



# DEA Analysis of National Oil Companies

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## Abstract

National Oil Companies (NOCs) have significant control over the world's energy resources, holding about 80% of oil reserves and 70% of oil production, with similar figures for natural gas, both the economies of their home nations and the larger global energy market depend on these businesses. However, they perform in a wide range of ways, and a number of factors, such as labor costs, environmental regulations, corporate size, and financial stability, affect how efficient they are. This paper utilizes Data Envelopment Analysis (DEA) to assess the efficiency of European NOCs, examining both importing and exporting nations. The results suggest that the average efficiency of NOCs is relatively low (0.27) and has been decreasing over the period 2010 - 2020. Notably, larger firms, particularly those with turnovers in the top 90% of the distribution, exhibit higher efficiency, implying the presence of scale economies. However, very small NOCs also show strong performance, likely due to niche competitive advantages, the study also finds that rising employee costs negatively impact the efficiency of smaller firms but not the largest firms, which benefit from greater economies of scale. The paper also discusses limitations in the DEA approach, such as its sensitivity to outliers and the need for robust data. It suggests that despite its utility, DEA should be complemented with other performance evaluation methods to provide a more comprehensive analysis of NOC efficiency. Finally, the study offers recommendations for NOCs to improve their performance by focusing on cost control, optimizing labor expenses, and leveraging economies of scale.

## Subject Areas

Business Management, Economic System, Sociology

## Keywords

DEA Analysis, National Oil Companies, Energy Resources

## 1. Introduction

National Oil Companies (NOCs) are key players in the global energy landscape, controlling a significant portion of the world's petroleum reserves and production. These companies, often fully or partially state-owned, represent an essential component of the global energy system. NOCs account for nearly 80% of global oil reserves and approximately 70% of global oil production, and they play a vital role in providing energy security and stability for both exporting and importing nations [1]. The growing significance of NOCs is underscored by their increasing dominance in the oil and gas sectors, surpassing International Oil Companies (IOCs) in both the size of reserves and production capacity [2]. In addition to their local importance, many NOCs have expanded operations beyond their home countries, becoming major players on the international stage. They invest in large-scale projects, build critical energy infrastructure, and contribute significantly to local employment and national revenues [3].

Historically, governments have chosen to nationalize their oil and gas industries to secure control over petroleum resources and access the substantial economic benefits generated from their exploitation. This process has allowed NOCs to accumulate vast assets and expand their operational scope internationally. As noted by Marcus [4], oil and gas are indispensable natural resources, and NOCs have evolved into economic giants controlling billions of dollars in assets while producing a substantial portion of the world's energy resources. This growing prominence of NOCs in both the domestic and global energy markets has led to increased scrutiny regarding their performance and efficiency, prompting researchers to explore new methodologies for assessing their operational effectiveness.

One such methodology is Data Envelopment Analysis (DEA), which is a widely used tool for evaluating the relative efficiency of decision-making units, such as NOCs [5]. DEA is particularly valuable for assessing companies operating in complex, multi-input and multi-output environments, where traditional performance metrics may not fully capture the nuances of efficiency [6]. In this paper, we utilize DEA to analyse the performance of European NOCs, both in oil-importing and oil-exporting nations, over the period from 2010 to 2020. The findings of this analysis reveal several critical insights into the factors influencing the efficiency of these companies, such as size, financial stability, labor costs, and environmental commitments. Moreover, the study suggests that very large NOCs tend to exhibit higher efficiency levels due to economies of scale, while small NOCs may benefit from niche advantages that allow them to compete effectively in the market [7].

