OR Spectrum (2024) 46:175–209
https://doi.org/10.1007/s00291-023-00717-z

ORIGINAL ARTICLE

The impact of corporate sustainability performance on advertising efficiency

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Received: 1 April 2022 / Accepted: 23 March 2023 / Published online: 29 April 2023

Abstract

Over the years several studies have reported a significant waste of advertising budget, a finding which calls for strategies to increase advertising efficiency. While some factors, such as brand extensions or an optimal marketing mix, have already been identified as relevant determinants of advertising efficiency, changes in consumer psychographics have so far been neglected. The current study fills this gap by investigating how the emerging awareness and demand for corporate sustainability serve as a contextual factor leveraging or hindering advertising efficiency. Furthermore, we investigate how advertising efficiency has changed across various industry sectors from 2010 to 2019. A two-step procedure was applied to analyze the secondary data of 1950 observations from 195 US firms in five industry sectors over a period of 10 years. The resulting time series of firm-specific multi-directional efficiency scores confirms that advertising efficiency varies over time, justifying the relevance of a dynamic perspective for analyzing advertising efficiency. Furthermore, in support of our main claim, the investigation of the relationship between advertising efficiency and the environmental, social and governance performance of firms over time using a time-fixed effects panel regression and a three-level hierarchical regression model confirm the significant impact of corporate sustainability performance on advertising efficiency. Interestingly, this effect varies among different industry sectors and not all corporate sustainability activities impact advertising efficiency to the same extent. The results not only emphasize the relevance of corporate sustainability performance in increasing advertising efficiency, but also guide marketers on strategic marketing decisions related to the allocation of advertising budget.

Keywords Advertising efficiency · Advertising expenses · Efficient frontier · Tobin's Q · Corporate sustainability · Environmental performance

JEL Classification M37 · C23 · C67

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1 Introduction

Global advertising expenditure reached 763 billion US dollars in 2021 and is expected to rise to 1050 billion in 2025 (Statista 2021). Given the large amount of money spent on advertising, marketers and scholars alike have continuously raised the question of advertising spending results (Luo and Donthu 2005). However, many advertisers are not aware of the efficiency of their marketing efforts (Lewis and Rao 2015). Advertising efficiency defines the relationship between advertising impact and its underlying investment, relative to a firm's competitors (Büschken 2007). High levels of advertising efficiency are desirable from a company perspective since they are an important predictor of profitability (Färe et al. 2004; Luo and Donthu 2001; Rahman et al. 2020). Since the work of Luo and Donthu (2001) on the application of data envelopment analysis (DEA) for assessing advertising efficiency, numerous articles have applied this technique to investigate advertising efficiency in various markets (Büschken 2007; Luo and Donthu 2005; Pergelova et al. 2010; Sellers-Rubio and Calderón-Martínez 2021). For instance, research conducted in the German car market reveals that only 20% of the brands investigated are efficient with respect to their advertising expenditure (Büschken 2007). Likewise, a study investigating the advertising efficiency of six US breweries reveals that only one company was efficient in terms of advertising and choice of media (Färe et al. 2004).

Some studies go one step further and investigate how advertising efficiency can be increased by contextual factors which are not directly included in its assessment (i.e., given by the set of input and output variables; Luo and Donthu 2001; Pergelova et al. 2010) and which can help to raise advertising efficiency. For instance, Deighton et al. (1994) suggest targeting new, instead of existing, consumers to increase advertising efficiency. Smith and Park (1992) reveal that brand extensions have the potential to increase advertising efficiency and Cheong et al. (2014) note that several internal and external factors have an impact on advertising efficiency. Both the demographic and psychographic structure of consumers represent external factors that need to be considered as relevant forces driving advertising efficiency. In this context, one major trend in consumer psychographics is the awareness and demand for corporate sustainability. Recent findings yielded by a survey with 1,028 US citizens highlight the relevance of sustainability in the US and reveal that US consumers may boycott or even avoid brands following poor sustainability practices (Kirienko and Schreiber 2021). Another study, conducted by the IBM Institute for Business Value with 16,439 global consumers, reports that half of the respondents (51%) indicate that environmental sustainability is more relevant for them today as compared to 12 months before (Cheung et al. 2022).

Accordingly, climate change and the related trends of green consumerism and environmentalism have forced organizations' business strategies to meet consumers' and investors' demands for firms with high corporate sustainability performance (McWilliams and Siegel 2001). Ignoring the relevance of environmentally and socially conscious operations might have severe consequences for

organizations, such as a negative reputation (Eccles and Serafeim 2013), brand dilution, or financial penalties (Hirunyawipada and Xiong 2018). An increase in negative reputation or brand dilution caused by the lack of corporate sustainability performance might result in a decrease in sales. Several practical examples—such as BP's Deepwater Horizon oil rig catastrophe in the Gulf of Mexico or Foxconn's (Apple's manufacturer in China) exploitation of its workforce—demonstrate that ignoring sustainable aspects can harm a company's profit considerably (Eccles and Serafeim 2013). Corporate sustainability refers to a company's engagement in environmental, social, and governance activities, also called ESG (Chabowski et al. 2011).[1] Environmental activities include corporate practices such as efficient resource use or a reduction in emissions (Boffo et al. 2020). Social activities include a firm's effort in promoting human rights and taking responsibility for their employees and products. Finally, activities in the governance domain cover organizational factors, like the board structure, codes of conduct, or a firm's tax strategy (Tang 2019).

Given the ongoing climate crisis and the associated severe consequences for humanity and life on earth (United Nations Environment 2013), investors and consumers alike are beginning to evaluate companies based on their corporate sustainability performance. Companies engage in sustainable behavior to improve their corporate image, as a competitive strategy, and to improve society and the lives of stakeholders (Hu et al. 2018). On the one hand, some evidence suggests that this strategy is promising from the perspective of maximizing profit: Ameer and Othman (2012) showed that, in some industry sectors, companies engaging in sustainable practices have higher mean sales growth, return on assets, income before taxes and cash flows from operations as compared to firms which do not implement sustainable corporate practices.

On the other hand, recent literature report increasing levels of consumer green skepticism (Farooq and Wicaksono 2021). Consumers become skeptical about the validity of environmental claims. This particularly holds for large companies (Carlos and Lewis 2018), which might have been associated with greenwashing and environmental scandals. Large companies are considered to be more self-serving (Farooq and Wicaksono 2021). Indeed, a recent study reports that consumers associate large fashion brands with negative sustainability practices (Reck et al. 2022). Decreasing levels of trust might attenuate any positive effect of corporate social performance on advertising efficiency. In this context, existing research reveals brand trust as an important predictor of purchase intention, while demonstrating that unethical corporate behavior decreases trust (Herbst et al. 2013). Likewise, inconsistencies in corporate sustainability perceptions decrease trust in the company and negatively impact purchase intentions (Lin et al. 2015). Low levels of trust negatively impact advertising effectiveness (Schouten et al. 2020) by hindering consumers to find any arguments for purchasing this particular brand (Herbst et al. 2013).

To expand the literature exploring opportunities for increasing advertising efficiency, this paper investigates the relationship between a firm's corporate

[1] We will use this abbreviation in the sequel.

sustainability performance—in terms of its environmental, social, and governance activities—and advertising efficiency. More formally, the following research question will be addressed:

RQ: To what extent does corporate sustainability performance (i.e., environmental, social, and governance activities) influence advertising efficiency across different industry sectors and over time?

A better understanding of the impact of a firm's corporate sustainability performance on advertising efficiency will contribute to the literature and practice of management in several ways. First, knowledge of the differential effects of the three different ESG dimensions (environmental, social, and governance) of corporate sustainability performance will offer deeper insights into the relevance of each dimension in increasing advertising efficiency. Second, the findings of this study will support marketers and advertisers in making strategic spending decisions. More specifically, identifying corporate sustainability activities which leverage the effect of advertising will support managers in developing an overall communication strategy that expands traditional advertising by communicating the relevant sustainability activities the company is engaged in. This would assist the company in building a favorable reputation for corporate sustainability. The problem of potential greenwashing in this regard is accounted for in this study by relying on independent, unbiased, and objective sustainability rating providers, instead of using self-reported measures by the companies. Third, our study offers insights into how advertising efficiency and corporate sustainability performance have changed over time and hence follows the call to investigate advertising efficiency from a long-term perspective (Cheong et al. 2014). In addition, the analysis of aggregated data in a time series allows for observation of general conclusions over time which are not specific to only one company.

Sections 2 to 6 of this paper are structured as follows. Section 2 provides conceptual underpinnings on the postulated relationship between corporate sustainability performance and advertising efficiency also driven by other contextual factors. Section 3 presents methodological details required for the empirical investigation: multi-directional efficiency analysis to determine companies executing efficient advertising (vis-á-vis their competitors), panel regression to estimate the impact of corporate sustainability performance on companies' success and a three-level hierarchical model to investigate the dynamic of this relationship over time for each industry sector. Section 4 details on the two data sets employed, Sect. 5 reports the results obtained, and Sect. 6 discusses the findings and concludes.

2 Theoretical background

2.1 Advertising efficiency

Advertising efficiency describes a firm's ability to minimize advertising inputs (i.e., advertising expenses) while maximizing advertising outputs at the same time (i.e., sales revenues; Pergelova et al. 2010; Rahman et al. 2020). Efficient firms have a competitive advantage, since—relative to their competitors—they manage to achieve

the same or higher advertising outputs while using fewer advertising inputs (Cheong et al. 2014; Rahman et al. 2020). In line with this conceptualization of advertising efficiency, the measurement of efficiency takes into consideration the role of competitors and defines advertising efficiency as the efficient use of inputs to generate the highest output possible relative to competitors (Cheong et al. 2014). The consideration of competitors' advertising activities helps marketers when assessing advertising efficiency and their advertising performance (Luo and Donthu 2001).

