assets and Operational costs).

To obtain homogeneous DMUs for the DEA, a cluster analysis was implemented and the results highlighted a cluster in each region of small and medium-sized companies (cluster C1) including most companies, plus a national cluster of a few large companies (cluster C2) from all regions (see Table 1).

Table 1: Number of cases per region and final cluster.

	North		Centre		Lisbon & Tejo		Setubal		Alentejo & Algarve		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Cluster C1	164	95.9	64	97.0	52	94.5	24	96.0	56	86.2	360	94.2
Cluster C2	7	4.1	2	3.0	3	5.5	1	4.0	9	13.8	22	5.8
Total	171	100.0	66	100.0	55	100.0	25	100.0	65	100.0	382	100.0

Source: own calculations from cluster analysis

Table 2: Average value and coefficient of variation of input and output variables.

	Small and medium sized companies – cluster C1					Large
	North	Centre	Lisbon & Tejo	Setubal	Alentejo & Algarve	companies cluster C2
Inputs (thousand euros):						
Inventory	1,125	408	492	1,265	221	20,131
	(3.18)	(1.23)	(1.33)	(2.82)	(1.34)	(1.59)
Fixed assets	1,404	694	1174	2,073	344	25,806
	(1.67)	(1.58)	(1.52)	(2.99)	(1.01)	(1.53)
Operational costs	1292	534	971	2,112	229	23,171
	(1.70)	(1.21)	(1.57)	(2.50)	(0.64)	(1.06)
Outputs (thousand euros):						
Sales revenue	1,310	481	933	2,115	206	25,470
	(1.81)	(1.22)	(1.68)	(2.50)	(0.77)	(1.20)
Cash-flow	176	13	106	259	15	3,841
	(2.14)	(11.39)	(1.80)	(2.39)	(4.55)	(1.36)
Operational profit	140	–15	62	211	–16	3,792
	(2.66)	(8.62)	(2.59)	(2.52)	(4.61)	(1.52)

Source: own calculations

Companies of the C2 cluster present the highest average values of inputs and outputs variables. These companies represent only 5.8% of our sample and account for almost 60% of sales revenue. The variables presenting the highest coefficient of variation are the Inventory (1.59), Fixed assets (1.53) and Operational profit (1.52). Among the small and medium sized regional companies of the C1 cluster, the regions of North and Setúbal show the highest average values of input and output variables. In turn, the region Centre presents the highest coefficients of variation for Cash-flow (11.39) and Operational profit (8.62). In the remaining regional C1 clusters, Cash-flow and Operational profit are also the variables with the highest coefficient of variation.

External variables

Nakana and Mkhabela (2011) argue that performance in the wine industry derives from firm size, strategic position, number of employees and national and foreign factors. Thus, for the econometric analysis, a set of regional variables was selected representing several external dimensions that might influence the efficiency scores of the DEA model, such as territory, population, agricultural production, and innovation and research (Urso *et al.,* 2018; Galluci *et al.,* 2015; Migliaccio and Tucci, 2019).

The above notwithstanding, before specifying the FRM, a Principal Component Analysis (PCA) was performed to reduce the number of variables (Table 3). This analysis was performed with the data referred above from the Statistics of Portugal for the year 2020. In the PCA only were retained the factors with Eigenvalues > 1. For the territory and population were extracted the components PC1: Territory and PC2: Population, which explain 84.3% and 81.4% of the variance. Regarding the dimension of agricultural production, three components were retained, namely PC3: Sustainability, PC4: Competitiveness and PC5: Structure, which explain 55.9%, 29.7% and 13.9% of the variance, respectively. Finally, the dimension of innovation and research includes the principal components of PC6: Innovation and PC7: Research, which explain 61.6% and 97.6% of the variance.

Table 3: Principal Component Analysis.

