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RESEARCH PAPER

Evaluating the efficiency of financial resource transformation into ESG performance: a DEA application in the german industry

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ABSTRACT

Purpose: To evaluate the efficiency of transforming financial resources into environmental, social, and governance (ESG) results by German companies in the Industrial Machinery and Equipment sector from 2018 to 2022 through Data Envelopment Analysis (DEA) application.

Design/methodology/approach: This study applies DEA to assess the efficiency of companies in the M&E sector, using data from the Refinitiv platform for the 2018–2022 period. The analysis is framed in the resource-based view (RBV) theory and incorporates qualitative benchmarking through Porter's Five Forces framework.

Findings: Nordex SE and SGL Carbon SE emerged as ESG efficiency benchmarks despite financial constraints, while Siemens AG stood out as a sectoral reference due to its market leadership, consistent performance, and strong integration of sustainability into corporate strategy.

Research limitations/implications: The study is limited by its five-year scope, which includes the Covid-19 pandemic period, and by its focus solely on German companies, potentially limiting broader applicability.

Practical implications: The study identifies practices and performance patterns among leading firms that can inform ESG-related decision-making in the industrial machinery and equipment sector.

Originality/value: This study introduces a novel approach by combining DEA alongside qualitative analyses to benchmark and assess ESG-driven competitive advantages, offering an innovative perspective on the effective allocation of financial resources toward ESG objectives in the M&E sector.

Keywords: ESG; RBV; Porter's Five Forces; DEA; Machinery and Equipment; Germany.

1 INTRODUCTION

Since the beginning of the new millennium, the world has experienced several macroeconomic and political crises, such as the climate emergency and the COVID-19 pandemic. As a result of these occurrences, it is evident that a fundamental alteration in the global economic paradigm is required (Becchetti *et al.*, 2022; Cheema-Fox *et al.*, 2021). Thus, to speed up this transition, it is important to establish a strong collaboration among the main global stakeholders.

The principles of Environmental, Social, and Governance (ESG) are recognized as key strategic actions for progress, influencing investment and lending decisions (Cheema-Fox *et al.*, 2021; Lins *et al.*, 2017). They also promote accountability among consumers and investors, guiding public and private choices (Alda, 2019). In this context, ESG principles emerge from the necessity to reward companies proficient in generating value, returns, and impacts beyond

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economic terms, maintaining balance in the triple bottom line (profit, planet, and people) (Hajian and Jangchi Kashani, 2021).

Such developments are made feasible through the application and utilization of ESG ratings and indices. This empowers investors and managers to evaluate and report on companies, not exclusively relying on financial metrics, but also incorporating social and environmental parameters. Empirical evidence indicates that firms committed to ESG principles and attaining higher ratings consistently outperform those with lower or no adherence in terms of financial performance (Kocmanová and Dočekalová, 2013; Koroleva *et al.*, 2020). Hence, the number of investors and investment funds that use ESG ratings and principles as a fundamental part of their investment analysis has grown in the last decade (GSIA, 2018).

One sector undergoing significant evolution driven by the ESG mindset is the Industrial Machinery and Equipment (M&E). According to Germany Trade & Invest (2022), the M&E sector, ranked as the second-largest in Germany's economy, played a vital role in the country's industrial growth in 2021, and on a global scale, Germany contributes 16% of trade in M&E products. In this context, historically associated with resource-intensive processes and environmental impact, companies within this sector are rethinking their operational paradigms to be in accordance with ESG principles (Germany Trade & Invest, 2022).

Consequently, it has become essential to evaluate which firms are leaders in ESG principles within the M&E sector, identifying the strategic initiatives these corporations undertake to enhance their value-creation efforts and the insights that can be learned from them. In light of this, the present study focuses on all publicly listed companies operating in the M&E sector in Germany.

The German market was selected for its status as Europe's leading economy, built on a strong manufacturing tradition central to its economic power (Yu, 2023). As a global leader in M&E, Germany provides a valuable benchmark for state-of-the-art industry practices (Theil, 2012). Additionally, Germany's alignment with European ESG standards ensures access to reliable data, supported by extensive historical ESG ratings available on the Refinitiv platform for all companies in the M&E sector.

The theoretical background of this part is the resource-based view (RBV) of strategic management theory (Barney, 1991; Newbert, 2007). The RBV assumes that valuable and rare firms' resources can culminate in superior value-creating strategies when they are empowered in the correct way, and not all the companies in a sector manage to achieve equivalent outcomes. This better use of resources creates a competitive advantage for the company (Alda, 2019).

Recognizing ESG factors as difficult-to-imitate, valuable, and rare resources (Koroleva *et al.*, 2020), and considering that Data Envelopment Analysis (DEA) enables the identification of the most efficient companies in deploying their resources towards improving their ESG ratings, this study investigates the sources of competitive advantage among these firms. Specifically, it examines the key organizational resources and the value-creation strategies adopted by ESG leaders within the sector.

The findings offer practical implications for management, delivering insights that enable stakeholders to improve business performance and operational efficiency. Furthermore, the results can serve as a basis for developing guidelines to implement ESG practices grounded in benchmark analysis. This study also contributes to the academic discourse by advancing the application of DEA and enriching the RBV within the context of entrepreneurship theory.

Given this context, the central research question can be formulated as follows: **Which companies in the sector of M&E are more efficiently employing their financial resources to improve their ESG score?** To answer the research question, this study aims to evaluate the efficiency of transforming financial resources into environmental, social, and governance (ESG) results by German companies in the Industrial Machinery & Equipment sector from 2018 to 2022, through Data Envelopment Analysis application.

By doing so, the study fills a relevant gap in the literature concerning the measurement of ESG efficiency in resource deployment, an increasingly strategic capability in a global economy where firms are no longer assessed solely on price and quality, but also on their sustainability performance and ethical standards (Aich *et al.*, 2021). The contribution is particularly significant given the intensification of global competition and the emergence of new industrial powers such as China, where ESG and operational efficiency have become pivotal differentiators in corporate strategy (Vu, 2015). As a result, this research supports firms

in strengthening their competitive positioning while aligning with the rising expectations of consumers, investors, and regulatory bodies.

The novelty of this study lies in an innovative approach that combines DEA with qualitative strategic frameworks such as Porter's Five Forces and the RBV. While previous research has applied DEA to assess efficiency in various industry contexts, limited attention has been given to its application in benchmarking ESG performance, particularly within the M&E sector. Furthermore, by integrating quantitative efficiency scores with qualitative strategic analysis, the study provides a comprehensive assessment of how companies can leverage internal resources and respond to competitive pressures to improve ESG outcomes. This dual-method approach advances current research by going beyond purely quantitative assessments to include strategic considerations, thereby offering both theoretical and practical contributions.

2 LITERATURE REVIEW

The RBV is a key strategic management theory that connects firm growth to resource utilization, emphasizing that a business is a collection of productive resources that can create value when effectively managed (Newbert, 2007). Barney (1991) categorizes resources into physical, human, and organizational capital, suggesting that a firm's performance depends not only on its products but also on the resources integrated into its production processes (i.e., organizational performance depends on the ability to integrate these resources strategically). He posits that firms within an industry are heterogeneous in their strategic resources, creating enduring competitive advantages.

In the context of entrepreneurship, RBV and ESG principles, Koroleva *et al.* (2020) argue that ESG factors represent rare and inimitable resources. Companies that adopt effective ESG value-creation strategies can achieve superior performance, ensuring long-term success. This way, by effectively implementing ESG strategies as resources, companies utilize their financial resources to enhance their competitive advantage, achieving superior performance and long-term success. Regarding the ESG principles, contrary to the misconception that it only contains actions to mitigate polluting emissions, ESG initiatives provide a guideline encompassing all stages in the value chain, which extends from cost reduction to securing a Sustained Competitive Advantage (Koroleva *et al.*, 2020).