However, it is important to note that while NOCs play an indispensable role in the global energy sector, their performance is not without challenges. As noted by Cahill *et al.* [8], the relationship between NOCs and their respective governments influences their climate and sustainability goals, which, in turn, affect their long-term profitability and efficiency. The efficiency of NOCs has fluctuated in recent years, with several factors, including rising labor costs, political instability, and global market shifts, contributing to the complex dynamics that shape their per-

formance. This study, therefore, aims to contribute to the ongoing discussion regarding NOC efficiency by providing an empirical analysis of the factors that influence their performance and offering insights into the strategies that can enhance their operational effectiveness in an increasingly competitive global energy market. (See **Table 1**)

**Table 1.** 2020 ranking of the Global's 500 largest oil companies.

Country	Name	Fortune global 500 rank	2019 revenues
China	Sinopec Group	2	\$443B
China	China National Petroleum Corporation (CNPC)	4	\$379B
Saudi Arabia	Saudi Aramco	6	\$330B
Russia	Rosneft	76	\$96B
Brazil	Petrobras	120	\$77B
India	Indian Oil Corporation (IOCL)	151	\$69B
Malaysia	Petronas	186	\$58B
Iran	National Iranian Oil Company (NIOC)	Not listed	\$19B*
Venezuela	Petróleos de Venezuela (PDVSA)	Not listed	\$23B (2018)

Value of Iranian petroleum exports in 2019. Source: [9].

It is against this background that this paper will utilize DEA to review and discuss the NOCs performances and efficacy. DEA is a powerful tool used to evaluate the efficiency and performance of decision-making units (DMUs) such as NOCs. The study utilized Data Envelopment Analysis (DEA) to analyze European NOCs between 2010 and 2020. DEA is a nonparametric method in operations research and economics for the estimation of production frontiers [10].

## 2. Literature Review

### Conceptualizing National Oil Companies (NOCs)

National Oil Companies (NOCs) are state-owned entities whose primary objective is to manage and exploit a country's hydrocarbon resources. They are integral players in the global energy market, as they control a significant portion of the world's oil and gas reserves. NOCs typically emerge as a result of a country's decision to nationalize or take control of its energy resources, often with the aim of ensuring energy security, economic stability, and maximizing state revenue from natural resources [11]. These companies can range in size from small national players to large multinational corporations, with many of the world's largest and most influential NOCs, such as Saudi Aramco, Petrobras, and PetroChina, operating on a global scale.

Historically, NOCs were primarily concerned with managing domestic reserves and fulfilling national energy needs. However, over the past few decades, many

NOCs have expanded their activities internationally, driven by the need for greater access to capital, advanced technology, and new markets. As a result, the global role of NOCs has evolved significantly, and they now contribute substantially to the energy security of many countries worldwide [12]. NOCs are now seen as not only suppliers of energy to their domestic markets but also as major international investors and stakeholders in the global oil and gas infrastructure. This trend has been particularly evident in nations like China, India, and the Middle East, where NOCs have made strategic investments in foreign oil fields and infrastructure projects [13].

The growing influence of NOCs on the global energy landscape has shifted the balance of control in the petroleum sector. In the 1970s, international oil companies (IOCs) dominated the global oil market, controlling most of the world's reserves. However, by 2012, NOCs had increased their control over global hydrocarbon resources to over 90% [14]. This shift has had profound implications for the global energy industry, as NOCs now oversee the majority of the world's oil and gas production, and increasingly, they are playing a central role in global energy supply chains.

One of the key advantages of NOCs is their ability to leverage state support in various forms, such as subsidies, favorable regulations, and access to national resources. In contrast to IOCs, NOCs often benefit from direct government backing, which allows them to manage resources with longer-term objectives in mind, such as national energy security and economic development. This ability to operate in the public interest, rather than being solely driven by profit motives, distinguishes NOCs from private sector firms. Furthermore, NOCs play a crucial role in national policy implementation, including achieving energy independence, fostering economic development, and addressing socio-political challenges related to energy and environmental sustainability [15].