Principal Components (CP)	Eigen values	% of variance explained
Territory:		
PC1: Territory	4.217	84.3
Population:		
PC2: Population	3.257	81.4
Agricultural production:		
PC3: Sustainability	5.587	55.9
PC4: Competitiveness	2.972	29.7
PC5: Structure	1.389	13.9
Innovation and Research		
PC6: Innovation	2.478	61.9
PC7: Research	1.426	35.7

Source: own calculations

Results

In this section, we present the analysis of our empirical results. First, the results of the DEA model are exhibited. As referred previously, firm performance is measured by assessing efficiency under a set of financial variables (Chopra and Meindl, 2016; Christopher, 2011). Then, the econometric model analysis shows the environmental factors that more influence the efficiency scores and hence the performance of wine firms.

Analysis of the DEA model results

Before solving the DEA model, we performed a correlation analysis of the inputs and outputs, where the respective results are shown in Table 4. From this analysis, we can conclude that all inputs and outputs variables are significantly correlated.

Table 5 presents, for the regional C1 clusters and C2 cluster of large companies, the overall efficiency analysis of the DMUs, including the average efficiency scores of all DMUs, the average efficiency scores of inefficient DMUs, the number of DMUs analysed and the percentage of efficient and inefficient DMUs, as well as, the average input and output values of efficient DMUs. For the latter, it is indicated on superscript the significance level (0.01 "***", 0.05 "**" and 0.1"*") at which the average value of efficient DMUs is statistically different from the average value of inefficient DMUs.

The average scores range between 0.932 in C2 of large companies and 0.733 in C1 of the North. Among C1 clusters of regional small and medium-sized companies, Setubal presents the highest efficiency scores (0.914) followed by the Alentejo & Algarve (0.842). C1 clusters of Centre and Lisbon & Tejo show average efficiency scores (0.797 and 0.764) close to the values of C1 of the North. The average scores of inefficient DMU are also highest in the large companies of C2 and C1 of Setubal and Alentejo & Algarve. These three clusters also show the highest share of efficient DMU, which are 0.788, 0.772 and 0.714, respectively.

The results show that the differences between efficient and inefficient DMUs are statistically significant mainly in the output variables. Sales revenue, cash-flow and operational profit are different at high levels of significance (0.01 and 0.05) in the C1 clusters of North, Centre and Lisbon & Tejo. Regarding the inputs, only operational costs, inventory and fixed assets from C1 clusters of North, Lisbon & Tejo and Alentejo & Algarve are different at the 0.01 level of significance. The differences in the remaining variables between efficient and inefficient DMU are not statistically significant or only are at the 0.1 level of significance.

Table 4: Pearson's correlation coefficients between variables of efficiency analysis.

	Inventory	Operational costs	Sales revenue	Fixed assets	Cash flow	Operational Profit
Inventory	1	.876**	.895**	.632**	.846**	.874**
Operational costs	.876**	1	.991**	.693**	.882**	.869**
Sales revenue	.895**	.991**	1	.686**	.909**	.900**
Fixed assets	.632**	.693**	.686**	1	.838**	.822**
Cash flow	.846**	.882**	.909**	.838**	1	.977**
Operational Profit	.874**	.869**	.900**	.822**	.977**	1

** The correlation is significant at the 0.01 level.
Source: own calculations

Table 5: Overall efficiency analysis of the DMUs.

	Small and medium-sized companies – cluster C1					Large
	North	Centre	Lisbon & Tejo	Setubal	Alentejo & Algarve	Companies cluster C2
Efficiency indicators:						
Average efficiency scores	0.733	0.797	0.764	0.914	0.842	0.932
Average scores of inefficient DMUs	0.641	0.683	0.650	0.772	0.714	0.788
Total no. of DMUs	164	64	52	24	56	22
% of efficient DMUs	25.6	35.9	32.7	62.5	44.6	68.2
% of inefficient DMUs	74.4	64.1	67.3	37.5	55.4	31.8
Average input values of efficient DMUs (thousand euros):						
Operational costs	2,101***	725*	1,725***	1,906	726	25,090
Inventory	1,872*	467	817***	719	457*	25,660*
Fixed assets	1,336	945	1,491	1,174	554***	27,537
Average output values of efficient DMUs (thousand euros):						
Sales revenue	2,278***	719***	1,754**	1,979	719	29,316
Cash-flow	399***	94***	246**	288	118**	4,926*
Operational profit	387***	58***	190***	232	43	4,988*