The environmental dimension is designed to examine a company's environmental stewardship (Sahut and Pasquini-Descomps, 2015), i.e., the responsible use and protection of the environment through conservation and sustainable practices. It also evaluates the environmental risks a company might face and how it manages those risks (Guo and Yang, 2024). The social dimension looks at how a company manages its relationships with employees, suppliers, customers, and the communities where it operates (Sahut and Pasquini-Descomps, 2015). The governance criterion deals with aspects of how the company operates and the mechanisms by which it, and its people, are held to account (Amel-Zadeh and Serafeim, 2018). It encompasses many aspects such as the company's leadership, executive pay, audits, internal controls, and shareholder rights, including measures of board diversity and structure, executive compensation, political contributions, and bribery and corruption policies. Moreover, according to Koroleva *et al.* (2020) company performance is closely linked to its governance level.

Furthermore, while traditional studies on ESG and stock performance primarily utilized qualitative methods like negative screening, there has been a notable trend toward employing quantitative methods to analyze ESG performance and its influence on stock performance (Boubaker *et al.*, 2023).

In this context, Koroleva *et al.* (2020) suggest a positive correlation between ESG factors and financial performance, indicating that companies engaged with ESG principles exhibit a 2% higher Return on Assets (ROA) and a 1% higher Return on Equity (ROE) and Return on Invested Capital (ROIC) compared to non-ESG-oriented counterparts. Furthermore, Pedersen *et al.* (2021) argued that ESG considerations could be integrated into investment optimization, highlighting a trade-off between risk, return, and ESG factors.

Besides, the integration of ESG principles has shown significant benefits in diverse contexts, such as urban planning in Mozambique and corporate strategies in India. In Mozambique, the application of Strategic Environmental Assessment (SEA) and Environmental and Social Impact Assessment (ESIA) in the planning of Katembe city demonstrated how ESG-aligned methodologies can mitigate environmental risks like flooding and biodiversity loss

while fostering sustainable urban development, a crucial factor for long-term economic growth (Coutinho *et al.*, 2018). Similarly, a study in India revealed that embedding ESG factors into the initial growth strategies of young companies positively impacts their long-term success, with governance emerging as the most influential dimension for driving sustainability and stakeholder value, which is often reflected in improved financial performance over time (Singh and Tarkar, 2024).

Moreover, the efficiency-based approach to performance evaluation, particularly within the sustainability context, has been explored across different industries. For instance, Hashemi Tabatabaei and Bazrkar (2019) proposed a model for ranking suppliers in the sustainable supply chain through the use of the cross-efficiency method within DEA. Their study focused on identifying core sustainability indicators across economic, social, and environmental dimensions in suppliers from the Iranian automotive industry, with the aim of ranking them in order of efficiency.

In the field of business strategy, understanding the competitive dynamics of an industry is crucial for developing effective strategic plans. Porter's Five Forces framework, introduced by Porter (1980), helps businesses identify the key forces that shape competition within an industry and determine its profitability. This model evaluates five key factors: the bargaining power of suppliers, which assesses suppliers' influence over pricing and quality; the bargaining power of buyers, which examines customers' capacity to demand lower prices or higher quality; the threat of new entrants, which considers barriers to entry that affect the ease of competition; the threat of substitute products, which analyzes the availability of alternatives that could replace industry offerings; and the competitive rivalry, which reflects the intensity of competition among existing firms. By systematically analyzing these forces, businesses can gain insights into the underlying drivers of profitability in their industry, enabling them to formulate strategies that leverage favorable conditions, mitigate threats, and enhance their competitive positioning.

The current state-of-the-art reveals a few studies linking Porter's Five Forces framework with ESG-based strategies, a gap that this work seeks to address. In this context, Yenita (2023) provides a relevant example by analyzing a retail company in Jakarta during the COVID-19 pandemic. The research applied Porter's Five Forces model with an assessment of ESG principles, demonstrating that adopting ESG strategies not only reinforced the company's resilience during the crisis but also contributed to its long-term competitive development by mitigating risks and enhancing market positioning (Yenita, 2023).

The choice of theoretical models (RBV, Porter's Five Forces, and ESG principles) highlights how these frameworks work together to analyze competitive advantage in a world where sustainability is becoming more important. The RBV focuses on the strategic value of a company's resources, while Porter's Five Forces looks at the external competitive environment, helping firms understand how adopting ESG practices, viewed as valuable resources according to Koroleva *et al.* (2020), impacts market dynamics. ESG principles take this further by connecting resource management and market analysis to tangible outcomes in the areas of environmental, social, and governance performance. Together, these approaches help companies not only improve efficiency and positioning but also create value for stakeholders and contribute to positive environmental and social change (Bhandari *et al.*, 2022; Porter and Kramer, 2019).

The RBV of strategic management theory was employed upon identifying the leading German companies within the Industrial Machinery & Equipment sector. Since DEA identifies the most efficient companies in deploying their resources to improve ESG ratings, it will enable the identification of these companies' competitive advantages. This analysis also identified the resources utilized and the value-creating strategies implemented by these firms. In addition, Porter's Five Forces framework is employed to support the in-depth benchmark analysis of the top-ranked companies in the German M&E sector. This combined approach provides a comprehensive understanding of both internal resources and the external competitive environment, helping to assess how ESG adoption influences competitive advantage and market positioning.

3 METHOD

3.1 Data envelopment analysis overview

Early introduced by Charnes *et al.* (1978), DEA is a non-parametric linear programming technique with huge applicability cases, from various sectors and situations. The tool allows the researcher to evaluate the productivity efficiency of a certain object of analysis via the interaction of defined inputs and outputs from a group of homogeneous Decision-Making Units (DMU) (Mariano and Rebelatto, 2014).

Moreover, the DEA applications are usually classified by the type of scale return and orientation. In the orientation case, the tool has three possible models: (I) input oriented, (II) output oriented, and (III) input-output-oriented (Charnes *et al.*, 1978; Santana *et al.*, 2014). Returns to scale are commonly classified as either Constant Returns to Scale (CRS) or Variable Returns to Scale (VRS), depending on the production technology. CRS was first introduced by Charnes *et al.* (1978) in the CRS model, where it guarantees that variations in the inputs will generate changes in the outputs in the same proportion, and vice versa, whereas in the VRS model, explained by Banker *et al.* (1984), the scale return is not necessarily proportional.

3.2 Model Specification

This paper evaluates the efficiency of companies in transforming inputs into ESG scores, considering the possibility of variable returns to scale in the transformation process. As can be seen in Banker *et al.* (1984), in the case of data presenting constant returns, the VRS model works in the same way as the CRS, so it is the most rational choice. Since the objective is to evaluate the efficiency of converting financial resources into ESG results, the (II) output-oriented model was chosen. This way, companies will seek to increase their output results (ESG scores) by keeping their inputs stable, rather than maintaining their outputs stable and decreasing their inputs.

Table 1 - VRS model

Model VRS with output orientation	
$Max\ \eta + \varepsilon * \left(\sum_{i=1}^{m} S_j^- + \sum_{i=1}^{m} S_i^+ \right)$	Objective Function
Subjected to:	
$\sum \lambda_k * x_{ik} + S_i^- = x_{i0}, \quad for\ i = 1,2,\dots,m$	(R1)
$\sum \lambda_k * y_{jk} - \eta * y_{j0} - S_i^+ = 0, \quad for\ i = 1,2,\dots,n$	(R2)
$\sum \lambda_k = 1$	(R3)
$\lambda_k\ and\ \theta \geq 0, \quad for\ k = 1,2,\dots,z$	(R4)

Source: Banker *et al.* (1984); Charnes *et al.* (1978).