The expansion of NOCs internationally, however, has not been without challenges. Many NOCs face structural and institutional barriers that limit their ability to operate effectively beyond their home countries. For example, NOCs in the Gulf Cooperation Council (GCC) countries face limitations due to rigid corporate structures and lack of flexibility in their operations, which hinder their ability to compete globally. Additionally, NOCs in these regions often face resistance to foreign investments due to concerns over national sovereignty, security, and the protection of local assets [16]. Despite these challenges, NOCs have increasingly sought to overcome these barriers by improving their corporate governance, investing in technological innovations, and forming partnerships with IOCs and other private entities.

The increasing prominence of NOCs has raised important questions about the sustainability of the traditional resource ownership business models employed by IOCs. While IOCs have historically focused on controlling and exploiting oil reserves globally, NOCs' ability to operate both domestically and internationally has led to a fundamental shift in the global energy market. The rise of NOCs has forced IOCs to adapt their strategies, often focusing on joint ventures or alliances with NOCs, rather than on direct competition. For IOCs, challenges such as pro-

duction declines in existing oil fields, difficulty in replacing reserves, rising production costs, and declining profit margins have compounded the difficulty of maintaining the status quo [17].

In recent years, NOCs have also increasingly turned to outsourcing, particularly through oilfield services companies (OFSCs), which provide specialized support in exploration, production, and refining. This has enabled NOCs to enhance their operational efficiency while focusing on their core competencies [13]. The strategic use of outsourcing has allowed NOCs to develop sophisticated supply chains and business models that enable them to compete effectively in an increasingly complex and competitive energy market.

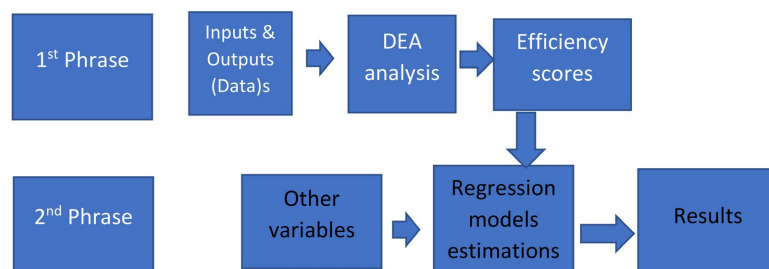
In terms of performance analysis, assessing the efficiency of NOCs has become an important area of research. Data Envelopment Analysis (DEA) has emerged as one of the most widely used methodologies for evaluating the efficiency of organizations across industries, including energy. DEA allows for the comparison of NOCs based on multiple input and output factors, such as production levels, capital expenditures, and technological innovations. By applying DEA, this paper aims to assess the efficiency of European NOCs, both in oil-importing and oil-exporting nations, and examine the factors influencing their performance over the period 2010-2020. The study will also explore how the size of NOCs, their financial stability, and their environmental commitment impact their overall efficiency [18].

The efficiency of NOCs is not just influenced by internal factors such as management practices and operational costs but is also affected by external variables, including fluctuations in oil prices, geopolitical risks, and regulatory changes. The performance of NOCs is thus closely tied to broader market dynamics, and understanding how these factors contribute to efficiency is essential for policymakers and stakeholders aiming to improve the performance of these entities.

This paper will contribute to the growing body of literature on NOCs by providing a comprehensive analysis of their efficiency using DEA, exploring the factors that drive performance, and offering insights into how NOCs can enhance their competitiveness in the global market.

### 3. Methodology

The methodology utilized in this paper is pragmatic and carried out in two distinct phases. **Figure 1** provides a visual summary of the methodology.



Source: Author.

**Figure 1.** Methodology phrases.

### First Phase

In the first phase of the study, we employ Data Envelopment Analysis (DEA) to compute efficiency scores for each company and year in the sample. DEA is a non-parametric technique used to assess the relative efficiency of Decision-Making Units (DMUs), in this case, National Oil Companies (NOCs). The technique constructs a technological frontier using data on inputs and outputs from the NOCs. The frontier is defined as the set of best performers in the sample, which, by definition, achieve the maximum efficiency score of 1. DEA calculates the efficiency of the remaining companies by measuring the distance to the frontier [19].