The extant literature acknowledges the importance of boosting advertising efficiency. Danaher and Rust (1994) state that rising advertising efficiency needs to be prioritized in the same way as increasing returns on investment. Following this call, advertising efficiency has become a focal point in the marketing literature. Most extant studies report a high proportion of inefficient firms in their sample. For instance, analyzing efficiency in media spending over a period of 27 years (1985–2012), Cheong et al. (2014) report a decrease of 25% in efficiency. The authors conclude that US advertisers not only continue to be inefficient but have also become even more inefficient over time. Analyzing 94 of the top 100 advertisers in 1997 and 1998, Luo and Donthu (2005) report a mean inefficiency score of 20%, with the highest inefficiency score being 60%. In other words, firms could have generated 20% or more in sales if they had spent their advertising budget more efficiently. Similar evidence is provided by Büschken (2007), who reveals that 8% of a brand's advertising budget is wasted in the German automobile industry. Luo and Donthu (2001) analyzed 23 outdoor campaigns and conclude that only six campaigns were efficient.

Given the high level of waste in advertising budgets, researchers have started investigating potential ways to boost advertising efficiency. In this context, Pergelova et al. (2010) state that companies that complement their traditional advertising mix with internet advertising are more efficient than firms that rely on conventional advertising methods only. Büschken (2007) reports that a larger brand portfolio has a positive influence on advertising efficiency in the German car market. A similar result was observed by a study conducted in the Spanish hotel industry: A broad brand portfolio, as well as internet advertising, have been identified as significant predictors of advertising efficiency (Sellers-Rubio and Calderón-Martínez 2021). However, despite the increasing demand for corporate sustainability, a firm's corporate sustainability performance has not been considered a driving force for boosting advertising efficiency.

2.2 Corporate sustainability performance and signaling theory

Corporate sustainability and advertising effectiveness. From a theoretical perspective, the positive effect of corporate sustainable performance on advertising efficiency can be explained by signaling theory. Signaling theory is built on the premise of information asymmetry in buyer-seller contexts. Buyers as externals to the organization cannot access all relevant information, while on the contrary, sellers have all information available (Spence 1973). Hence, consumers often lack important information when making buying decisions (Kivetz and Simonson 2000), causing them

to rely on inferences which can be prompted by signals. Signals can come in the form of company's actions and strategies (Atkinson and Rosenthal 2014), with a company's sustainability performance being considered as a signal if it is communicated to stakeholders. For the present purpose, signals are used to inform consumers about a company's ESG achievements (Lee et al. 2022).

Indeed, the consumers' ability to judge corporate sustainability is highly dependent on a company's willingness to disclose sustainability practices (Rustam et al. 2020). ESG ratings can be considered as a proxy for corporate sustainability performance (Uyar et al. 2020) and hence serve as an observable signal about investments in sustainable activities and efforts (cf. Connelly et al. 2011), which in turn helps companies to build their corporate reputation (Luo and Bhattacharya 2006; Bigné et al. 2012). Accordingly, one way to communicate sustainable activities is the use of sustainability reports (Sweeney and Coughlan 2008). ESG reports are predominately used by investors to assess a company's performance risk (Cornell 2021). In addition, the increasing demand for green products (e.g., Martínez et al. 2020) requires firms to foster their corporate sustainability performance. Consumers prefer purchasing products from firms with a good corporate responsibility reputation (Gillan et al. 2021; Panda et al. 2020; Wang et al. 2019), in particular when a high degree of fit exists between the firm's portfolio and corporate sustainability activities (Du et al. 2007). Especially for firms operating in consumer markets, corporate sustainability performance is an important indicator of firm quality perceptions (Taylor et al. 2018).

Furthermore, corporate sustainability positively affects firm reputation (Fombrun 2005; Saeidi et al. 2015) which, in turn, has been acknowledged to relate positively to the performance of a firm (Amon et al. 2021; Bird et al. 2007; Brammer and Pavelin 2006; Fombrun and Shanley 1990; Lai et al. 2010; Pham and Tran 2020). In general, consumers perceive brands with a strong reputation as more favorable than competitor brands causing a greater advertising effectiveness and brand equity (Chaudhuri 2002). Likewise, a company's ethical reputation has been identified as relevant predictor for the effectiveness of corporate social responsibility communications in advertising (García de los Salmones and Pérez 2018). Advertisements with a strong welfare-centered orientation encourage consumers to evaluate the advertising company as socially responsible, which positively affects brand attitude and purchase intention (Diehl et al. 2016).

Hence, brands can leverage corporate social responsibility signals to increase their brand equity (Cowan and Guzman 2020). On the contrary, a poor corporate reputation hinders organizations in building strong brands (Page and Fearn 2005).

Although most extant studies investigate the impact of an aggregate ESG score on firm value (e.g., Hu et al. 2018; Servaes and Tamayo 2013), preliminary evidence suggests that not all corporate sustainability activities impact on business performance to the same extent. For instance, a study reports that the environmental dimension correlates much stronger with economic performance than the governance dimension (Ferrero-Ferrero et al. 2016). On the contrary, other research demonstrates a significant positive impact of the governance dimension on firm value in the airline industry, while no significant effect was observed for the environmental and the social dimension (Abdi et al. 2022). Likewise, a

study demonstrates that ESG scores impact on corporate efficiency only at moderate levels positively, with the governance dimension having the largest impact, followed by the social and environmental dimensions (Xie et al. 2019). Other research stresses the importance of the environmental dimension by referring to the increasing interest in strategies to tackle climate change (Becchetti et al. 2022). Based on this evidence, we investigate the impact of each of the three ESG dimensions on advertising efficiency on an individual level. In sum, we state research proposition 1:

RP1 Corporate sustainable behavior, as measured by environmental, social and governance activities, impacts on a company's advertising efficiency. The impact levels of these ESG activities depend on context factors.

Corporate sustainability and advertising effectiveness in different industry sectors. Some evidence suggests that focusing on corporate sustainability is also promising from the perspective of profit maximization: Ameer and Othman (2012) show that, in some industry sectors, companies engaging in sustainable practices have higher mean sales growth, return on assets, income before taxes and cash flows from operations as compared to firms that do not implement sustainable corporate practices. Using fuzzy-set qualitative comparative analysis, Lee et al. (2022) reveal that signaling corporate sustainability achievements directly or indirectly (via social media) impacts positively on brand evaluation in the automotive industry. Likewise, Rehman et al. (2020) report a positive correlation between a companies' environmental, social, and governance ratings and its reputation. In the financial sector, another study notes that signaling corporate sustainability achievements affects brand value positively (Ajour El Zein et al. 2019). Results of a survey conducted with 280 Australian companies in the manufacturing and services sectors reveal the positive impact of corporate-social-responsibility activities on the value of a firm (Galbreath and Shum 2012).

Consequently, it is reasonable to assume that corporate sustainability performance does not have the same effect across all industries. Industries that are associated with high levels of environmental pollution might have difficulties to trustfully communicate consumers their corporate sustainability performance. For instance, energy-intense industries, such as manufacturing, might be more critically evaluated in terms of the environmental behavior as compared to other industry sectors with a less obvious connection to environmental pollution (e.g., banking and finance). Collaborating this line of reasoning, research reveals that consumers distrust the oil industry most (Farooq and Wicaksono 2021). Additionally, previous incidents of greenwashing and low governmental regulations represent a significant determinant of consumer skepticism (Farooq and Wicaksono 2021; Li et al. 2023).

Other research confirms that news related to corporate sustainability performance have a more positive impact on financial performance for companies in the services industry than for companies operating in a product-based industry (Casado-Díaz et al. 2014). These diverging effects can be explained by institutional

theory, which suggests that the consumers' judgement on corporate sustainability activities depends on several contextual factors. Consumers expect different levels of corporate sustainability efforts depending on the industry's general standards (Pérez and García de los Salmones 2020), which might differ based on the negative environmental impact an industry has. In other words, consumers expect a certain level of sustainability and not reaching this level will result in dissatisfaction (Lacey et al. 2015). These considerations substantiate research proposition 2:

RP2 The fit between industry characteristics and sustainability moderates the impact corporate sustainability has on advertising efficiency.

Corporate sustainability and advertising effectiveness over the course of time. Research claims that time needs to be considered as an important factor when assessing advertising efficiency (Pergelova et al. 2010). The rationale behind this is twofold: First, the advertising effects on sales revenues most likely transfer to future periods (Dekimpe and Hanssens 1995); second, different types of advertising not only have short term effects, such as an increase in sales, but also long-term effects by creating brand awareness (Cobb-Walgren et al. 1995). In support of this reasoning, extant literature reports that companies engage in sustainable behavior to improve the society and the lives of stakeholders but also to enhance long-term marketing related outcomes, such as corporate image. Indeed, corporate sustainable performance can be considered as a competitive strategy (Hu et al. 2018).

Expectations on a company's activity concerning corporate sustainability also might change over time, and companies need to adapt to rising expectations to stay competitive (Vargo et al. 2007). Accordingly, it is essential to monitor the change in impact of corporate social responsibility activities on advertising effectiveness over time. Hence, our third research proposition reads:

RP3 Time moderates the impact corporate sustainability has on advertising efficiency.

3 Methodology

In this section, we outline the two-step procedure used for obtaining the relative firm-level advertising efficiency scores and analyzing the relationship between advertising efficiency and corporate sustainable behavior.