Table 1 presents the mathematical formulation of the DEA model used in this study, based on an output-oriented approach with VRS. This approach ensures that greater weights are given to the outputs and inputs that the given DMU is more productive, fostering a fairer comparison by emphasizing the strengths of each DMU.

The model includes four constraints (R1–R4): R1 ensures that the weighted sum of inputs across peer DMUs, adjusted by the input slack variables (S^-), equals the input level of the DMU under evaluation; R2 guarantees that the weighted output, minus the output slack variables (S^+), matches the observed output of the DMU; R3 imposes the convexity condition required by the VRS assumption by constraining the sum of the intensity variables (z_k) to unity; and R4 enforces non-negativity for all z_k values. All data were normalized before analysis to ensure comparability across DMUs. This model was systematically implemented to all units in the sample, and the resulting efficiency scores provided the basis for the benchmarking assessment discussed in the results section (Banker *et al.*, 1984).

The variables were normalized using min-max scaling (Equation 1), as previously performed by Ferraz *et al.* (2020):

$$Z_e = \frac{x_e - min\ (x)}{max(x) - min\ (x)} \quad (1)$$

In which,

Z_e: normalized value that represents the ratio between the difference of its original value subtracted by the minimum sample value and the difference between the maximum and minimum values of the sample.

The application of the model described may result in ties in the efficiency indexes of the units studied, thus requiring the application of an additional tool. To this end, in addition to using the classical approach described, this study incorporates the inverted frontier approach, a distinct analytical framework that involves a sequential three-step process. First, the input and output positions are exchanged and, subsequently, the modified model is solved. Finally, a composite index is computed, integrating assessments of the conventional (classic model) and inverted frontiers (Santana *et al.*, 2014).

Leta *et al.* (2005) specify that the composite index is determined by averaging the classical frontier index (E_classical) with one minus the inverted frontier index (1 – E_inverted). To ensure that the composite index values fall between 0 and 1, they need to undergo standardization. Based on this composite index, the most proficient DMU (Decision-Making Unit) is identified as one that excels in its strengths, measured by the standard efficiency level. Simultaneously, it should not exhibit significant deficiencies in its weaknesses, as determined by the efficiency derived from the inverted frontier subtracted from one.

The study incorporated the window analysis method, also known as the time-dependent analysis in DEA, as outlined by Cooper *et al.* (2001). This approach recognizes time intervals as distinct entities, treating each company during a specific period as an individual unit. The window analysis operates as a moving average technique. The formula to determine the quantity of windows and their respective span is as seen in Equations 2 and 3.

$$W = k - p + 1 \tag{2}$$

$$p = \frac{k+1}{2} \tag{3}$$

In which,

W: number of windows;

k: number of years;

p: window amplitude.

Considering that a five-year analysis was made (k = 5), both the amplitude (p) and number of windows (W) should be three.

3.4 Data source and variables selection

This research employs the Refinitiv Eikon platform as the primary data source. It was used to (i) screen all the German companies from the M&E sector; (ii) identify the market cap of the M&E sector compared to the whole universe of German public companies; (iii) extract the financial performance ratios and the ESG indexes from the analyzed companies; and (iv) obtain other qualitative information for the project.

The choice for the Refinitiv platform was made based on many previous studies that used the platform and obtained reliable results (Berg *et al.*, 2020; Drago *et al.*, 2019) and for having a reliable and trustworthy ESG database, indexes, and analysis (Stellner *et al.*, 2015). The Refinitiv platform offers more than 400 ESG data points, analytics, and indexes (Refinitiv, 2023). From those, Table 2 shows the indexes that were chosen for this study. The decision to analyze these scores separately, rather than using the overall ESG score, allows for a more detailed examination of each category.

Table 2 - Relevant ESG indexes from Refinitiv

Indexes	Description
Environmental Pillar Score	This is about how a company affects living and non-living things like air, land, water, and whole ecosystems.
Social Pillar Score	Measures a company's capacity to generate trust and loyalty with its workforce, customers, and society through its use of the best management practices.

Governance Pillar Score	The assessment of a company's systems and processes ensures that its board members and executives act in the best interests of its long-term shareholders.

Source: Refinitiv (2023).

The RBV of strategic management was employed to analyze leading German companies within the M&E sector, focusing on those with ESG scores and alignment with ESG principles, in line with Koroleva *et al.* (2020), who view ESG factors as rare and inimitable resources that contribute to sustained competitive advantage. In this context, regarding the data source, out of a total of 56 companies identified, only 18 from the M&E sector (listed in Table 4) were analyzed due to the unavailability of ESG data for the period considered in this study (2018–2022).

To address this limitation, companies were excluded strictly based on inconsistent or missing ESG scores across the full study period, rather than on any performance-related criteria, thus preserving internal consistency and enabling a coherent longitudinal analysis. This approach aligns with Zhou *et al.* (2022), who similarly excluded firms with incomplete ESG or financial data to ensure the validity of their mediation analysis. Complementarily, Chen *et al.* (2021) highlight the necessity of complete ESG and financial data when applying DEA models, as missing information compromises the reliability of efficiency evaluations. The DEA model was uniformly applied to all selected firms using normalized data, thereby enhancing comparability even with the reduced sample size.

In regression models, performance variables serve as dependent variables and are evaluated using various indices (Gozali *et al.*, 2020). While some studies opt for absolute performance measures like gross profit, revenue, and net income (Fried and Tauer, 2015; Santos and Brito, 2012), these measures are not suitable for this dataset due to the considerable diversity in company sizes and subsectors. Instead, it is more advisable to use dimensionless numerical metrics and indexes such as ROA, ROE, and ROIC (Mayer-Haug *et al.*, 2013). These metrics provide a more reliable means to evaluate a company's performance and allow for meaningful comparisons across companies of various sizes. A summary of the input and output variables used in this study is presented in Table 3, as well as the references used for the selection of these indicators.

Table 3 - Summary of inputs and outputs variables

Variable	Equation	Type	Literature Review
ROE	$(Net\ Income)/(Total\ Equity)$	Input	(Alda, 2019; Mayer-Haug *et al.*, 2013)
ROA	$(Net\ Income)/(Total\ Assets)$	Input	(Kocmanová and Dočekalová, 2013; Mayer-Haug *et al.*, 2013)
Environmental Score	Refinitiv Score	Output	(Clarkson *et al.*, 2011; Guo and Yang, 2024; Sahut and Pasquini-Descomps, 2015)
Social Score	Refinitiv Score	Output	(Boubaker *et al.*, 2023; Sahut and Pasquini-Descomps, 2015)
Governance Score	Refinitiv Score	Output	(Amel-Zadeh and Serafeim, 2018; Koroleva *et al.*, 2020)

Source: The authors themselves.

ROA is understood as a financial ratio that indicates how profitable a company is in relation to its Total Assets (Alda, 2019). Similarly, ROE is another financial ratio that assesses a company's profitability relative to its total shareholders' Equity, serving as an indicator of how effectively Equity is utilized to generate net income (Kocmanová and Dočekalová, 2013; Mayer-Haug *et al.*, 2013).