DEA operates under the assumption that the best performers lie on the efficiency frontier, and their efficiency score is set to 1. The technique then calculates efficiency scores for other companies by solving a linear programming problem. This involves optimizing the combination of inputs and outputs to identify the best performing DMUs, subject to a set of constraints that include the total available quantity of inputs, the desired levels of output, and non-negativity of input-output quantities [20]. A critical component of the DEA methodology is the determination of returns to scale, which can be either constant or variable. In this study, we adopt the input-oriented model and assume variable returns to scale. This assumption is appropriate given the capital-intensive nature of the oil industry, where large fixed costs are required for the installation and maintenance of infrastructure, leading to decreasing average costs as production scales up [21].

**The efficiency score  $\theta_j$  for DMU  $j$  is defined as:**

$$\theta_j = \frac{\text{minimum inputs needed for DMU}_j}{\text{inputs used by DMU}_j}$$

where  $0 < \theta_j \leq 10 < 1$ . A score of 1 indicates that the DMU is efficient, while a score of less than 1 suggests that there is room for input reduction [22]. The formulation of the problem is solved by maximizing  $\theta_k$  subject to the constraints, ensuring that the inputs used by the DMU do not exceed the weighted sum of inputs of the peer group, while also maintaining the output efficiency.

### Second Phase

In the second phase of the analysis, we design a **statistical model** to investigate the correlation between the efficiency scores obtained from DEA (first phase) and various internal and external variables. These variables capture aspects of firm management as well as the macroeconomic and institutional context in which the companies operate. The objective is to examine which factors are associated with the efficiency of NOCs.

**We use the following equation for the regression analysis:**

$$\hat{\theta}_{it} = z_{it}\beta + \epsilon_{it}$$

**where:**

$\hat{\theta}_{it}$  Is the efficiency score for company  $iii$  at time  $t$ , derived from the DEA model.

$z_{it}$	Is a vector of internal and external variables for company iii at time ttt.
$\beta$	Is a vector of parameters to be estimated.
$\epsilon_{it}$	Is the error term.

The model is estimated using panel data regression, which allows us to exploit both time-series and cross-sectional variations in the data. This increases the degrees of freedom and accounts for heterogeneity across firms and over time [23]. We specifically use a Tobit model for the regression analysis due to the censored nature of the efficiency scores. Since the scores are bounded between 0 and 1, with the best performers being assigned a score of 1, the dependent variable is limited [24]. The Tobit model accounts for this censoring and allows us to estimate the relationship between efficiency scores and the explanatory variables effectively. The functional form of the model is:

$$\hat{\delta}_{it}^* = z_{it}\beta + u_i\epsilon_{it}$$

where:

$\hat{\delta}_{it}^*$	is the latent (unobservable) efficiency score for company iii at time t
$u_i$	represents the firm-level unobserved effects (panel-level variance component).
$\epsilon_{it}$	is the idiosyncratic error term.

The observed efficiency score  $\hat{\delta}_{it}$  is then determined by:

$$\hat{\delta}_{it} = \begin{cases} 1 & \text{if } \hat{\delta}_{it}^* \geq 1 \\ \hat{\delta}_{it}^* & \text{if } 0 \leq \hat{\delta}_{it}^* \leq 1 \\ 0 & \text{if } \hat{\delta}_{it}^* \leq 0 \end{cases}$$

To handle heteroskedasticity in panel data, we use observed information matrix (OIM) corrected standard errors, which adjust for variability in the error terms across different firms and time periods [25].

#### Limitations of DEA

Although DEA is a powerful tool for evaluating the efficiency of NOCs, several limitations must be acknowledged.

**Data Quality and Availability:** The availability and quality of data are crucial to DEA, inaccurate efficiency scores may result from inconsistent and lacking data, although extensive datasets were used in this investigation, problems with data quality may still affect how reliable the findings are.