* - indicates a significantly different average from one of the inefficient companies at the 0.1 level;
** - indicates a significantly different average from one of the inefficient companies at the 0.05 level;
*** - indicates a significantly different average from one of the inefficient companies at the 0.01 level;
Source: DEA model results

Analysis of the econometric model results

To determine which external factors most influence SC performance, a FRM was applied, considering as dependent variable the efficiency scores of the DEA model and as independent variables the set of principal components related to regional environmental factors, which were presented previously in Table 3.

To select the best functional form of the FRM, the functional forms of Probit, Loglog and Cloglog were tested through the RESET test and *P*-test. Table 6 presents the p-values of these specification tests. The results show that the Loglog form is the most suitable FRM model. In the *P*-test, H1 is always rejected at less than a 1% of significance level, but the Loglog is the only model where the null hypothesis is not rejected (at a 1% significance level) in the RESET test, showing that among the three alternatives, this model is the best for predicting the efficiency scores.

Table 7 presents the results of the application of the FRM, showing for each independent variable, the value of the estimated coefficient, its standard deviation and its mean partial effect. However, as the FRM estimated coefficients do not show the proportion of change in efficiency due to an increase of a unit in independent variables, our analysis has been focused on the coefficient signals and the partial effect of each variable.

Table 6: Specification tests for selecting FRM (*p*-values).

	H0: Probit	H0: Loglog	H0: Cloglog
RESET	0.002	0.011	0.0013
P-test			
H1: Probit	1.000	0.003	0.003
H1: Loglog	0.007	1.000	0.008
H1: Cloglog	0.001	0.001	1.000

Source: own calculations

Table 7: Estimation results and mean partial effects.

	Coefficients		Partial effect dy/dx
	B	STD	
Independent variables:			
PC1: Territory	–1.891***	0.947	–0.354
PC2: Population	–16.574***	1.059	–3.106
PC3: Sustainability	38.183***	6.625	7.154
PC4: Competitiveness	–42.410***	7.759	–7.947
PC5: Structure	14.779***	1.742	2.769
PC6: Innovation	55.610***	8.514	10.419
PC7: Research	–49.032***	6.531	–9.817
Constant	1.534***	0.064	
R^2	0.041		
N	382		

Note: STD – standard deviation.
* - indicates a significantly different average from one of the inefficient companies at the 0.1 level;
** - indicates a significantly different average from one of the inefficient companies at the 0.05 level;
*** - indicates a significantly different average from one of the inefficient companies at the 0.01 level;
Source: own calculations

All independent variables have a statistically significant effect on efficiency at a 0.01 level. However, notice that our independent variables are PCs and include a balance of diverse variables. For instance, PC1 related to the territory is the combined effect of several variables, such as altitude, mean temperature, solar radiation, precipitation and coastline.

The independent variables associated with PCs of territory, population, research and competitiveness present a negative influence on the efficiency scores. However, the PCs of sustainability, structure and innovation influence positively the efficiency scores.

Among the independent variables with a positive influence on efficiency, innovation and sustainability show the highest mean partial effect (10.419 and 7.154). The former is associated with the households' access to computers and the internet. The latter is mainly related to the combined effect of the available labour force in agriculture, wine production, wine quality and rural tourism establishments. The most negative mean partial effects are observed in the variables of research (-9.187) and competitiveness (-7.947). PC7 of research is mainly associated with the expenses and employment in research and development. The PC4 of competitiveness reflects the combined effect of farms revenue, percentage of irrigated farms and age of singular producers.

Discussion and Conclusions

This article aimed to assess the firm performance of the Portuguese wine industry based on a sample of companies from the Amadeus database and a two-stage efficiency analysis, where a DEA and an FRM were implemented.