3.1 Efficiency analysis

The analysis of firm efficiency can be traced back to Koopmans (1951) and Debreu (1951). Farrell (1957a) suggests an approach based on these studies to investigate a decision-making unit's (DMU) relative efficiency with respect to several input and output variables, in which certain variables are defined as inputs that will be used as

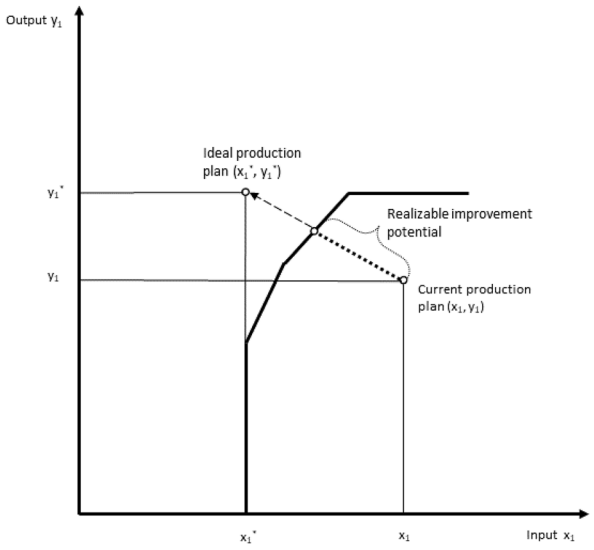

Fig. 1 Illustration of multi-directional efficiency analysis in input–output orientation. *Notes*: This figure illustrates the measurement of the realizable improvement potential for a DMU with one input denoted as x_1 and its ideal reference point x_1^*, one output denoted as y_1 and its ideal reference point y_1^* in an input–output oriented MEA model. The solid line represents the efficient frontier as a function of the set of DMUs under consideration

resource to achieve one or multiple outputs (also called production plan) and which are typically positively correlated. This so-called data envelopment analysis (DEA) is a non-parametric approach to determine the relative efficiency of different DMUs, such as firms.

For this study we rely on a related, more recent DEA-like approach to measure efficiency called multi-directional efficiency analysis (MEA), which was first introduced by Bogetoft and Hougaard (1999) and further developed by Tone (2001) and Asmild et al. (2003). While DEA uses linear programming to determine the weights used to maximize the ratio of the weighted sums of outputs over inputs, this approach allows the measurement of the improvement potential for each input and output variable separately based on a system of linear programs. Based on the set of firms in each industry sector, we measure the maximum improvement potential for each firm's input and output variable by determining an ideal production plan, which consists of the set of the theoretically optimal values for each input and output variable.

Generally, it is not possible to implement the ideal production plan due to the technological boundaries derived from the set of DMUs. However, starting from the current production plan given by the firm's current values for the input and output variables, movement in the direction of the ideal production plan is still possible up to the point where the technological limits are reached. The efficient frontier reflects these technological constraints inherent in the set and represents the benchmark for measuring the relative efficiency of all DMUs. Firms that are located on the efficient frontier, and thus help to define the technological boundaries, have no further improvement potential and are fully efficient. The distance between the current production plan and the efficient frontier is the realizable improvement potential, which indicates the level of efficiency of a firm. A higher realizable improvement potential implies higher inefficiency.

Table 1 Overview of input and output variables

Performance indicator	Input	Output
Advertising intensity (AdInt)	Advertising expenses	Sales revenues
Tobin's Q	Total assets	Market value

Notes: This table gives an overview of the input and output variables used in the multi-directional efficiency analysis, whereby the ratios have been decomposed into nominators and denominators and assigned as inputs and outputs, respectively, according to the intended direction of improvement

Figure 1 provides a simplified illustration of the MEA approach for a sample firm with one input x_1 and one output y_1.[2] The illustration visualizes the current production plan by x_1 and y_1, as well as the ideal production plan by x_1^* and y_1^* and indicates the direction of movement between these two points until the efficient frontier is reached. Section 2 of the "Appendix" describes MEA in a more stringent, formal manner.

After conducting the MEA, we transform the resulting distance measure and obtain a relative efficiency measure η similar in its interpretation as the traditional Farrell efficiency scores (Farrell 1957b) between 0 and 1 with $\eta = 1$ for fully efficient firms and $\eta < 1$ for inefficient firms. Since the efficiency measurement is conducted relative to the set of firms under consideration, the term "fully efficient" also refers to a firm's relative efficiency score and does not indicate full efficiency beyond the boundaries of the sample set used in this analysis. For the evaluation of advertising efficiency, we rely on an input–output oriented model with variable returns to scale, and determine the firms' relative advertising efficiency scores at the industry sector level to ensure homogeneity of the DMUs.

For selecting the relevant input and output variables used to determine advertising efficiency, we relied on existing literature. Advertising expenses (i.e., total spending on advertising across all media channels) have been considered as an input variable and sales revenues as an output variable in previous studies assessing advertising efficiency (e.g., Cheong et al. 2014; Färe et al. 2004; Pergelova et al. 2010; Sellers-Rubio and Calderón-Martínez 2021). The ratio between advertising expenses and sales revenue constitutes advertising intensity, a key metric in marketing. It accounts for a company's fraction of revenue allocated to advertising spending. It is a normalized measure and therefore a meaningful indicator of a company's advertising activity that is comparable across different sizes of firms.

Nevertheless, a firm's ultimate objective is the maximization of its firm value (cf. Joshi and Hanssens 2018), which has been acknowledged to represent an important variable when investigating advertising efficiency (Servaes and Tamayo 2013). Tobin's Q is a commonly used indicator for firm value, in which a value greater than 1 indicates that a company is worth more than the sum of its assets. It is given by the ratio of market value of assets and the replacement value of assets. The market value

[2] The illustration is inspired by Bogetoft and Hougaard (1999).

is the sum of a firm's market value of equity[3] and debt, which enters the efficiency analysis as an additional output variable. The replacement value is approximated by total assets, which is used as an input variable in the efficiency analysis. In other words, the nominators and denominators of the key metrics advertising intensity and Tobin's Q represent our performance indicators (i.e., the input and output variables) in the MEA, respectively (see Table 1).

3.2 Regression analysis

For the second step in our analysis we investigate the impact of environmental, social and governance activities on advertising efficiency and rely on panel regression methodology, in which we analyze the cross section of firms j over time t and investigate the effect of corporate sustainability performance, as measured by the ESG scores, on a firm's advertising efficiency score η_{jt}. In particular, we are interested (cf. RP1) in the effect of the three ESG dimensions individually to understand the impact of the corporate sustainability performance in these areas on a firm's advertising efficiency. The data set is a balanced micropanel[4] and we use the following fixed-effects model:

$$\eta_{jt} = \beta_{\text{ENV}}\text{ENV}_{jt} + \beta_{\text{SOC}}\text{SOC}_{jt} + \beta_{\text{GOV}}\text{GOV}_{jt} + \beta_{0t} + u_{jt} \tag{1}$$

where η_{jt} represents the advertising-efficiency score as the dependent variable and β_{ENV}, β_{SOC} and β_{GOV} the response coefficients of the independent variables: ENV_{jt} the environmental subscore, SOC_{jt} the social subscore and GOV_{jt} the governance subscore of firm j at time t, respectively. $\beta_{0\,t}$ represents a time-fixed effect, as we are interested in the variation over time, rather than across firms and u_{jt} the error term.

Due to the large increase in relevance of ESG over the last decade, we are also interested in analyzing the dynamic (cf. RP3) of this relationship, which we investigate using two approaches. This analysis will allow us to observe any changes in the coefficients over time for the cross section of firms as well as within each industry sector (cf. RP2). First, we split the overall sample in two equal subsamples and estimate the coefficients for each subsample separately.[5] Second, we specify the following hierarchical regression model with three levels:

$$\begin{aligned}
\eta_{jts} &= \beta_{0\,ts} + \beta_{\text{ENV}\,ts}\text{ENV}_{jts} + \beta_{\text{SOC}\,ts}\text{SOC}_{jts} + \beta_{\text{GOV}\,ts}\text{GOV}_{jts} + u_{jts}\beta_{kts} \\
&= \bar{\beta}_k + v_{kts} \quad E(v_{kts}) = 0 \quad \forall \quad k, t, sE(v_{k_1ts}, v_{k_2ts}) \\
&= \begin{cases} \sigma_k^2, & if \quad k_1 = k_2 = k \\ 0, & if \quad k_1 \neq k_2 \end{cases}
\end{aligned} \tag{2}$$

[3] The market value of equity is also called market capitalization as the product of a firm's share price and its common shares outstanding.

[4] The data set is balanced as it is comprised of the same firms in each period. It is a micropanel as the number of firms is greater than the number of periods.

[5] The chosen median split is used in order to ensure an unbiased sampling of the data for the two subperiods, such that results are not driven by the length of the observation periods of the subsamples.

where $k \in \{0, \text{ENV}, \text{SOC}, \text{GOV}\}$ and fixed effects are considered via $\bar{\beta}_k$. Level 1 represents companies j in a given industry sector for a given time period, level 2 time period t and level 3 industry sectors s.

4 Data

For this study, we rely on two data sets of public equity firms from the US from two different data providers, thereby eliminating the threat of common method bias in our study. Furthermore, the majority of the firms used in our sample operates outside the US as well. For instance, the dataset included firms such as Amazon Inc., Netflix Inc., Microsoft Corp., Walmart Inc, Mattel Inc., Coca Cola CO, Starbucks Corp., and General Motors Co to name just a few examples for firms that serve customers worldwide. This high globalization level across industries allows a holistic global perspective and contributes to the generalizability of our results.

We obtain firm-level data from the firms' annual financial statements from Compustat including revenue, advertising expenditure, closing prices, common shares outstanding, total assets and shareholders' equity.[6] Furthermore, we use firm-level ESG data from Sustainalytics including the overall ESG scores as well as the environmental, social and governance subscores.

ESG scores relate to a firm's performance regarding the three ESG dimensions (environment, social, governance) and are assessed by ESG rating services (e.g., Kinder Lydenberg Domini (KLD) Research & Analytics, Refinitv, Bloomberg ESG, and Morningstar Sustainalytics). These standardized criteria to measure firms' environmental, social and corporate governance activities serve as a proxy for corporate sustainability performance (Hu et al. 2018). Depending on the provider, ESG scores are based on a large number of dimension-specific key performance indicators, which are reported at the aggregated dimensions and overall level. Firms are scored between 0 and 100.