Several studies (e.g., Alda, 2019; Cherkasova & Nenuzhenko, 2022; Clarkson *et al.*, 2011; De Lucia *et al.*, 2020; Kocmanová & Dočekalová, 2013; Le *et al.*, 2022; Rahi *et al.*, 2022; Rodríguez-Fernández *et al.*, 2019) further support the correlation between ESG indicators and financial performance. In this way, the selection of ROA and ROE as indicators of financial performance for the DEA model was guided by their established relevance in prior empirical studies and their widespread use as proxies for financial performance (Alda, 2019; Kocmanová

and Dočekalová, 2013; Mayer-Haug *et al.*, 2013).

In addition to their widespread empirical use, the selection of ROA and ROE in this study is grounded in their suitability as dimensionless financial ratios, which makes them particularly appropriate for comparative analyses across firms with varying sizes and operational scales, as seen in this research. Moreover, ROA and ROE were selected for their ability to accurately reflect a company's financial performance, as they are less influenced by market perceptions and speculative factors that can affect market-based measures like Tobin's Q (Brealey *et al.*, 2011), which may not fully reflect a company's internal operational efficiency or the effective allocation of financial resources toward achieving ESG performance.

According to the research question, financial factors like ROA and ROE were considered inputs and ESG scores were considered outputs. The research procedure is shown in Figure 1. To streamline and categorize the data, all obtained values were normalized, and DEA models were constructed utilizing RStudio® software.

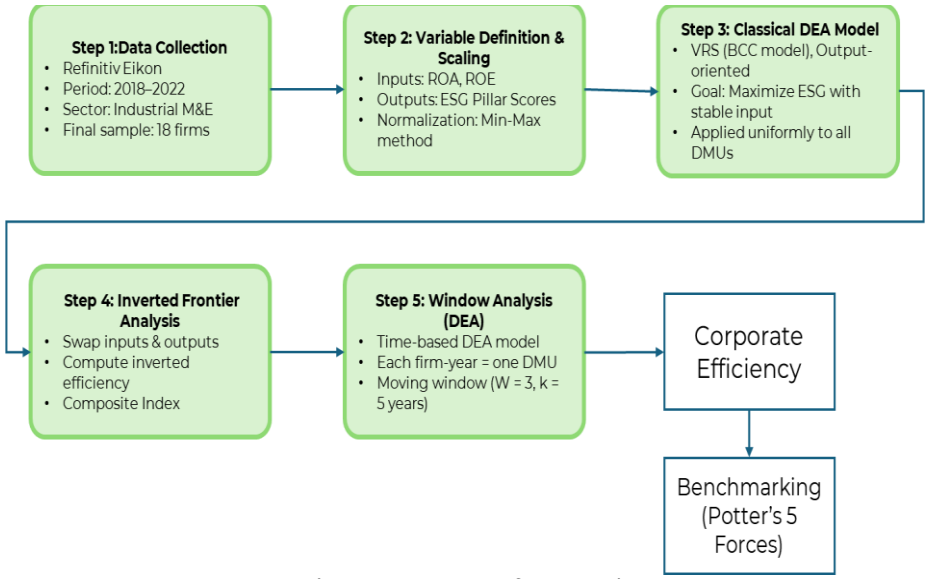

Figure 1 - Stepwise framework
Source: The authors themselves.

The analysis of the results was supported by the application of Porter's Five Forces model to the benchmark companies, following a methodological approach based on multiple data sources. The initial stage of the analysis involved reviewing annual reports and publicly available corporate documents, including sustainability reports and socio-environmental balance sheets. This information was complemented with financial and market data retrieved from the Refinitiv Eikon platform. The content analysis of these sources was conducted according to the principles proposed by Bardin (2011), ensuring a structured analysis and a systematic summary of the information collected.

4 RESULTS

Based on the application of the DEA method, the outcomes of this study are presented in Table 4. The columns in Table 4 represent the average return for each analyzed time window (2018 to 2020, 2019 to 2021, and 2020 to 2022) for every DMU. The ranking was derived from the slack mean result and answers the main question of the study by providing a ranking of German companies that best employ their resources to achieve better ESG scores. Furthermore, it is important to comment that the standard deviation of this study was calculated based on the annual efficiency of each company in the DEA ranking, not on the results of the window analysis averages. Additionally, the subsequent DEA analysis exclusively utilized the normalized dataset. The normalization process involved converting all ROE, ROA, and ESG scores to a scale ranging from 0 (lowest value) to 1 (highest value) to avoid compromising DEA calculations with negative values.

Table 4 - DEA results

Ranking	Company	Market Cap (USD)	2018-2020	2019-2021	2020-2022	Slacks Mean	Standard Deviation
1	Heidelberger Druckmaschinen AG	$ 362.148.210,77	62,9%	67,9%	65,7%	65,5%	25,4%
2	Nordex SE	$ 2.401.033.279,07	57,8%	63,1%	72,3%	64,4%	10,3%
3	SGL Carbon SE	$ 788.085.603,40	65,2%	65,2%	59,5%	63,3%	12,3%
4	Norma Group SE	$ 518.842.057,59	58,7%	61,2%	61,2%	60,4%	3,0%
5	Siemens AG	$ 144.954.826.645,21	59,8%	60,3%	59,7%	59,9%	0,8%
6	DEUTZ AG	$ 787.228.497,05	61,2%	58,0%	56,1%	58,4%	7,6%
7	Kion Group AG	$ 6.090.910.981,72	54,2%	55,7%	57,7%	55,9%	4,4%
8	GEA Group AG	$ 6.951.024.603,01	56,5%	55,3%	52,2%	54,7%	4,3%
9	Knorr Bremse AG	$ 10.291.211.042,81	49,3%	51,4%	52,8%	51,1%	3,6%
10	Koenig & Bauer AG	$ 195.108.821,99	42,3%	50,2%	51,2%	47,9%	13,0%
11	Duerr AG	$ 1.604.049.126,00	38,8%	43,9%	48,5%	43,7%	8,2%
12	Pfeiffer Vacuum Technology AG	$ 1.667.156.860,37	36,6%	45,0%	46,7%	42,8%	11,0%
13	Jungheinrich AG	$ 1.658.465.519,30	41,0%	41,3%	40,7%	41,0%	3,1%
14	DMG Mori AG	$ 3.753.278.614,90	37,6%	39,6%	43,0%	40,1%	6,0%
15	Wacker Neuson SE	$ 1.346.690.440,21	29,7%	37,6%	44,7%	37,3%	11,1%
16	WashTec AG	$ 482.328.307,99	25,0%	31,6%	40,8%	32,5%	13,5%
17	Varta AG	$ 726.099.667,79	14,0%	20,2%	43,6%	25,9%	21,2%
18	Aumann AG	$ 259.840.396,85	24,7%	25,9%	26,6%	25,7%	4,4%

Source: The authors themselves.

The three leading companies identified were Heidelberger Druckmaschinen AG, Nordex SE, and SGL Carbon SE, on which a more in-depth benchmark analysis will be conducted below.

Heidelberger presented the highest slack mean, i.e., the highest average of the average return per DMU, and even though the company presented negative results during the pandemic, it is one of the leading and most established conglomerates in the printing industry subsector, with around 87% of sales generated internationally, across Europe, the Americas, Asia-Pacific, and Africa (Heidelberger Druckmaschinen AG, 2024a). Nordex SE is specialized in wind turbines operating all over the world, their business strategy focuses on producing environmentally and climate-friendly power, with operations in all significant wind markets, excluding China (Nordex SE, 2024).

SGL Carbon is an international leader in carbon-based technologies, serving key markets such as Mobility, Energy, Digital, Industrial Applications, and Chemistry (SGL Carbon, 2024a). Furthermore, Siemens AG, the largest company in the M&E sector, was included in the analysis due to its notable performance, such as presenting the lowest standard deviation in the ranking, despite not being the top-ranked company (Siemens, 2024).