**Static Nature:** Since DEA only shows efficiency at one particular moment in time, it is unable to take into consideration dynamic changes in the operational environment or the overall performance of businesses over time.

**Homogeneity Assumption:** In reality, this is frequently not the case, as DEA presupposes that the units being compared are homogeneous, the efficiency of NOCs may be impacted by the various legal frameworks, market dynamics and strategic goals under which they operate.

**Sensitivity to Outliers:** Efficiency scores may get distorted due to DEA's sen-

sitivity to outlying data and extreme values, for instance, changes in oil prices might have a big impact on NOC performance, resulting in inefficiencies that could not accurately represent the company's true potential.

**Non-Commercial Objectives:** DEA does not capture non-commercial objectives such as social and political goals that may influence the behaviour and performance of NOCs. These objectives may not be easily quantifiable but can significantly impact a company's efficiency.

#### **Data and Variables**

Data for the study is obtained from NOCs operating in Europe, with a focus on both European firms and affiliates of non-European multinationals. The sample covers the period from 2010 to 2020, and data are organized into internal and external variables.

**Internal Variables:** These variables are directly related to the business operations of the NOCs and can be controlled by the company. We use data from the Amadeus database, which provides detailed company-level microdata. In the first phase, internal variables include inputs such as the number of employees (labor input) and the total assets (capital input). In the second phase, we expand the analysis to include other internal variables, such as company size (divided into five categories), employee costs, and solvency ratios. Size categories are defined based on real turnover percentiles, with dummy variables used to categorize companies as very big, big, medium, small, and very small.

**External Variables:** The macroeconomic elements that affect NOC performance are captured by these variables, the price of oil, GDP growth for the EU and nation and area dummies to account for possible regional variations in efficiency are important external variables. The Federal Reserve Bank of St. Louis provides data on oil prices, while Eurostat provides data on GDP growth, furthermore, country-specific impacts (like Germany) and regional effects (like Western Europe) are taken into consideration by using dummy variables.

## **4. Empirical Results**

As already mentioned, we have organized our empirical analysis in two stages. In the first stage, we compute efficiency scores for each firm and year in our sample. In the second stage, we explore the association between the efficiency scores obtained in the first stage and several candidate variables potentially correlated with them. First stage: efficiency, levels, and evolution.

#### **Notes**

The real oil price is defined as the price of Brent crude oil (in dollars per barrel), adjusted for inflation using the Harmonized Index of Consumer Prices (HIPC) for the EU 27 [27]. Similarly, real GDP growth for the EU 27 is adjusted for inflation with the HIPC for EU 27 [25] (Eurostat, 2021). In this study, a single-output case is considered, and it was shown that if the pairs  $(x, y)$  have strictly positive density, the baseline DEA estimator becomes the maximum likelihood estimator, although the rate of convergence is slow [28]. Given the relatively large

sample size (almost 70 firms and 100 observations), we assume that the baseline DEA provides consistent efficiency scores [29].

The efficiency score obtained using the baseline radial DEA procedure is denoted by  $\theta^*$ . Table 2 provides summary statistics for  $\theta^*$  where the mean efficiency score across firms in our sample (2010-2020) is 0.27, with a standard deviation of 0.24. The median efficiency score is 0.19. This suggests a modest level of efficiency, indicating that firms could reduce their input consumption by 73% on average, compared to the best-performing companies.

**Table 2.** Real oil price and real GDP growth, 2010-2020.

Year	Oil price (USD)
2010	79.5
2011	111.26
2012	111.67
2013	108.66
2014	98.95
2015	52.39
2016	43.73
2017	54.19
2018	71.31
2019	64.21
2020	41.84

Source [26].

#### **Average Efficiency: Levels and Trends**

Table 4 shows the evolution of average efficiency over time. Average efficiency exhibited a decreasing trend until 2013, followed by growth thereafter. However, it showed a decline again in 2018.