The environmental dimension deals with issues related to climate change, such as environmental policy and management, protection of biodiversity, and water use and management (Muñoz-Torres et al. 2019). Examples of indicators for the environmental subscore are carbon, waste, and water intensity. The social dimension represents human welfare, diversity, human rights, and equality among others (Markopoulos et al. 2020). Indicators such as employee training, number of fatalities, and health and safety certifications determine the social subscore. Finally, the governance dimension assesses an organization's direction and performance, strategy formulation, policy-making, accountability of the board, management structure, and employee compensation (Markopoulos et al. 2020). Examples of indicators assessing the governance dimension are tax transparency, disclosure of directors' remuneration, and board independence.

[6] These datapoints are required in order to compute the key metrics of interest, namely advertising intensity and Tobin's Q.

Since the ESG data is reported quarterly, we compute annual average ESG scores and subscores for each firm and year to match the annual frequency of the data from the financial statements. In total, the final data set only includes firms with full data availability in both data sets and is composed of 1,950 observations from 195 firms in five industry sectors and spans an observation period of 10 years from 2010 to 2019.[7] We investigate a potential shift in customer's awareness and demand for corporate sustainability performance by generating two subsamples with each subsample including an observation period of five years: subsample 1 includes annual observations from 2010 to 2014 and subsample 2 consists of observations from 2015 to 2019. Hence, the latter data set considers recent events driving environmental awareness, such as the Fridays-for-future movement which started in September 2018 (Fridays for Future 2022). A longitudinal study conducted by the Center For Climate Change Communication with US citizen reported that the same percentage (64%) of respondents experience climate change as personally important in 2019 and 2022 (Leiserowitz et al. 2019, 2022). Accordingly, disregarding the last three years (i.e., 2020–2022) does not seem to be a major limitation of our study.

The relevant descriptive statistics for the dataset are reported in Table 3, which includes the overall ESG score as well as the three ESG subscores serving as the independent variables for the panel regression[8] and, on the other hand, Tobin's Q and advertising intensity as key performance indicators. An analysis of the descriptive statistics provides essential information on the homogeneity or heterogeneity of the firms, which informs the subsequent analysis conducted in this study.

The firms have been grouped by industry sector according to their SIC code (Standard Industry Classification). The manufacturing sector reports the highest average overall ESG score with a value of 61.28, as well as the highest social and environmental subscores. At the same time, the manufacturing sector invests a considerable amount of its revenue in advertising, with the highest average advertising intensity of 3.66% across all industry sectors. Tobin's Q is also high on average with a value of 2.53, representing the second highest Tobin's Q among all industry sectors.

The transportation sector reports the second highest average ESG score (56.42), but the lowest Tobins'Q (1.50), with a moderate level of advertising intensity (3.10%). Retail trade as well as services have a similar average ESG score of 55.33 and 55.70, respectively. However, Tobins' Q and advertising intensity are higher in the services sector with values of 3.09 and 3.18%, respectively, compared to the retail trade sector with a Tobin's Q of 2.49 and

[7] As the efficiency analysis is conducted at the sector level, only industry sectors with more than 8 firms are considered in the final data set. According to Golany and Roll (1989), it is advisable to ensure that the number of decision making units is at least twice the number of inputs and outputs. Furthermore, firms with an advertising intensity of more than 100% of revenue have been excluded as extreme outliers. These firms need to be considered as heterogeneous and therefore removed to avoid a bias in the measurement of the relative efficiencies.

[8] While the overall ESG score is reported in the descriptive statistics for completeness, we focus on the ESG subscores (cf. RP1) in our analysis in order to derive more differentiated conclusions with respect to each dimension.

Table 2 Correlation matrix of ESG subscores

	ENV	SOC	GOV
ENV	1		
SOC	0.41	1	
GOV	0.09	0.14	1

Notes: This table provides the average correlation coefficients over time (for instance: $\sum_{j=1}^{J} \underbrace{\text{Corr}}_{\text{t}}(\text{ENV}_{jt}, \text{SOC}_{jt})/J$ and $J = 195$, number of firms) between the firm-specific environmental, social and governance subscores across all firms for the full observation period from 2010 to 2019

Table 3 Descriptive statistics of data analyzed

Sector	#		ESG	ENV	SOC	GOV	Tobin's Q	AdInt (%)
Manufacturing	80	Mean		60.68	58.47	67.04	2.53	3.66
		SD	8.96	13.47	10.56	7.05	1.45	4.39
		Min	42.01	35.36	37.44	48.76	0.98	0.06
		Max	84.70	90.88	87.63	84.84	8.92	25.72
Transportation, communication, electric, gas and sanitary service	14	Mean	56.42	56.32	50.55	67.09	1.50	3.10
		SD	8.44	13.04	8.87	7.75	0.60	2.49
		Min	41.61	38.29	37.04	49.86	0.85	0.32
		Max	68.99	79.62	64.95	77.77	3.18	8.30
Retail trade	38	Mean	55.33	50.78	52.95	65.65	2.49	2.12
		SD	7.29	11.34	8.39	6.43	1.35	1.83
		Min	43.90	35.27	39.5	48.66	1.06	0.16
		Max	70.75	77.51	71.55	76.19	6.47	7.86
Finance, insurance and real estate	35	Mean	53.40	47.39	56.73	56.60	1.55	2.24
		SD	6.85	12.65	7.23	8.98	1.17	2.44
		Min	44.10	31.50	41.67	42.73	0.96	0.3
		Max	73.10	75.38	73.26	78.04	5.99	12.36
Services	28	Mean	55.70	54.22	52.90	62.92	3.09	3.18
		SD	9.63	15.30	10.62	6.31	1.57	3.27
		Min	42.56	35.93	37.71	50.86	1.21	0.10
		Max	76.87	85.84	79.39	75.44	7.70	11.54

Notes: This table shows the descriptive statistics for the US public equity firms and reports the mean and standard deviation, as well as the minimum and maximum values. Column 1 states the industry sector affiliation according to the Standard Industry Classification. Column 2 indicates the number of firms contained in each industry sector. Columns 4 to 7 report the ESG scores and environmental, social and governance subscores for each sector. Columns 8 and 9 report the Tobin's Q and advertising advertising intensity (%) for each industry sector, respectively

an advertising intensity of 2.12%. The finance, insurance and real estate sector exhibits the lowest average ESG score and environmental subscores, as well as a low advertising intensity of 2.24% and relatively low Tobin's Q of 1.55.

Table 4 Advertising efficiency per sector

Sector	Mean	SD	Min	Max	Fully efficient (%)	Least efficient (%)
Manufacturing	0.72	0.16	0.45	1	23	16
Transportation	0.88	0.18	0.54	1	68	13
Retail trade	0.75	0.19	0.49	1	33	21
Finance	0.75	0.18	0.49	1	32	18
Services	0.78	0.19	0.51	1	41	13
Overall	0.75	0.18	0.41	1	32	17

Notes: This tables reports the results of the average advertising efficiency for all industry sectors individually and for the overall cross-section. Columns 2 to 5 present the mean and standard deviation as well as the minimum and maximum values over all firms and periods. Columns 6 and 7 show the average percentage of fully and least efficient firms in each sector over all periods, whereby fully efficient firms have an advertising efficiency score of 1 and the least efficient firms have a score of less than 0.6. The lower average minimum (i.e., 0.41) for the cross-section is a result of the accumulation of the minimum values across all sectors and periods due to pooling the data

Average ESG scores vary from 53.40 (finance, insurance and real estate) to 61.28 (manufacturing) across the five different industry sectors, and standard deviations range from 6.85 (finance, insurance and real estate) to 8.96 (manufacturing). At the same time, we observe an increase in ESG scores (with intermediate peaks for some industry sectors) from 2010 to 2019 of about four (for manufacturing, services) to about eight percentage points (for transportation, retail trade, finance). Similarly, Amon et al. (2021) document increasing ESG scores over time which is likely due to an increase in general investor and consumer awareness of corporate sustainability over time. Overall, the descriptive analysis of the data set indicates that, on average the firms are rather homogeneous in terms of standard deviation of ESG scores, Tobin's Q and advertising intensity across the industry sectors.

Table 2 shows the average correlation coefficients over time between the environmental, social and governance subscores across all firms for the full observation period. All ESG dimensions report on average a positive correlation with each other with a weak correlation being observed between governance and the other two ESG dimensions, while the environmental and social subscores are moderately correlated with each other.

Table 5 ESG scores and performance indicators

Sector	ENV	SOC	GOV	Tobin's Q	AdInt(%)
Fully efficient firms					
Manufacturing	62.30	59.27	67.45	2.74	1.18
Transportation	56.46	51.88	66.97	1.44	2.27
Retail trade	51.32	52.28	67.34	3.29	1.10
Finance	51.76	55.50	62.43	1.54	1.38
Services	63.56	58.51	62.95	3.35	1.08
Least efficient firms					
Manufacturing	59.54	55.87	66.47	1.96	3.20
Transportation	55.35	52.51	68.79	1.24	4.99
Retail trade	43.35	51.26	66.53	2.04	2.98
Finance	37.09	57.96	51.97	1.07	1.33
Services	48.42	46.25	63.17	2.19	3.16

Notes: This table shows average ESG subscores and performance indicators for fully (upper panel) and least efficient (lower panel) firms for all industry sectors. For each sector the average values are reported for the ESG subscores in columns 2–4, Tobin's Q in column 5 and advertising intensity (%) in column 6

5 Results

This section presents the results of the efficiency analysis and the subsequent panel and hierarchical regressions. First, we report the results of the advertising efficiency measurement at the sector level in Sect. 5.1. Then we investigate the output of the fixed effects panel and hierarchical regression models in Sect. 5.2.