To better comprehend the dynamics of Heidelberger Druckmaschinen AG, Porter's Five Forces analysis is applied, as illustrated in Figure 2 (Heidelberger Druckmaschinen AG, 2024b).

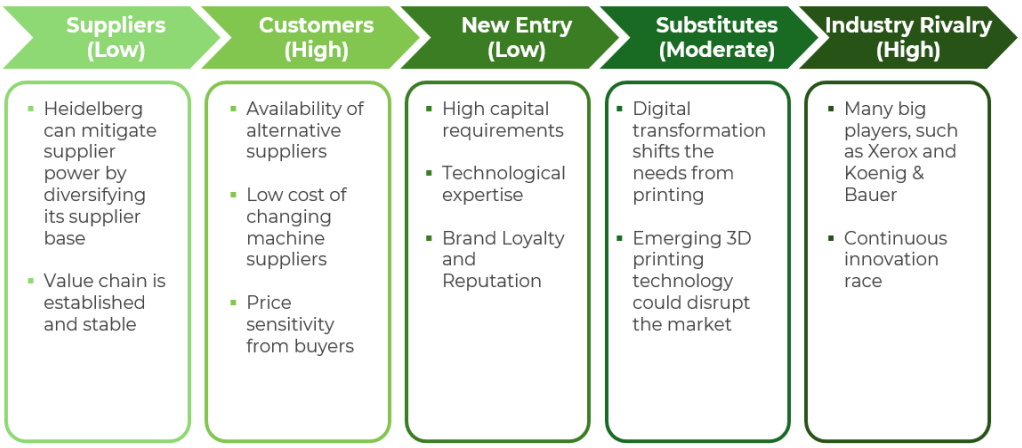

Figure 2 - Heidelberger Druckmaschinen AG Five Forces of Porter
Source: The authors themselves.

Heidelberger Druckmaschinen AG operates in a highly competitive environment. The company's ability to innovate, maintain strong customer relationships, and manage supplier partnerships is critical to its success. While barriers to entry protect the company to some extent, there is a constant threat of technological substitution and price sensitivity from buyers.

Heidelberger Druckmaschinen AG has taken significant actions to integrate ESG principles into its operations. The company is committed to being sustainable in all metrics and has a clear long-term vision and strategic goals. Some examples of milestones achieved are, for the environment, it integrates lifecycle assessments into its ISO 14001 management system and aims for climate neutrality by 2040. Socially, the company promotes diversity through a mentoring program for young female employees and supports schools to provide hands-on technology experiences. On the governance side, an ESG Council guides its sustainability strategy, aligning with UN Global Compact principles on human rights and environmental protection (Heidelberger Druckmaschinen AG, 2024a, 2024b).

Despite Heidelberg's leadership in ESG initiatives, financial analysis reveals fluctuating performance, notably with negative ROE and ROA during the COVID-19 impacted years of 2020 and 2021 (Table 5). This led to an eventual debt restructuring in 2021 to guarantee that the company remained solvent.

Nevertheless, Heidelberger's commitment to advancing its ESG goals remained steady, with notable improvements in its Governance score, and stable results in the E and S scores. As Koroleva *et al.* (2020) and the RBV theory pointed out, ESG factors are rare and difficult-to-imitate resources. Therefore, because of Heidelberger's efficient value-creation strategy, the company achieved a sustained competitive advantage in ESG performance, despite poor

financial results.

Table 5 - Normalized consolidated data for Heidelberger Druckmaschinen AG

Company	year	DMU	ROA	ROE	E	S	G
HDDG.DE	2018	HDDG.DE_2018	0,544	0,787	0,632	0,473	0,568
HDDG.DE	2019	HDDG.DE_2019	0,554	0,798	0,620	0,530	0,528
HDDG.DE	2020	HDDG.DE_2020	0,066	0,000	0,653	0,531	0,639
HDDG.DE	2021	HDDG.DE_2021	0,465	0,577	0,630	0,458	0,682
HDDG.DE	2022	HDDG.DE_2022	0,574	0,886	0,651	0,449	0,633

Source: Refinitiv (2023).

This normalization enabled the inclusion of Heidelberger in the DEA calculation, ensuring a comprehensive analysis. However, it also produced a result with a standard deviation of 25.4%, considerably above the top five other companies from the ranking. Such a high standard deviation indicates a large spread in the data points around the mean. This spread suggests that the values in the dataset vary widely from the average value, which in turn implies high variability and less consistency. This way, Heidelberger was chosen to be excluded from the ranking, since the company has the lowest market cap among the best positioned, and its results are not stable enough. Consequently, the company was not considered eligible as an example and reference to be followed in the German M&E sector.

Regarding Nordex SE, Figure 3 shows the five forces of Porter analysis to better comprehend the dynamic of the company.

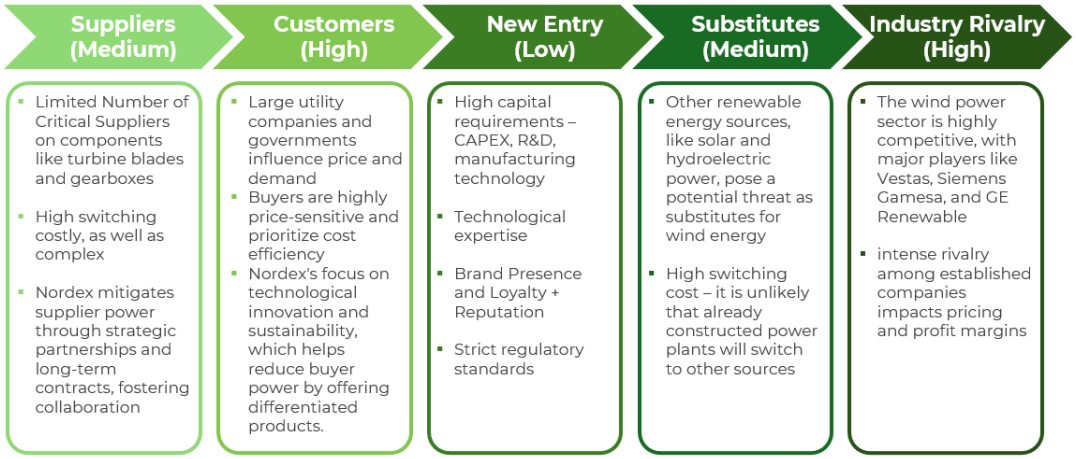

Figure 3 - Nordex SE Five Forces of Porter
Source: The authors themselves.

Some examples of Nordex SE's main ESG achievements and long-term goals include the commitment to provide fully recyclable blades by 2032 and achieve climate neutrality by 2023. On the social front, the company aims to reduce accidents to a lost-time injury frequency of less than 1.5, ensure a minimum of 25% female representation in management positions, and develop a comprehensive mental health strategy for employees. In governance, Nordex promotes responsible business conduct and has conducted audits of suppliers, with 46% of employees completing a course on preventing corruption (Nordex SE, 2024b, 2024a).

Regarding its DEA results, Nordex is in a unique situation: ROA and ROE inputs were negative for all years of the analysis, deteriorating further in 2022. This suggests that the company is becoming increasingly less efficient at generating profit from its assets and equity, which links with the Five Forces of Porter analysis, suggesting that the management has not been able to navigate the intense rivalry among competitors and the significant power of buyers properly to generate revenue.

Despite its financial challenges, Nordex has maintained an exemplary focus on environmental sustainability and social responsibility efforts, evidenced by a consistent upward trend in the E and S scores (Table 6). Additionally, the company has shown substantial improvement in its G score, more than doubling since 2018, indicating better governance practices.