#### **Top Performers According to Efficiency**

Table 3 presents the top performers for the entire period, defined as companies with an average efficiency of 0.9 or higher from 2010 to 2020. Three companies Eni, Total Belgium, and Total Raffinage France achieved the maximum efficiency score of 1 for the entire period. Other firms with excellent performance include Tamoil, Waxoil, and Gilops, which registered an average efficiency greater than 0.98. Gunvor Deutschland and Repsol achieved mean efficiencies above 0.95. Cepsa completes the list of top performers. Notably, there is some country heterogeneity among the top-performing companies: Eni, Tamoil, and Waxoil are Italian, Gilops is Belgian, and Repsol and Cepsa are Spanish. The top-performing companies are generally stable over time, with little movement in the sample with respect to efficiency.

**Table 3.** Summary statistics, baseline DEA score, 2010-2020.

Variable	<i>N</i>	Mean	St. dev	Minimum	Maximum
$\theta$	2484	0.27	0.24	0.01	1

Summary statistics, baseline DEA score, 2010-2020.

**where:**

*N* is number of observations.  
St. dev standard deviation

**Table 4.** Top performers, baseline DEA efficiency, 2010-2020.

Rank	Company	Average efficiency, 2010-2020
1	Eni	1
1	Total Belgium	1
1	Total Raffinage France	1
4	Tamoil Italy	0.988
5	Waxoil S.R.L	0.981
6	Gilops	0.981
7	Gunvor Deutschland GmbH	0.964
8	Repsol	0.955
9	Cepsa	0.914

Average efficiency and internal variables.

It may be useful to conduct a first explanatory analysis of the connection of efficiency scores with various variables. Moreover, this exploration provides grounds for the second stage, where the evaluation will be carried out more thoroughly.

#### *Efficiency by size*

##### Company size

Size may be a key determinant of the performance of a company, especially if the production function does not exhibit constant returns to scale, as it is the case in this kind of industry capital-intensive. In order to explore the potential connection between efficiency and size, we have distributed the oil companies in our sample into five categories. These categories are determined by the 90th, 75th, 50th, and 25th percentiles of real turnover, as detailed above.

**Table 5** displays summary statistics of efficiency for each category of size. This test should be considered with caution and just as an orientation, though, since it assumes normality.

According to **Table 5**, efficiency is not homogeneous across different firm sizes. The highest average efficiency is reported by very big companies, whose efficiency score (0.6) greatly exceeds the global average efficiency (0.27). Very small companies register an average efficiency of 0.32, which is also higher than the global

average. Medium-sized firms exhibit the lowest average efficiency, while big and small firms also report average efficiencies below the global average. The null hypothesis of equality of means is rejected for all size categories.

**Table 5.** Efficiency by size, 2010-2020.

Size category	Mean	St. dev	<i>N</i>	<i>P</i> value test equality of means
Very big	0.6	0.34	248	0***
Big	0.23	0.22	383	0***
Medium	0.19	0.14	641	0***
Small	0.21	0.15	610	0***
Very small	0.32	0.25	602	0***
Whole sample	0.27	0.24	2478	

Significant at 99%.

These findings are consistent with [30], who argue that efficiency tends to be higher in both very large and very small firms in their sample. Similarly, the results align with the findings of Mekaroonreung and Johnson [31], who report similar patterns of efficiency in a sample of U.S. oil companies.

This pattern is consistent with the coexistence of increasing returns to scale and niche advantages resulting from specialization in production technology. The standard deviation of efficiency by size category is larger for very big and very small companies, suggesting greater heterogeneity within these groups. (See **Table 6**)

**Table 6.** Efficiency by main activity, 2010-2020.

Activity	Mean	St. dev	<i>N</i>	<i>P</i> value test equality of means
Refineries	0.29	0.3	2324	0***
Coke plants	0.19	0.15	163	

Significant at 99%.