5.1 Advertising efficiency

The results of the efficiency analysis are reported in Tables 4 and 5, which illustrate the average advertising efficiency per industry sector and the sector results of advertising intensity and Tobin's Q as well as the environmental, social and governance subscores for the fully and least efficient firms over the whole observation period, respectively. The detailed results for each industry sector and period are available in the "Appendix" in Tables 9, 10, 11, 12 and 13. We classify firms into four groups depending on their efficiency levels. This allows us to investigate the firms' efficiency levels as well as their input and output variables based on the average results in each group. The first group describes fully efficient firms, which are characterized by an efficiency score of 1. This means that no further improvement can be achieved by changing input or output variables. These firms constitute the efficient frontier in each industry sector and period. Firms with efficiency scores lower than 1 and greater or equal to 0.8 are considered to be moderately efficient, while an efficiency score between 0.8 and 0.6 indicates modest efficiency. Finally, all companies below an efficiency score of 0.6 are defined as

least efficient. These firms are at least 40% less efficient than their fully efficient competitors.

Table 4 reports the mean advertising efficiency. Only 23% of the firms analyzed in the manufacturing sector are fully efficient relative to their competitors. This implies that 77% of firms in this sector have the potential to increase their advertising efficiency to varying extent. Furthermore, the average efficiency score of this sector is 0.72, which is the lowest value of all industry sectors. Similar results can be observed for the retail sector with a mean efficiency of 0.75, the finance sector with a value of 0.75 and the services sector with 0.78. The transportation sector yields a higher mean efficiency of 0.88 when compared to the other four industry sectors.

Overall, the results indicate that 68% of the firms analyzed have the potential to improve their advertising efficiency across all the industry sectors with the average efficiency scores being quite similar. The transportation sector reports the highest number of fully efficient firms among all the industry sectors with 68% of firms being fully efficient on average throughout the observation period. For the retail sector, the finance sector as well as for the services sector, the number of efficient firms ranges from 33% to 41%.

Table 5 provides more detailed insights into the average ESG subscores as well as the average Tobin's Q and advertising intensity at the sector level. Fully efficient firms typically have higher ESG subscores in all three dimensions compared to the least efficient firms (with the exception of the governance and social subscore for the transportation sector and the social subscore for the finance sector). Only the environmental subscore shows a clear picture and is consistently higher for the fully efficient firms than for the least efficient firms with an average difference of 19 percentage points across all industry sectors.

Regarding the performance indicators that constitute our input and output variables (i.e., Tobin's Q as the ratio of market value over total assets; advertising intensity as the ratio of advertising expenditure over sales), we observe consistently a higher Tobin's Q and lower advertising intensity for fully efficient firms (with the exception of the finance sector).[9] For illustration, we report the results of the manufacturing sector in detail, which shows an average advertising intensity of 1.18% for fully efficient firms. This is 63% lower compared to the least efficient firms with a value of 3.20%. At the same time, fully efficient firms show an average Tobin's Q of 2.74, which is 40% higher than for the least efficient firms with a value of 1.96 for manufacturing companies.

Looking at the development in corporate sustainability performance throughout the observation period, our results indicate that in general ESG subscores mostly increase on average over time for both fully and least efficient firms across all industry sectors (cf section 4). Furthermore, the environmental subscores tend to

[9] These results are as expected given the assumed relationship between Tobin's Q and advertising intensity and the corresponding set of input and output variables. They are reported in order to better comprehend the differences between fully and least efficient firms for each industry sector and as a plausibility check for the efficiency measurement to ensure that the relative efficiency scores correctly represent this relationship.

Table 6 Discretization of advertising efficiency changes over time

l	#	Mean	SD	Min	Max	Volatility (see notes)
− 5	3	− 0.56	2.01	− 5.00	1.67	1.15
− 4	10	− 0.44	1.62	− 3.90	1.50	0.87
− 3	10	− 0.33	1.28	− 3.00	0.70	0.62
− 2	12	− 0.22	0.77	− 1.75	0.58	0.39
− 1	38	− 0.11	0.66	− 1.29	0.84	0.36
0	86	0.00	0.54	− 0.94	1.00	0.31
1	11	0.11	0.64	− 0.73	1.36	0.35
2	3	0.22	1.59	− 2.67	2.67	0.96
3	14	0.33	1.40	− 1.21	3.29	0.70
4	8	0.44	1.72	− 2.00	3.50	1.03

Notes: The domain of advertising efficiency η is [0, 1]. We split this domain into ten categories k, $1 \leq k \leq 10$, such that $(k-1)/10 < \eta \leq k/10$ and analyze category membership k_{jt} of η_{jt}. In more detail, we look at the changes of category membership over time $\Delta k_{jt} = k_{jt} - k_{jt-1}$ and compute $U_j = \sum_{t=2}^{10} \Delta k_{jt}\, \forall j$. Changes Δk_{jt} might be positive (improvement) or negative (decline of advertising efficiency), such that for U_j opposite changes might compensate each other (in part). For the present data we find $U_j \in \{-5, -4, ..., 4\}$; i.e., in extreme cases firms' advertising efficiency decreased by five categories, increased by 4 categories over the 10-year time span. Whereas column 1 lists the domain of U, denoted as l, column 2 presents the number (#) of firms with $U_j = l$. Columns 3-6 offer statistics of $(\Delta k_{jt} | U_j = l)$, e.g., for the mean $\sum_{t=2}^{10}(\Delta k_{jt} | U_j = l)/9$. Finally, column 7 shows $\sum_{j=1}^{J_l} \sum_{t=2}^{10} |\Delta k_{jt} | U_j = l|/(9J_l)$ and J_l as in column 2 of corresponding row $l = [-5, \ldots, 4]$; these values reflect the volatility of absolute changes between efficiency categories over time. The results shown in columns 3 to 7 are average values across all firms and sectors

experience the highest increase suggesting a particular importance of the environmental dimension.[10] These results confirm the findings of previous studies documenting increasing ESG scores for US firms (e.g., Amon et al. 2021) and indicate a rising overall importance of corporate sustainability across all industry sectors.

While the reported results describe our findings at the sector level, we are also interested in how advertising efficiency has changed over time at the firm level. For this purpose, we explore the changes in advertising efficiency for each firm across all the industry sectors throughout the observation period by discretizing the advertising efficiency score in a given year into ten categories. Then we track the changes between categories over time. Table 6 reports the results of this exercise. 44% (cf. row with l=0) of firms end up in the same category at the end of the observation period in 2019 as at the beginning of the initial efficiency

[10] These results can be derived by investigating Tables 9, 10, 11, 12 and 13 in more detail by analyzing the average periodic temporal changes in ESG subscores for the fully and least efficient firms.

Table 7 Results of the panel regression

	Dependent variable		
	Advertising efficiency (η)		
	Full	2010–2014	2015–2019
ENV	0.358**	0.370**	0.339**
	(0.019)	(0.028)	(0.020)
SOC	− 0.250**	− 0.320**	− 0.165
	(0.057)	(0.021)	(0.096)
GOV	− 0.075**	− 0.093**	− 0.042**
	(0.018)	(0.023)	(0.012)
Observations	1950	975	975
R^2	0.049	0.053	0.048
Adj.R^2	0.043	0.047	0.041

Notes: This table shows the results of the panel regression with time-fixed effects for the set of US public equity firms. The second column reports the regression results for the full observation period from 2010 to 2019, while columns 3 and 4 show the results for the first (2010–2014) and second subsample (2015–2019), respectively. Entries indicate estimates of beta coefficients and their standard errors in parentheses. The low R^2 and Adj. R^2 indicate that potential covariates are missing because of a lack of data and due to the fact that two different kinds of data sources are combined. Herein, $^{*}p < 0.05$; $^{**}p < 0.01$

measurement in 2010. When assessing the stability of firms in terms of advertising efficiency, it is reasonable to also identify firms as stable, for which the final efficiency evaluation deviates by just ± 1 category from the initial measurement. A comparison of rows $l = [-1, 0, 1]$ (columns 3–7 of Table 6) shows only marginal differences between these firms. This implies that the share of firms considered to have relatively stable efficiency levels over time increases to 69%. From the whole sample, 18% of firms become less efficient (i.e., $l = [-2, \ldots, -5]$), while 13% become more efficient (i.e., $l = [2, \ldots, 4]$) as shown in columns 1 and 2 of Table 6. The larger number of categories with a negative overall change (column 1 of Table 6) and, correspondingly, the larger values in column 7 (reflecting volatility of changes, upper part of Table 6), indicate that firms with decreasing efficiency are also more unstable in their efficiency levels when compared to firms with positive changes (lower part of Table 6). As a robustness check we conducted the same analysis for a more fine grained discretization of advertising efficiency (e.g., twenty categories instead of ten) and essentially arrived at the same results.[11]

[11] Detailed results are available from the authors.

While we cannot provide any further insights into the reasons for the observed decrease in advertising efficiency based on the available data, possible determinants for low advertising efficiency can be identified in the extant literature, such as competition on advertising budget strategies (Yoo and Mandhachitara 2003), less effective advertising content (Spotts et al. 1997), the choice of an unfavorable media mix (Bhargava et al. 1994) or a decrease in the product brand portfolio.

Overall, the efficiency analysis shows the potential for efficiency gains in each industry sector as fully efficient firms systematically outperform in terms of advertising efficiency by achieving on average a higher Tobin's Q with lower advertising intensity (with the exception of the finance sector). Fully efficient firms also consistently report higher environmental subscores on average, while for the other dimensions, no such clear conclusion can be made. ESG subscores mostly increase on average over time for fully efficient firms and the environmental subscore tends to experience the highest increase. This implies an increased relevance of corporate sustainability during the observation period across all the industry sectors and suggests a systematic relationship between advertising efficiency and corporate sustainability performance (in particular the environmental dimension), which will be explored further in the following subsection.