Table 6 - Normalized consolidated data for Nordex SE

Company	year	DMU	ROA	ROE	E	S	G
NDXG.DE	2018	NDXG.DE_2018	0,43	0,69	0,64	0,51	0,41
NDXG.DE	2019	NDXG.DE_2019	0,46	0,69	0,64	0,50	0,51
NDXG.DE	2020	NDXG.DE_2020	0,42	0,65	0,70	0,87	0,81
NDXG.DE	2021	NDXG.DE_2021	0,35	0,59	0,73	0,93	0,90
NDXG.DE	2022	NDXG.DE_2022	0,15	0,42	0,71	0,96	0,93

Source: Refinitiv (2023).

Considering that, unlike Heidelberger, which had a 25% standard deviation in its results, Nordex SE has a 10% standard deviation, even though it had negative inputs, the company cannot be classified as an outlier in the DEA analysis. Nordex is, in fact, an example in the M&E sector, suggesting thatit is possible to maintain a strong and resilient ESG performance despite poor financial results, and the necessity to achieve profitability should not imply the abandonment of long-term sustainable goals.

As Barney (1991) proposed in his RBV works, value-creating strategies can be derived from assets and resources, mainly physicalcapital assets, human capital resources, or organizational capital resources. Companies aiming for better ESG outcomes should examine how Nordex utilizes these assets and resources and take inspiration from their actions to implement more effective value-creation strategies in their management and future agendas.

Figure 4 presents SGL's analysis using Porter's Five Forces to illustrate the company's market position. SGL Carbon SE operates in a competitive yet highly specialized industry with substantial barriers to entry. The company benefits from a diverse customer base, a strong focus on innovation, and strategic investments in high-growth markets like semiconductors. As a result, both supplier and customer bargaining power are low, and competitive rivalry is moderate. However, the threat of substitutes remains high, necessitating continuous investment in R&D to avoid obsolescence.

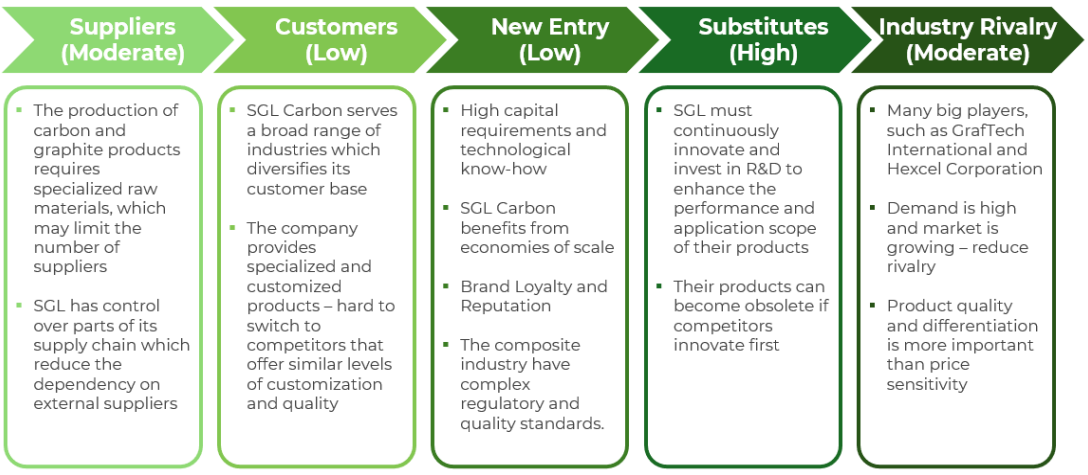

Figure 4 - SGL Carbon Five Forces of Porter
Source: The authors themselves.

As an energy-intensive company, SGL places sustainable management and action at the core of its corporate strategy. Recognizing the importance of ecological, social, and governance responsibilities in today's world, SGL has earned multiple ratings and certifications, including an AA rating on MSCI ESG, ISO 14001, and ISO 50001. Some examples of the main ESG milestones for the company include a target for a 50% reduction in CO2 emissions by 2025 and achieving climate neutrality by 2038. Socially, the company aims for a 5% annual reduction in Lost Time Injury (LTI) frequency and maintains a 20% women's quota in senior management. On the governance side, the company emphasizes a 100% signature of its supplier code of conduct, reviews suppliers' ESG performance, and maintains zero tolerance for compliance violations, with no confirmed cases of fraud, bribery, or corruption (SGL Carbon, 2024b).

Concerning its DEA results, SGL faces similar challenges to Nordex and Heidelberger, with negative inputs in the ROA and ROE indexes, as shown in Table 7. However, unlike Nordex and Heidelberger, SGL's problems began before the COVID-19 crisis. Today, the company is more profitable than it was in 2018, indicating improved efficiency in generating profit from its assets and equity.

In contrast to Nordex, which achieved exemplary ESG scores despite negative financial indicators in all years, SGL maintained its E scores but saw a continuous decline in its S scores (Table 7). The reason for SGL's third-place position in the DEA analysis is its improving G scores, which increased even during the crisis cycle.

Table 7 - Normalized consolidated data for SGL Carbon

Company	Year	DMU	ROA	ROE	E	S	G
SGCG.DE	2018	SGCG.DE_2018	0,63	0,83	0,80	0,70	0,71
SGCG.DE	2019	SGCG.DE_2019	0,33	0,63	0,79	0,69	0,77
SGCG.DE	2020	SGCG.DE_2020	0,21	0,48	0,84	0,64	0,85
SGCG.DE	2021	SGCG.DE_2021	0,71	0,93	0,81	0,64	0,91
SGCG.DE	2022	SGCG.DE_2022	0,81	0,94	0,80	0,60	0,95

Source: Refinitiv (2023).

This does not diminish SGL's status as a benchmark for ESG actions in the M&E sector in Germany. However, it indicates that the company did not achieve the remarkable milestones from 2018 to 2022 that Heidelberger and Nordex did. It is important to highlight that in other aspects, SGL outperforms these benchmarks, particularly in profit stability, diversity of products and markets served, and global impact. This way, it is possible to state that, according to the RBV theory, SGL has a sustained competitive advantage over Nordex and Heidelbeger in terms of business management. Moreover, on ESG value-creation and resource employment, SGL has an advantage against the other worse achievers from the DEA ranking.

Based on the DEA calculations, Siemens AG was identified as the fifth-most efficient company in converting financial results into ESG outcomes, ranking behind Heidelberger AG, Nordex SE, SGL Carbon SE, and Norma Group SE. However, Siemens is the largest company in the M&E sector, with a market capitalization greater than all the other companies combined. Additionally, the standard deviation of Siemens' DEA results is only 0.8%, indicating a high degree of consistency and making it imperative to test it as a benchmark given the solidity of these results.

The extensive range of market segments and business lines explains the substantial size of Siemens AG. Furthermore, when developing the Five Forces of Porter analysis for the company, this size was a critical factor in all five dimensions of the analysis. Figure 5 presents the Five Forces of Porter analysis, to better comprehend the company's business situation.