**Table 6** illustrates the evolution of efficiency over time by size categories. Efficiency in very big firms has remained relatively consistent and stable throughout the period, despite a dip in 2015. Efficiency in big, medium, and small firms has also remained stable. Conversely, very small firms have experienced more volatility in their efficiency scores. This observation is consistent with Mekaroonreung and Johnson [31], who argue that small firms are more vulnerable to fluctuations in oil prices.

**Activity:** Refineries exhibit a higher average efficiency, exceeding coke plants by ten percentage points (**Table 7**). However, this result should be interpreted with caution due to the asymmetric distribution of firms between these two categories in the sample.

**Table 7.** Efficiency and environmental commitment, 2010-2020.

Variable	Mean	St. dev	N	P value test
Environmental reporting	0.47	0.37	236	0***
No environmental reporting	0.25	0.22	2251	
Large GHG reduction	0.48	0.37	96	
No GHG reduction	0.27	0.23	2391	0***

p value corresponds to test of equality of means.

The “Significant at 99%” column of the table displays the *p*-value of the [32] test of equality of means for both subsectors, which can be rejected at the 99% significance level. (See **Table 8**)

**Table 8.** Efficiency by geographical area and country, 2010-2020.

	Mean	St. dev	N	P value test equality of means
Western Europe	0.28	0.25	1843	0.26
Eastern Europe	0.27	0.22	644	
Belgium	0.40	0.39	137	0.0001***
Nordic countries	0.35	0.27	98	0.0061***
Italy	0.26	0.22	1176	0.0007***
Spain	0.47	0.37	60	0.0001***
Romania	0.31	0.25	142	0.07**
Ukraine	0.24	0.24	154	0.06**
Whole sample	0.27	0.24	2478	

Efficiency by geographical area and country, 2010-2020.

## 5. Discussion, Conclusions, and Recommendations

### 5.1. Conclusions

This paper aimed to analyze the efficiency levels and evolution of National Oil Companies (NOCs) in Europe, focusing on both oil-importing and oil-exporting nations over the period from 2010 to 2020. By utilizing Data Envelopment Analysis (DEA) and the Simar-Wilson methodology, the study provides valuable insights into the factors influencing the performance of NOCs and their potential for future development.

The results indicate that the average efficiency across the firms in the sample is relatively low, with a score of 0.27, and has exhibited a declining trend over the decade (2010-2020). These findings suggest that, on average, NOCs in Europe have faced challenges in achieving optimal efficiency, and there are clear inefficiencies that need to be addressed. Notably, efficiency was found to be positively correlated with company size, financial stability, controlled labor costs, and environmental commitment. Larger firms, particularly those with turnovers higher

than 90% of the distribution, tend to perform better, suggesting economies of scale in the industry.

While larger firms exhibit higher efficiency due to their access to more resources, technology, and capital, the study also uncovered an unexpected result very small firms also showed relatively high efficiency. This finding suggests that smaller NOCs might benefit from niche advantages, such as specialization in certain operational areas or geographic markets. Furthermore, the study revealed that employee costs had a negative impact on efficiency, particularly for medium-sized, small, and very small firms, but had a negligible effect on larger firms. These results underscore the importance of managing labor costs effectively to enhance efficiency in the industry.

Macroeconomic factors, such as fluctuations in oil prices, were found to be procyclical, with efficiency levels positively correlated to oil prices, although these relationships were not robust in all cases. In terms of regional differences, the technological gap between Western and Eastern European NOCs has almost been fully bridged, with no significant differences in efficiency observed across most countries. The analysis also indicated a high correlation (95 - 97%) between the efficiency scores derived from DEA and the Simar-Wilson methods, providing a consistent pattern of results across the two approaches.

These findings have significant implications for policymakers, company managers, and other stakeholders in the European oil sector. The low average efficiency and declining trend suggest that many NOCs may not be sustainable in the long run without a strategic focus on improving productivity and reducing inefficiencies. Companies with poor performance may need to consider modernizing their operations, rationalizing resources, or, in some cases, consolidating through mergers and acquisitions.