5.2 Effect of corporate sustainability performance on advertising efficiency

Table 7 summarizes the results of the panel regression that estimates the impact of the three ESG subscores (environmental, social, and governance) on advertising efficiency across all firms and industry sectors. The sample was split into two subsamples (2010–2014, 2015–2019, see Table 7)[12] to allow for observations of any changes in the relationship between the three corporate sustainability dimensions and advertising efficiency over time.[13] In general, the analysis reveals a significant relationship between the three ESG dimensions and advertising efficiency (see Table 7, column "Full").[14] A more detailed inspection shows that the environmental dimension has a significant positive impact.[15] This result implies that companies conducting corporate environmental activities, and thus increasing their environmental subscore, are able to achieve a higher advertising efficiency. This finding is

[12] In the absence of dramatic events during the time frame considered—which might require other splits of the data—the median split appears to be the canonical choice.

[13] Following Iacobucci et al. (2015) we don't expect our results to be biased due to the lack of multicollinearity between the independent variables as evident by an investigation of the correlation between ESG scores as shown in Table 2 of Sect. 4.

[14] Following Hoechle (2007) we apply the Driscoll-Kraay Robust Covariance Matrix Estimator (Driscoll and Kraay 1998) to account for serial correlation and cross sectional dependence after testing the residuals for serial correlation using the Breusch-Godfrey Test (Breusch 1978; Godfrey 1978) and Woolridge Test (Wooldridge 2010), and for cross sectional dependence using the Breusch-Pagan LM (Breusch and Pagan 1980) and Pasaran CD Test (Pesaran 2015).

[15] While we report the results based on the efficiency analysis using input and output variables from the same period t, we have also conducted the full analysis using the lag(-1) of advertising spending as additional input variable in the efficiency measurement and receive very similar results. These results are available from the authors upon request.

in line with the main claim of the current research, i.e., that consumers' awareness and demand for corporate sustainability needs to be taken into consideration when assessing a firm's advertising efficiency. However, both the social and the governance dimensions have a significant negative impact on advertising efficiency.

A possible explanation for these results could be that activities related to these corporate sustainability dimensions do not necessarily translate into a firm's communication strategy in the same way as environmental activities, but still require company resources to implement. In particular for the governance dimension it might be reasonable to assume that any activities addressing this dimension will mostly affect the internal processes of the firm (i.e., board structure, reporting standards), which could explain why investing in this dimension fails to raise advertising efficiency. Indeed, the governance score captures activities which are mainly targeted at a firm's shareholders, and are therefore less visible to the final customer. This result is in line with previous studies showing a lower contribution of the governance dimension on performance variables (Foote et al. 2010). On the contrary, the environmental subscore evaluates practices which are targeted at other stakeholder groups as well, such as customers, suppliers and communities (Yoon et al. 2018). Hence, governance activities seem to fail to produce any signaling effect. The effect of the environmental dimension on advertising efficiency is further leveraged by the media coverage on climate change, and as a result, the advancing introduction of control measures at the firm level. This implies, that as compared to the governance and social dimensions, the environmental dimension has gained more relevance (Becchetti et al. 2022).

An investigation of the two subsamples provides insights into how the relationship between the three ESG dimensions and advertising efficiency has changed over time. For both, the social and governance subscores, the negative coefficient becomes smaller (absolutely), and even insignificant in case of the social subscore.[16] This result suggests that the potential negative impact of these ESG dimensions, and in particular the social dimension, on advertising efficiency diminishes or even disappears over time. One possible explanation is the increased expectations regarding firms' corporate sustainability practices representing the social dimension. Herzberg's motivation-hygiene theory might explain why activities relating to the social dimension fail to increase advertising efficiency. The theory suggests that sources of satisfaction (motivators) and dissatisfaction (hygiene factors) need to be assessed separately, implying that sources that avoid dissatisfaction do not automatically increase satisfaction (Herzberg 1968). A firm's corporate social performance is assessed through respecting human rights, taking responsibility of its products and the quality of employment. All these factors can be considered as a pre-requisite for consumers to engage in a business relationship with a company, while these factors cannot stimulate good customer relationships (Lacey et al. 2015).

While the panel regression analysis is used to investigate the overall relationship between ESG scores and advertising efficiency for the full cross section of firms, we

[16] While the coefficient of the environmental subscore also decreases, the change is much less pronounced than for the other two subscores.

Table 8 Results of the three-level hierarchical model

Dependent variable: advertising efficiency (η)		
Regressor variables	Estimates	Test statistic
		Fixed effects
Intercept	0.652	$F_{1,\ 1898.26} = 333.643^{**}$
ENV	0.423	$F_{1,\ 1090.53} = 118.437^{**}$
SOC	− 0.214	$F_{1,\ 1902.733} = 19.395^{**}$
GOV	0.008	$F_{1,\ 1828.764} = 0.021$
Random effects		
Variance (Residuals)	0.029	$Wald_z = 30.849^{**}$
Variance (ENV)	0.007	$Wald_z = 3.562^{**}$
Information criterion: $LL_0 = -1305.949$		

Notes: This table shows the results of the three-level hierarchical regression model for the full observation period from 2010 to 2019. Level 1: companies; Level 2: time series; Level 3: industry sector. Herein, $^{*}p < 0.05$; $^{**}p < 0.01$

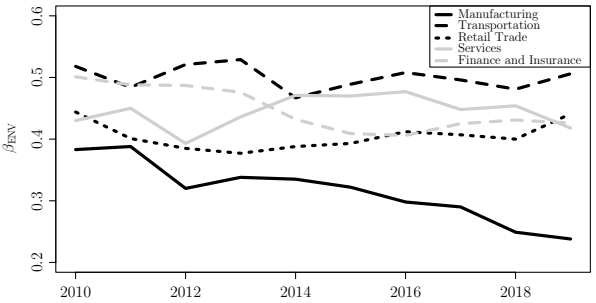

Fig. 2 Results of the three-level hierarchical model for β_{ENV}. *Note*: This figure shows the results of the three-level hierarchical model with respect to the effect of the environmental dimension on advertising efficiency for all industry sectors. The graphs present the time paths of the beta coefficients for each industry sector

analyze this relationship as well as the dynamics over time for each industry sector and ESG dimension individually using a three-level hierarchical regression model (cf. RP2, RP3). These results largely confirm the results presented in the panel regression and indicate a significant overall effect of corporate sustainability performance on advertising efficiency for each industry sector. The results of the hierarchical regression do not indicate a significant dynamic in this relationship over time for the social and governance dimensions in any of the investigated industry sectors.[17]

However, this is not the case for the environmental dimension, for which a significant downward trend can be observed for the manufacturing sector. Table 8 presents the results of the hierarchical regression and Fig. 2 shows the time paths of the response coefficients for the environmental dimension for each industry sector. The manufacturing sector reports the lowest and the transportation sector the highest beta coefficients. Furthermore, for the manufacturing sector a significant decrease

[17] Based on the likelihood ratio test, we selected the most parsimonious model and found that the random component of SOC, GOV and the intercept were statistically not significant.

in the beta coefficients from 0.383 in 2010 to 0.238 in 2019 can be observed.[18] The weaker impact of environmental activities for the manufacturing sector than for the other industry sectors reflects the more critical assessment of energy-intensive industries in this regard as reported in the literature (e.g., Casado-Díaz et al. 2014). The decreasing influence might again mirror consumers' increasing expectations concerning environmental issues, however, meeting these expectations helps avoiding dissatisfaction rather than increasing satisfaction.

6 Conclusion

In general, advertising has the overall objective of increasing sales and a company's profits and ultimately its firm value. However, several scholars have questioned the efficiency of advertising spending. The current research aims at identifying new opportunities to increase advertising efficiency without directly changing the input or output variables, but indirectly by managing a firm's corporate reputation for sustainability. In doing so, we first analyzed the advertising efficiency of 195 US public equity firms in five industry sectors over a period of 10 years using multi-directional efficiency analysis. Our data set allows us to draw more general conclusions beyond the scope of this geographical region relevant for other economies similar to the US as well, because many of the companies in the data set are multinationals.

The efficiency of a firm is measured by considering the relevant input and output variables, while no relative importance is defined for these input- and output-specific improvements (Asmild and Matthews 2012). Furthermore, the reliance on two different data sets (i.e., firms' financial statements from Compustat and ESG scores from Sustainalytics) avoids the risk of common method bias in our data set.

Our analysis reveals that most of the firms in our dataset are inefficient. Relative to their competitors, 68% of the firms analyzed have the potential to improve their advertising efficiency across all the industry sectors. Our analysis further indicates that—although advertising efficiency remains relatively stable for 69% of firms—a larger proportion of companies became more inefficient (18%) than efficient over time (13%). This result confirms previous research in this field (Cheong et al. 2014) and justifies calls for new opportunities to increase advertising efficiency.

At the same time, we observed that—compared to less efficient firms—fully efficient firms have higher corporate sustainability performance. This observation provides the first indication that corporate sustainability performance might be linked to advertising efficiency. To further test this assumption, we estimated a fixed effects

[18] As a robustness check, we have also conducted the full analysis using a larger, unbalanced sample of 1113 firms and receive similar results, with the exception of the governance dimension, for which insignificant results are reported for the full sample and subsample 2, while the results of the hierarchical model can be confirmed. Together with the low reported coefficients for β_{GOV}, this supports our conclusion that the relevance of GOV for advertising efficiency is limited. Detailed results are available from the authors upon request.

panel regression model. The results reveal a positive and significant effect of corporate environmental performance on advertising efficiency. To observe any changes in the relevance of the three ESG dimensions over time, we further divided the sample into two subsamples, each consisting of a period of five years. The influence of the environmental dimension on advertising efficiency was highly significant in both periods. Hence, our findings support our main claim that a strong environmental reputation can leverage advertising efficiency. While the effects of the social and governance dimensions were negative and significant between 2010 and 2014, these effects decreased and the effect of the social dimension became insignificant for the period between 2015 and 2019. It seems that social practices are considered as a hygiene factor, or in other words, "doing good" in the social dimension is a requirement to avoid any negative effect on advertising efficiency. An investment made in governance practices does not seem to lead to increases in advertising efficiency. One possible explanation for this result can be found in the nature of governance activities: They mainly relate to a firm's internal processes, such as tax transparency, disclosure of directors' remuneration, and board independence, which are not as useful as environmental practices (i.e., reductions in carbon emission or waste) for marketing communication purposes.