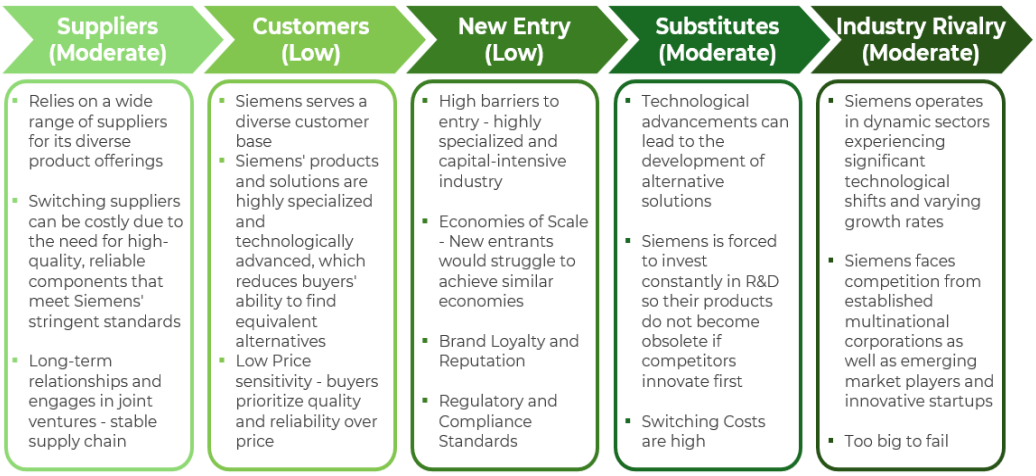

Figure 5 - Siemens Five Forces of Porter analysis
Source: The authors themselves.

Concerning Siemens ESG achievements, it uses a DEGREE framework, which outlines the company's comprehensive approach to sustainability (Siemens, 2024). The framework focuses

on six key areas: decarbonization, ethics, governance, resource efficiency, equity, and employability. DEGREE guides Siemens' efforts across its operations, including setting clear priorities and measurable ambitions in key ESG areas.

Some examples of Siemens' key ESG milestones include its goal of achieving net-zero operations by 2030, with a 32,000 metric ton (8%) reduction in Scope 1 and Scope 2 emissions compared to fiscal 2022. In ethics, Siemens aims to train 100% of employees on its Business Conduct Guidelines every three years, currently reaching 71% of its global workforce. For governance, the company mandates supplier commitment to its Supplier Code of Conduct and integrates ESG criteria into long-term incentives. On resource efficiency, Siemens plans to implement robust eco-design for all products and has reduced landfill waste by 15% since 2021. In terms of equity, the company targets 30% female representation in top management by 2025, currently at 31.1%, and has 43% of employees participating in the share plan. Lastly, for employability, Siemens aims to expand access to its Employee Assistance Program to 100% by 2025, achieving zero fatalities in 2023 and a 28% reduction in high-consequence work-related injuries (Siemens, 2024).

Table 8 presents normalized Siemens' ESG and financial indicators for the DEA analysis. Unlike Heidelberger, Nordex and SGL, who experienced negative inputs (ROA and ROE) for at least one year of the analysis periods, Siemens financial indicators remained positive during all the years, even during the COVID-19 crisis. This further restates the company's stability and competitive advantage as shown in the five forces of Porter analysis.

Moreover, Siemens' diversification across products, markets, and geographies further mitigates its intrinsic risks. In terms of ESG achievements, all three indexes grew from 2018 to 2022, consistently exceeding eighty points (except for S in 2019), demonstrating the efficiency of the company's sustainability framework and initiatives.

Table 8 - Normalized consolidated data for Siemens

Company	Year	DMU	ROA	ROE	E	S	G
SIEGn.DE	2018	SIEGn.DE_2018	0,66	0,84	0,96	0,85	0,92
SIEGn.DE	2019	SIEGn.DE_2019	0,64	0,83	0,97	0,84	0,98
SIEGn.DE	2020	SIEGn.DE_2020	0,62	0,82	0,99	0,87	0,99
SIEGn.DE	2021	SIEGn.DE_2021	0,67	0,84	1,00	0,87	0,97
SIEGn.DE	2022	SIEGn.DE_2022	0,62	0,81	1,00	0,87	0,93

Source: Refinitiv, 2023.

Thus, Siemens serves as a benchmark. While some may argue that Siemens' size makes it an outlier compared to other companies in the M&E sector, its fifth-best DEA result, lowest standard deviation, and strong metrics across all areas counter this argument. Other companies can draw valuable lessons and inspiration from Siemens' business and sustainability practices, independently of size differences.

Moreover, as Clarkson *et al.* (2011) demonstrated, not all firms possess the capacity to emulate the strategy of others; only those with the right management and financial capabilities do. Therefore, it is also possible to infer that Siemens' ESG indicators are rare and difficult-to-imitate resources that lead to a sustained competitive advantage, which better improves the company's cash flow generation and overall performance.

5 DISCUSSION

Benchmarking, which compares business processes and performance metrics to industry bests and best practices from other companies (Anand and Kodali, 2008), is crucial for organizations aiming to enhance performance by identifying gaps, setting goals, and implementing strategies derived from industry leaders. Two types of benchmarking were considered in this study: competitive benchmarking and functional benchmarking.

Competitive benchmarking compares an organization's performance directly against its competitors, providing insights into relative positioning and areas for improvement that can lead to a competitive advantage (Camp, 2024). This method is useful for understanding market standards and identifying strengths and weaknesses relative to direct competitors.

Functional benchmarking compares similar functions or processes across different

organizations within the same industry (Camp, 2024), allowing companies to gain insights into best practices and innovative solutions prevalent in other companies performing similar functions.

For competitive benchmarking, the focus was on Nordex SE and SGL Carbon SE, as Heidelberger Druckmaschinen AG was identified as an outlier. For functional benchmarking, Siemens AG was considered.

Although Heidelberger Druckmaschinen AG was included in all stages of the analysis and its data were normalized to ensure comparability across companies, a high degree of variability was observed in its performance (standard deviation of 25.4%) over the analyzed period. As a result, its suitability as a reliable reference point within the benchmarking framework was limited, since such frameworks are supported by more stable and consistent performance patterns to enable meaningful qualitative comparisons. It should be emphasized that this decision is not intended to reflect the company's relevance within the sector—on the contrary, its importance is fully acknowledged.

Formal robustness tests were not conducted; the quantitative analyses on which the study is based were carried out using the complete dataset, including Heidelberger. The company was excluded only from the qualitative benchmarking phase. Accordingly, it is considered that the study's main conclusions would not be affected by its inclusion. Consequently, its exclusion was considered the most appropriate course of action to ensure methodological consistency and analytical clarity.

Nordex SE is a global specialist in onshore wind turbines and operates as an integrated full-service provider. Their business model emphasizes environmental and climate-friendly power generation, presenting a slack mean DEA result of 64.4% combined with a standard deviation of 10.3%. Despite facing financial challenges, Nordex has maintained strong ESG performance, evidenced by a consistent upward trend in E and S scores and substantial improvement in its G score. This highlights the possibility of maintaining strong ESG performance despite poor financial results and underscores the necessity of achieving profitability without abandoning long-term sustainable goals. Therefore, Nordex is a clear benchmark for the M&E sector.

SGL Carbon SE is an international leader in carbon-based solutions. SGL specializes in specialty graphite, carbon fibers, and composites, serving key industries including climate-friendly mobility and renewable energy. SGL operates in a competitive yet highly specialized industry with substantial barriers to entry but faces a high threat of substitutes, necessitating continuous R&D investment. SGL's DEA results show similar challenges to Nordex and Heidelberger, with negative inputs in the ROA and ROE indexes, although SGL's issues began before the COVID-19 crisis. The company has improved efficiency in generating profit from its assets and equity since 2018, presenting a slack mean of 63.3% combined with a standard deviation of 12.3%. As with Nordex, the combination of strong and solid results also classifies SGL as a benchmark.