The results of the efficiency analysis allowed concluding that large wine companies are the most efficient, followed by the small and medium-sized companies of Setubal and Alentejo & Algarve regions. The North region is on average the least efficient region and has less efficient companies. These results are aligned with the studies of Galindro *et al.* (2018) and Rebelo *et al.* (2018) on wine business efficiency in the North of Portugal, which found that large average firm size is associated with the highest efficiency indexes. Urso *et al.* (2018), in a study on the efficiency of the wine industry in Italy, also achieved similar findings.

Efficient and inefficient companies differ mainly in output variables, and in some cases in inventory and fixed assets. The study of Goncharuk and Lazareva (2017) identified in the Ukrainian wine industry potential for input reduction, namely at the level of fixed assets, and for output growth, where net sales were used.

According to the results of the FRM, to improve firm performance, wine companies should take advantage of territorial opportunities associated with sustainability and innovation. Crick and Crick (2021) in a study on the coopetition of wine producers in the United States also found a positive and significant association between innovation and firm performance. A study based on the theoretical approach of Mol and Spaargaren (2000), concluded that companies using innovation processes and resources towards sustainability have more benefits and competitive advantages than other companies (Khan and Ponce, 2022). Khan *et al.* (2021) also conclude that firm performance is positively influenced by environmental and economic performance.

Theoretical and managerial implications

Underpinned by production theory and resource-based theory (Barney, 2018), our findings extend the knowledge about firm performance and benchmarking analysis, highlighting the use of financial measures from the income statement and balance sheet in the efficiency analysis. Performance measurement is of huge importance for planning and optimisation purposes, and the use of financial measures has a nexus with economic performance (Gallucci and D'Amato, 2013). Economic and environmental factors are important elements of the business context that must be joined to the analysis of performance, and we analyse the influence of these factors on firm performance.

This study is one of the few studies in the literature that addressed the firm performance of the wine industry, and we can highlight the following contributions. First, it provides one of the few empirical assessments of firm performance in the wine industry, contributing to the knowledge of the relation between efficiency, environmental context, and firm strategy. Second, the paper proposes an innovative interdisciplinary framework involving statistical and mathematical methods, namely the use of DEA and FRM in an efficiency approach. Econometric models have been used to characterise the heterogeneity of efficiency scores, but several authors identified the existence of biases and low precision in the estimates. We have reduced these biases by using an FRM (Ramalho *et al.*, 2010; Moutinho *et al.,* 2020; Silva *et al.,* 2022), instead of the traditional econometric approaches. Finally, this study extends the contribution of financial statements to the knowledge of firm performance (Migliaccio and Tucci, 2020). Therefore, our results may interest to academics from several research streams, such as management, efficiency, agribusiness and others.

From a practical standpoint, the results of this study are of great relevance for decision-makers and academics and can be considered for the context of other important wine-producing countries in Europe or other regions, such as Latin America, Australia or New Zealand. The managers of wine companies should adopt measures to increase the efficiency of fixed assets and inventory management. In addition, they have to improve sales revenue, perhaps by adopting more effective marketing strategies to improve the sales and the price of wines. The cash flow is another financial variable with an impact on performance to which the managers should pay attention, and where the effects of sales revenue, inventory and accounts payable and accounts receivable are determinants. For policymakers, our results may help to design European and national policies to support the activities in the wine industry. Policy measures addressing innovation and sustainability should be improved, and new policies should be discussed and designed to promote the competitiveness of wine companies.

Limitations and further research

This study faced several limitations and barriers that have to be overcome. First, the data do not cover non-financial variables, due to the limitations of the database used in this study. The fact of considering only one year for analysis limits the scope of the results. In the future, the research should complement financial data with non-financial data. Furthermore, the study is limited to the wine industry and the context of Portugal. To have results that can be efficiently generalised, for further research, we would like to extend the study to other food and drink sectors and compare different countries.

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