The analysis of the dynamics over time for each industry sector and ESG dimension individually using a three-level hierarchical regression model offers further evidence of the significant effect of corporate sustainability performance on advertising efficiency. The results indicate a significant downward trend in the relationship between advertising efficiency and the environmental dimension for the manufacturing sector. This finding corroborates our theoretical reasoning postulating that consumers have higher expectations related to energy-intense industries and meeting these expectations is considered a minimum requirement to compensate for the intense use of natural resources.

Previous studies' findings show a positive relationship between a firm's reputation, corporate sustainability performance, and the value of a firm (e.g., Saeidi et al. 2015). In contrast to previous research, we explicitly focus on a firm's reputation for sustainability, which we identified as highly relevant for advertising efficiency. We advance existing findings by illuminating the direct link between corporate sustainability performance and advertising efficiency and we investigate the separate impact of a firm's environmental, social and governance activities. Overall, our findings suggest that firms' environmental practices increase advertising efficiency.

Further extensions of this research could be a more refined separation of various advertising expenses for the measurement of the advertising efficiency. Additionally, the consideration of the individual key performance indicators in each ESG dimension would be interesting to further investigate in detail which corporate sustainability activities impact a firm's advertising efficiency.

Appendix

Detailed results: efficiency analysis

Table 9, 10, 11, 12 and 13.

Table 9 MEA results—manufacturing

Year	ENV	SOC	GOV	Tobin	AdInt (%)	#	Eff
2010	55.50	56.00	63.00	2.06	1.12	21	1
	52.25	54.00	68.00	1.95	2.15	55	0.8–0.6
	67.25	62.54	71.50	1.98	2.48	4	0.6–0.4
2011	53.08	56.17	68.50	1.50	1.00	23	1
	54.67	56.00	70.00	1.87	2.07	51	0.8–0.6
	64.00	58.21	69.33	2.13	4.15	6	0.6–0.4
2012	62.13	53.58	66.79	1.81	1.51	16	1
	61.96	61.00	69.83	1.79	1.98	56	0.8–0.6
	50.42	48.50	71.50	2.26	3.00	8	0.6–0.4
2013	54.50	54.00	67.58	2.86	1.03	19	1
	63.00	62.00	68.50	2.13	2.25	56	0.8–0.6
	63.25	57.50	72.42	1.70	5.22	5	0.6–0.4
2014	62.71	61.00	69.50	2.17	1.96	42	0.8–0.6
	62.63	61.46	64.08	1.99	5.32	16	0.6–0.4
2015	65.83	62.88	67.63	3.28	1.73	18	1
	62.75	62.63	67.92	2.20	1.94	52	0.8–0.6
	65.75	58.67	66.38	1.82	5.09	10	0.6–0.4
2016	65.43	59.26	66.87	3.22	1.37	18	1
	63.11	60.21	68.97	2.32	2.24	44	0.8–0.6
	61.00	56.74	64.71	1.75	3.46	18	0.6–0.4
2017	61.97	61.96	69.94	3.79	1.30	19	1
	62.88	59.25	65.26	2.30	3.30	39	0.8–0.6
	60.63	54.85	64.29	1.88	0.71	22	0.6–0.4
2018	66.83	61.59	67.82	2.61	0.79	14	1
	64.32	58.50	63.01	1.98	2.85	42	0.8–0.6
	57.47	56.08	60.62	2.07	0.99	22	0.6–0.4
	47.33	49.02	75.28	2.38	0.67	1	0.4–0.2
	43.97	45.27	58.53	3.82	0.59	1	0
2019	71.89	60.75	67.85	3.06	0.67	15	1
	71.13	58.09	63.49	2.48	2.70	29	0.8–0.6
	56.52	54.94	61.92	2.03	1.87	36	0.6–0.4

Notes: This table shows the results of the multi-directional efficiency analysis for the manufacturing sector. For each year the average values are reported for the ESG subscores in columns 2–4, Tobin's *Q* in column 5 and advertising intensity (%) in column 6. Column 7 reports the number of firms contained in each efficiency group, which is described in column 8

Table 10 MEA results—transportation, communications, electric, gas and sanitary services

Year	ENV	SOC	GOV	Tobin	AdInt (%)	#	Eff
2010	48.00	49.00	65.00	1.28	2.29	9	1
	41.50	41.50	65.00	1.18	3.57	4	0.8–0.6
	44.17	37.33	64.00	1.11	4.00	1	0.6–0.4
2011	53.67	43.17	65.50	1.27	1.86	9	1
	54.00	48.83	71.92	0.99	1.51	3	0.8–0.6
	55.00	48.08	68.96	1.04	5.53	2	0.6–0.4
2012	62.00	49.83	69.00	1.35	2.06	11	1
	52.92	48.42	73.75	0.92	2.91	2	0.8–0.6
	54.50	49.92	68.67	0.96	4.31	1	0.6–0.4
2013	60.33	48.67	69.00	1.33	2.02	11	1
	53.79	48.50	72.42	1.08	2.76	2	0.8–0.6
	55.50	52.75	71.25	1.08	4.31	1	0.6–0.4
2014	63.71	53.67	68.63	1.79	2.23	8	1
	56.21	48.21	69.50	1.84	2.84	4	0.8–0.6
	57.42	63.83	74.50	1.53	2.37	2	0.6–0.4
2015	59.00	53.42	65.83	1.54	2.09	9	1
	62.00	45.75	68.00	1.29	1.11	3	0.8–0.6
	56.38	57.42	69.50	1.64	5.05	2	0.6–0.4
2016	61.12	53.09	66.15	1.52	2.01	10	1
	58.20	60.54	76.79	1.46	0.70	1	0.8–0.6
	51.81	49.11	68.15	1.38	5.15	3	0.6–0.4
2017	57.35	54.65	69.36	1.67	2.35	9	1
	51.81	44.48	69.07	1.25	0.69	3	0.8–0.6
	59.32	59.62	69.13	1.44	7.08	2	0.6–0.4
2018	51.10	55.86	64.99	1.28	2.99	9	1
	53.21	53.19	65.92	1.34	0.98	3	0.8–0.6
	67.06	61.14	68.45	1.30	5.59	2	0.6–0.4
2019	48.36	57.44	66.25	1.38	2.85	10	1
	60.54	61.82	71.69	1.36	2.37	2	0.8–0.6
	52.33	45.93	65.33	0.95	6.55	2	0.6–0.4

Notes: This table shows the results of the multi-directional efficiency analysis for the transportation, communications, electric, gas and sanitary services sector. For each year the average values are reported for the ESG subscores in columns 2–4, Tobin's Q in column 5 and advertising intensity (%) in column 6.Column 7 reports the number of firms contained in each efficiency group, which is described in column 8

Table 11 MEA results—retail trade

Year	ENV	SOC	GOV	Tobin	AdInt (%)	#	Eff
2010	38.81	47.25	63.88	2.14	0.86	14	1
	41.83	46.17	60.00	1.69	1.59	17	0.8–0.6
	42.42	51.00	65.00	1.39	4.91	7	0.6–0.4
2011	44.92	49.00	68.00	2.93	1.14	11	1
	46.08	47.00	63.00	1.83	1.62	19	0.8–0.6
	40.63	50.75	64.50	2.16	3.32	8	0.6–0.4
2012	46.50	51.67	68.33	3.07	1.34	11	1
	53.04	55.88	69.96	1.69	1.51	18	0.8–0.6
	39.00	49.00	67.00	1.89	2.45	9	0.6–0.4
2013	48.42	51.21	67.46	3.69	1.21	10	1
	53.00	55.50	67.92	1.87	1.32	21	0.8–0.6
	39.58	50.92	68.50	2.24	3.80	7	0.6–0.4
2014	52.67	56.00	69.92	3.31	1.21	11	1
	51.96	59.00	65.00	2.07	1.26	16	0.8–0.6
	41.00	57.08	67.00	2.52	3.56	11	0.6–0.4
2015	56.25	57.42	69.29	4.39	1.12	10	1
	52.46	58.67	67.17	2.15	1.61	22	0.8–0.6
	37.71	56.00	69.71	2.66	3.28	6	0.6–0.4
2016	52.70	52.64	67.52	4.16	0.98	15	1
	49.87	53.23	68.61	1.76	1.30	13	0.8–0.6
	55.14	50.63	70.14	2.08	3.37	10	0.6–0.4
2017	56.56	53.75	67.61	4.09	1.17	14	1
	52.61	51.59	69.31	1.84	1.76	16	0.8–0.6
	45.75	50.12	64.86	1.74	2.35	8	0.6–0.4
2018	56.66	50.22	66.39	2.72	1.05	13	1
	59.74	53.93	64.31	1.85	1.69	17	0.8–0.6
	45.27	48.78	63.18	2.05	1.17	8	0.6–0.4
2019	59.74	53.64	65.00	2.37	0.90	18	1
	53.96	51.60	65.39	1.90	2.76	14	0.8–0.6
	46.99	48.29	65.37	1.66	1.60	6	0.6–0.4

Notes: This table shows the results of the multi-directional efficiency analysis for the retail trade sector. For each year the average values are reported for the ESG subscores in columns 2–4, Tobin's Q in column 5 and advertising intensity (%) in column 6. Column 7 reports the number of firms contained in each efficiency group, which is described in column 8