## 5.2. Recommendations and Areas for Further Research

Based on the findings of this study, several recommendations can be made for both industry stakeholders and policymakers.

**Encourage Consolidation through Mergers and Acquisitions:** The findings suggest that smaller and medium-sized NOCs with low efficiency are at risk. Mergers and acquisitions could be a viable strategy to improve efficiency and competitiveness. This process should be facilitated by policymakers, who should avoid implementing legislation that artificially protects underperforming companies, such as policies that impose excessive bureaucratic, fiscal, or labor costs.

**Improve Labor Cost Management:** One of the key findings of the study is the negative impact of mounting employee costs on efficiency. Therefore, NOCs should focus on improving labor productivity by optimizing labor costs without compromising employee welfare. Policymakers should avoid introducing regulations that increase labor market rigidity, as these could further harm efficiency and growth in the sector.

**Promote Resource Reallocation and Technological Innovation:** The low le-

vels of efficiency observed in many firms suggest that there is substantial room for improvement in resource allocation and technological advancement. Policymakers should consider promoting innovation in the oil sector through targeted incentives and policies that encourage investment in research and development (R&D). This would help firms achieve better efficiency through process innovation and technological catch-up.

**Reevaluate Subsidy Policies:** The study suggests that oil price increases should not automatically lead to higher consumer prices. Instead, the costs can be absorbed by the producers through increased efficiency. Therefore, governments should carefully evaluate subsidies for oil products to final consumers, as indiscriminate subsidies can perpetuate inefficiencies and mask the true cost of energy production. Policies that incentivize efficiency improvements in production and distribution would be more beneficial in the long term.

**Support Industry Restructuring:** The oil sector in Europe is facing overcapacity and declining efficiency. Structural reforms that allow for the gradual exit of inefficient firms are essential for enhancing overall industry productivity. Policymakers should work to reduce barriers to exit, particularly those imposed by local authorities due to political considerations, as these barriers often prevent the closure of inefficient plants. A more flexible approach to restructuring could lead to a healthier, more competitive oil industry.

**Focus on Long-Term Industrial Policy:** Finally, the study highlights the need for a long-term industrial policy focused on improving the overall efficiency of the oil sector. Policymakers should prioritize economic goals over short-term political objectives and ensure that any interventions in the sector support sustainability and competitiveness. Strategic measures that facilitate the modernization of the sector, reduce inefficiencies, and encourage consolidation are essential for the future success of European NOCs.

#### **Areas for Further Research**

**Sector-Specific Efficiency Drivers:** Further research could explore in greater detail the specific internal factors (e.g., management practices, technological capabilities) and external factors (e.g., geopolitical risks, regulatory environments) that drive efficiency in NOCs. This would provide a deeper understanding of the complexities involved in improving performance.

**Regional Comparison:** A more detailed comparison between NOCs in different regions (e.g., Middle East, Asia, Europe) could help identify best practices and strategies for improving efficiency. This could provide valuable insights into how global NOCs adapt to changing market conditions and technological advancements.

**Impact of Environmental Policies:** Given the growing emphasis on sustainability and environmental impact, future research could investigate how environmental policies affect the efficiency of NOCs. Examining the relationship between environmental commitment and financial performance could yield important insights for policymakers focused on balancing energy security and environmental goals.

**Post-COVID-19 Recovery and Efficiency:** The oil industry has been significantly impacted by the COVID-19 pandemic, and ongoing changes in market dynamics may continue to influence the efficiency of NOCs. Future research could examine the impact of the pandemic on oil companies' performance and how NOCs are adapting to post-pandemic challenges.

In conclusion, this study has provided a comprehensive analysis of the efficiency of European NOCs, highlighting key factors that influence performance and offering practical recommendations for enhancing industry competitiveness. Through the implementation of these recommendations and continued research, NOCs can strengthen their position in the global energy market and contribute to the economic growth of their respective nations.

### Conflicts of Interest

The authors declare no conflicts of interest.

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