Siemens AG was considered a functional benchmark due to its massive market capitalization, larger than all the other companies combined. This significant market presence underscores Siemens AG's substantial influence and stability within the industry, highlighting its capability to leverage economies of scale and achieve competitive advantages in cost management and resource allocation. Additionally, Siemens AG's low standard deviation indicates an elevated level of consistency in its financial and operational performance, suggesting stable performance across various economic conditions. This consistency can be attributed to Siemens AG's robust risk management practices, diversified portfolio, and strategic investments in innovation and technology. Siemens AG's commitment to sustainability and adherence to high corporate governance standards also contribute to its standing as a benchmark, not only for the M&E sector but for all companies that seek improved ESG results.

Finally, the lowest rankings in the analysis were attributed to WashTec AG, Varta AG, and Aumann AG. Despite some good indicators, such as Aumann AG's low standard deviation, their overall returns per DMU were not competitive, which by DEA efficiency frontier analysis, indicates that the companies are not efficient in transforming financial resources into performance. For future studies, examining with the RBV theory and Five Forces of Porter framework the reasons for their inferior performance can provide further insights into not ideal business management decisions and inefficient value-creation strategies, both of which should be avoided.

Some honorable mention remarks should also be made about this study:

i. DEA was the appropriate analytical framework for this study, allowing the identification of top-performing benchmark companies in the M&E sector and the exclusion of outliers through standard deviation analysis. The qualitative assessment confirmed that the benchmark firms developed strategic advantages based on resource deployment and market positioning, further supporting the validity of DEA calculations. However, the time frame for the analysis presented challenges. The Covid-19 pandemic led to a crisis period where many companies, such as Heidelberger and Nordex, recorded negative ROA and ROE.

For data collection, Refinitiv Eikon was a powerful and reliable source. The software was easy and intuitive to use, and the results were clear and easy to process, with data export to Excel being straightforward.

The RBV theory and Porter's Five Forces analysis were essential for the qualitative analysis in this study. The researcher's focus on identifying the forces of all stakeholders provided a clear, fast, and assertive understanding of each company's characteristics. Furthermore, the Porter Framework provided a clear resume and understanding of the competitive dynamics within the M&E industry and its companies, which is crucial for developing effective business plans.

By identifying Barney's (1991) three types of assets and resources that enable value-creation strategies (physical capital, human capital, and organizational capital), differences between companies were clear. Competitive advantages can be achieved when these resources are effectively deployed, as demonstrated by the benchmark companies identified in this study. The studies from Koroleva *et al.* (2020) and Clarkson *et al.* (2011) reinforce that ESG factors represent rare, hard-to-imitate resources that can significantly enhance cash flow generation and overall financial performance.

The selection of Nordex SE, SGL Carbon SE, and Siemens AG as benchmarks in this study is aligned with the research objective of identifying firms that effectively balance ESG performance with financial resource allocation, even under adverse economic conditions. The application of DEA as the main methodological approach is consistent with previous studies (e.g., Sueyoshi & Goto, 2012; Zhou *et al.*, 2022) that integrate efficiency measurement with sustainability assessment, thus highlighting the multidimensional assessment capability that encompasses environmental and social dimensions. By combining DEA with RBV theory and Porter's Five Forces, this study offers a dual-method perspective that links ESG efficiency scores to strategic capabilities and competitive positioning, a gap under-addressed in previous DEA-based ESG assessments. The identification of benchmark companies corroborates findings from earlier studies (e.g., Clarkson *et al.*, 2011; Koroleva *et al.*, 2020) demonstrating that strategic investments in ESG initiatives can alleviate financial inefficiencies and sustain competitive advantage. Consequently, this study contributes to the extant literature by empirically validating the coexistence of high ESG performance with financial challenges, offering a nuanced understanding of how organizations strategically reallocate resources to foster long-term value creation.

6 CONCLUSION AND FUTURE ANALYSIS

This study further contributes to the DEA literature by successfully establishing a connection between financial resources and ESG achievements within the German M&E sector using the DEA methodology. It was found that Heidelberger Druckmaschinen AG, Nordex SE, SGL Carbon SE, and Siemens AG effectively transformed financial resources into high ESG performance. However, Heidelberger was excluded from the benchmarking list due to its high standard deviation of results. In contrast, WashTec AG, Varta AG, and Aumann AG were identified as the worst performers, highlighting potential areas for improvement.

A subsequent benchmarking analysis was conducted using Porter's Five Forces framework and RBV Theory to understand the competitive dynamics of the leading firms. As for another contribution to the DEA literature, the qualitative findings from RBV and Porter matched with the quantitative results from the DEA ranking and financial indicators, indicating that further research can also use this combination to find adequate results. To distinguish companies according to their size, market role, and ESG integration, the analysis employed both competitive and functional benchmarking approaches. Competitive benchmarking was applied to Nordex SE and SGL Carbon SE, while functional benchmarking focused on Siemens

AG.

Nordex SE, focused on onshore wind turbines, demonstrated significant ESG achievements despite financial challenges, indicating a sustained competitive advantage in ESG value creation. Similarly, SGL Carbon SE improved efficiency and ESG performance, overcoming pre-pandemic financial difficulties. Siemens AG's substantial market capitalization reflects its ability to leverage economies of scale and maintain consistent financial and ESG performance, making it a benchmark for both the M&E sector and other companies aiming to enhance ESG outcomes.

These findings indicate that companies with targeted allocation of financial resources tend to achieve more consistent and higher ESG scores, particularly for firms in industrial sectors facing environmental and social challenges. Insights from this analysis can support both policymakers and industry leaders in their efforts to align financial decision-making with ESG priorities. Policymakers may consider developing targeted incentives to foster the adoption of ESG practices across the M&E sector, while industry leaders should seek to integrate ESG considerations into strategic resource allocation, enhancing both corporate sustainability and long-term competitiveness.

To support the alignment of financial decision-making with ESG priorities, policymakers could consider implementing concrete measures, such as tax incentives for companies demonstrating measurable ESG improvements. In this regard, (Zhang *et al.*, 2024) found that tax incentives significantly enhance corporate ESG performance, particularly by fostering innovation and improving technological capabilities, which ultimately supports sustainable development. Furthermore, Carreno (2024) highlights that the successful integration of ESG principles relies on a structured approach, supported by clear performance indicators and a willingness to adapt to evolving ESG standards and expectations. Within this process, regulatory frameworks that promote standardized and transparent reporting play a key role in guiding companies as they align their strategies with global sustainability demands, manage risks, and identify opportunities for innovation. In this context, for industry leaders, incorporating ESG criteria into resource allocation and executive decision-making, such as linking compensation to ESG outcomes and prioritizing investments in sustainable innovation, can help strengthen internal accountability and enhance competitiveness in markets increasingly shaped by sustainability considerations.

The integrated methodological framework used in this study can be adapted for cross-sectoral ESG efficiency assessments in different national contexts. However, the study presents limitations related tothe time horizon and the number of companies analyzed. The COVID-19 outbreak affected all companies during the studied period, leading to negative ROA and ROE for many. Future research should consider a longer time frame to mitigate the impact of systemic crises. Furthermore, focusing only on German companies in the M&E sector limits the representativeness and applicability of these results to other sectors or regions. Nevertheless, the methodological procedures presented are quite applicable to different contexts, which reinforces the practical relevance of the study in terms of replicability. Expanding future analyses to include companies from multiple countries and industries would increase understanding of benchmarks for converting financial resources into ESG outcomes. Additionally, the inclusion of formal robustness checkscould improve the reliability of benchmarking results, especially in cases involving companies with high-performance variability. Considering other previously unaddressed longitudinal datasets would also provide new insights and benefit future discussions.

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