Table 12 MEA results—finance, banking and real estate

Year	ENV	SOC	GOV	Tobin	AdInt (%)	#	Eff
2010	43.33	51.13	61.04	1.07	1.36	12	1
	34.56	49.25	52.00	1.06	1.60	21	0.8–0.6
	35.78	51.00	52.22	1.07	0.99	2	0.6–0.4
2011	48.71	52.79	62.13	1.25	1.55	12	1
	35.50	50.38	53.25	1.03	1.72	20	0.8–0.6
	40.00	61.00	51.08	1.06	1.08	3	0.6–0.4
2012	53.67	53.08	60.17	1.04	1.62	13	1
	44.13	54.04	52.25	1.04	1.85	16	0.8–0.6
	34.63	56.50	51.25	1.03	1.35	6	0.6–0.4
2013	50.33	54.08	60.17	1.10	1.30	12	1
	39.17	56.50	50.92	1.08	1.74	20	0.8–0.6
	45.50	61.00	50.33	1.21	0.75	3	0.6–0.4
2014	50.33	59.17	63.79	1.95	1.39	10	1
	48.67	60.42	51.00	1.07	1.76	17	0.8–0.6
	38.00	60.71	51.67	1.06	1.45	8	0.6–0.4
2015	50.08	58.83	62.92	2.02	1.68	10	1
	50.00	63.00	53.00	1.04	1.68	17	0.8–0.6
	35.67	56.92	51.04	1.06	1.49	8	0.6–0.4
2016	57.58	55.58	68.02	2.65	1.89	9	1
	46.68	59.37	53.74	1.09	1.66	19	0.8–0.6
	37.17	58.06	54.34	1.08	1.35	7	0.6–0.4
2017	52.45	54.10	61.39	1.97	1.09	11	1
	48.56	58.49	55.07	1.08	1.52	16	0.8–0.6
	34.77	57.74	53.34	1.08	1.74	8	0.6–0.4
2018	53.93	58.51	61.74	1.23	0.86	11	1
	52.20	59.82	54.09	1.07	1.57	16	0.8–0.6
	34.45	57.03	51.83	1.05	1.57	8	0.6–0.4
2019	57.14	57.71	62.94	1.15	1.05	11	1
	54.97	63.10	53.21	1.09	1.56	15	0.8–0.6
	34.93	59.67	52.56	1.03	1.52	9	0.6–0.4

Notes: This table shows the results of the multi-directional efficiency analysis for the finance, banking and real estate sector. For each year the average values are reported for the ESG subscores in columns 2–4, Tobin's *Q* in column 5 and advertising intensity (%) in column 6. Column 7 reports the number of firms contained in each efficiency group, which is described in column 8

Table 13 MEA results—services

Year	ENV	SOC	GOV	Tobin	AdInt (%)	#	Eff
2010	46.75	48.50	69.50	3.04	1.27	10	1
	43.00	44.25	61.00	1.95	4.14	13	0.8–0.6
	44.00	39.00	63.00	3.03	1.85	5	0.6–0.4
2011	45.25	49.00	65.50	3.09	1.13	11	1
	39.75	44.25	61.25	1.86	4.60	13	0.8–0.6
	41.38	45.29	67.83	2.04	1.48	4	0.6–0.4
2012	68.58	56.92	65.25	2.72	1.03	9	1
	41.33	52.92	63.00	2.05	2.45	13	0.8–0.6
	47.00	48.00	64.83	2.22	1.52	5	0.6–0.4
	75.67	57.33	62.25	2.57	2.17	1	0.4–0.2
2013	53.08	53.63	59.54	3.34	0.89	12	1
	40.92	49.38	65.83	2.37	3.84	12	0.8–0.6
	58.42	57.38	63.46	2.15	3.47	4	0.6–0.4
2014	72.13	60.38	62.63	2.96	1.08	12	1
	42.17	52.38	64.00	2.40	4.00	14	0.8–0.6
	41.96	45.04	64.58	2.30	2.18	2	0.6–0.4
2015	70.54	62.79	60.46	3.46	1.28	12	1
	46.50	50.67	63.17	2.46	2.44	15	0.8–0.6
	42.00	43.00	65.00	1.70	4.76	1	0.6–0.4
2016	66.81	61.71	63.13	3.67	1.24	14	1
	47.67	51.32	61.57	2.32	2.89	12	0.8–0.6
	41.72	45.52	65.18	2.54	7.06	2	0.6–0.4
2017	69.03	64.55	63.33	3.65	0.90	12	1
	44.71	50.65	60.75	3.06	3.03	11	0.8–0.6
	45.99	43.05	63.34	2.48	3.41	5	0.6–0.4
2018	72.89	65.48	60.58	3.94	1.08	12	1
	45.33	50.10	57.78	2.72	3.33	13	0.8–0.6
	46.39	41.09	58.87	1.62	3.25	3	0.6–0.4
2019	70.55	62.19	59.61	3.65	0.89	11	1
	48.25	48.75	60.62	2.93	3.39	12	0.8–0.6
	46.67	45.80	58.15	1.47	1.99	5	0.6–0.4

Notes: This table shows the results of the multi-directional efficiency analysis for the services sector. For each year the average values are reported for the ESG subscores in columns 2–4, Tobin's Q in column 5 and advertising intensity (%) in column 6. Column 7 reports the number of firms contained in each efficiency group, which is described in column 8

Brief recap on multi-directional efficiency analysis (MEA) adapted for the current application

This analysis uses the following data:

Input variable	Output variable
x_{1jt}: adv. expenses for company j in period t	y_{1jt}: sales for company j in period t
x_{2jt}: total assets for company j in period t	y_{2jt}: market value for company j in period t
t=2010,..., 2019	
$j = 1, \ldots, J_s, J_s \in \{80, 14, 38, 35, 28\}$	
s sector index, $s \in$ {Manufacturing, Transportation, Retail Trade, Finance, Services}	

For each sector s and year t (indices will be omitted for ease of notation) MEA conducts the following steps:

1. The ideal points for each company j' $x_{1j'}^{ideal}$, $x_{2j'}^{ideal}$, $y_{1j'}^{ideal}$, $y_{2j'}^{ideal}$ are determined by solving separate linear programs (LP) for all input and output variables; only 2 of them (for $x_{1j'}^{ideal}$, $y_{2j'}^{ideal}$) are shown explicitly below: Constraints (3), (4) and (5) of these LPs ensure that the ideal point stays for, say input variable $x_{1j'}^{ideal}$, within the convex hull of the other variables (i.e., x_{2j}, y_{1j}, y_{2j}), but optimization (1), (2) that it is *minimal* with respect to $x_{1j'}$ (for output variable y_{2j}, that it is *maximal* with respect to $y_{2j'}$). With respect to Fig. 1 (for presentational convenience, Fig. 1 focuses on one input x_1 and one output y_1 only) constraints (3), (4) and (5) restrict search to the efficient frontier (solid line), optimization searches for (minimal feasible) x_1, i.e., x_1^*. Analogously, (maximum feasible) for y_1, i.e., y_1^*. Combining results of these four optimization steps, a hypothetical ideal plan is established: $(x_{1j'}^*, x_{2j'}^*, y_{1j'}^*, y_{2j'}^*)$ (cf Fig. 1).

$\min_{\lambda_j} x_{1j'}^{ideal}$	$\max_{\lambda_j} y_{2j'}^{ideal}$	(1)
$\sum_{\substack{j=1 \\ j \neq j'}}^{J_s} \lambda_j x_{1j} \leq x_{1j'}^{ideal}$	$\sum_{\substack{j=1 \\ j \neq j'}}^{J_s} \lambda_j y_{2j} \leq y_{2j'}^{ideal}$	(2)
$\sum_{\substack{j=1 \\ j \neq j'}}^{J_s} \lambda_j x_{2j} \leq x_{2j'}$	$\sum_{\substack{j=1 \\ j \neq j'}}^{J_s} \lambda_j x_{ij} \leq x_{ij'}$ for $i = 1, 2$	(3)
$\sum_{\substack{j=1 \\ j \neq j'}}^{J_s} \lambda_j y_{ij} \geq y_{ij'}$ for $i = 1, 2$	$\sum_{\substack{j=1 \\ j \neq j'}}^{J_s} \lambda_j y_{1j} \geq y_{1j'}$	(4)
$\lambda_j \geq 0 \ \forall j$		(5)

2. The distance between the actual values ($x_{1j'}$, $x_{2j'}$, $y_{1j'}$, $y_{2j'}$) and this hypothetical plan amounts to the potential improvement of the company's performance, the intersection with the efficient frontier the realizable improvement potential $\tilde{\eta}_{j'}$ and is computed by solving another LP:

$$\max_{\lambda_j} \tilde{\eta}_{j'}$$

$$\sum_{\substack{j=1 \\ j \neq j'}}^{J_s} \lambda_j x_{ij} \leq x_{ij'} - \tilde{\eta}_{j'}(x_{ij'} - x^*_{ij'}), \quad i = 1,2$$

$$\sum_{\substack{j=1 \\ j \neq j'}}^{J_s} \lambda_j y_{ij} \geq y_{ij'} + \tilde{\eta}_{j'}(y^*_{ij'} - y_{ij'}), \quad i = 1,2$$

$$\lambda_j \geq 0 \; \forall j$$

3. As a final step, the optimal $\tilde{\eta}^*_{j'}$ is transformed to receive a measure that allows for an interpretation similar to the Farell efficiency measure, in which higher values indicate higher efficiency:

$$\eta_{j'} = 1 - \tilde{\eta}^*_{j'}$$

Acknowledgements The authors would like to thank the processing guest editor and anonymous reviewers for their valuable comments on a previous version of this paper.

Funding Open access funding provided by MODUL University Vienna GmbH.

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