Environmental efficiency and market value: Using the DEA method to evaluate public companies from the European Union

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Abstract

Enterprises that reduce their consumption of raw materials and production of pollution should observe the resulting high degree of environmental efficiency, which is understood as the minimisation of environmental costs (energy and water consumption, carbon dioxide production and waste). High environmental efficiency should translate positively into their financial performance. Our study compares the environmental efficiency of companies listed on the regulated markets of the European Union and its impact on their market value from the point of view of natural resource management. We use the non-parametric Data Envelopment Analysis method and the Ohlson Valuation Model to assess the impact of environmental efficiency on companies' market value. The research sample includes public companies from the 27 EU Member States listed on their respective stock exchanges during the period 2014–2023. Data come from the Refinitiv Eikon database. The research shows that while the surveyed companies cannot be considered environmentally efficient, there is a positive relationship between environmental efficiency and market value. Companies' environmental performance may, therefore, be an important factor for investors.

Keywords: environmental efficiency, market value, DEA method, public companies, European Union

Introduction

Sustainable transformation is an inherent element of the modern global economy. There is a growing awareness among societies and businesses of the threats that result from the progressive degradation of the natural environment, which contributes to destructive and irreversible changes. Consequently, narratives discrediting the growing concerns and pointing to climate change cycles as a natural consequence of the development of the Earth's ecosystem are slowly disappearing. Never before have natural resources been consumed and the environment polluted on such a large scale. This resulted not so much from conscious economic policies pursued by countries but from technological limitations and because enterprises internationalised to a lesser extent.

Although rankings and criteria for assessing businesses still focus on their financial performance, environmental changes have forced the global community to question the environmental costs of the global race, which are inextricably linked to business activities. Questions have arisen regarding not only deteriorating living conditions (e.g., increased air temperature, more frequent dangerous natural phenomena, species extinction, and ecosystem pollution) but also the prospects for life as such on our planet.

Production and service companies, in their constant pursuit of profit, market value, and global expansion, are major contributors to this situation. Therefore, to halt the environmental decline, most companies need to change their operating model to include their environmental impact in their strategies.

Many companies delay taking actions that are a financial burden and require a change in the way they operate. To address this, many countries have adopted regulations requiring them to publish information on their impact on the natural environment. The European Union (EU) exemplifies this with its latest Directive EU (2022 – 2022/2464/EU), which requires companies to disclose non-financial information. Currently, reports are still prepared based on the provisions contained in Directive EU (2014 – 2014/95/EU), and the first reports based on the provisions of the new directive will not be available until 2025. According to the 2014 Directive, public companies have been required to provide non-financial ESG (environmental, social, and governance) information since 2018.

Our focus of interest is the environmental area. We hypothesise that companies that reduce their consumption of raw materials and the production of pollution will achieve high levels of environmental efficiency as a result. We understand environmental efficiency as minimising environmental costs (energy and water consumption, as well as carbon dioxide (CO2) and waste production), i.e., reducing the negative impact on the environment. It is reflected in environmental metrics like the Environmental Pillar Score published by rating agencies. A high degree of environmental efficiency should translate positively into economic performance. Improving a company's environmental impact, as well as its financial results, should translate into improved stakeholder opinions and a higher market valuation.

Therefore, we have formulated the following research question:

1. Does a decrease in a company's resource consumption and production of environmental pollutants lead to higher environmental efficiency?
2. Does a company's environmental efficiency significantly increase its market value?

The study aims to compare the environmental efficiency of EU-listed companies and show how it impacts their market value from the point of view of natural resource management. How a company's environmental performance impacts its market value has not been still resolved. Previous studies documented both positive and negative effects of environmental performance on market valuation (e.g., Al-Tuwaijri et al., 2004; Elsayed and Paton, 2005; Nakaoet al., 2007; Horváthová, 2010; Albertini, 2013; Dixton-Flower et al., 2013; Trumpp and Guenther, 2015; Li et al., 2017; Manrique and Martí-Ballester, 2017). Therefore, we want to use a different methodical approach to investigate this relationship using EU listed companies.

The EU and its member states have set very ambitious challenges related to sustainable economic reconstruction, which have been specified in EU plans and legal regulations. To assess environmental efficiency, we use the non-parametric DEA (Data Envelopment Analysis) method, which is commonly used to assess economic and especially environmental efficiency. In our study, efficiency refers to the relationship between a company's outputs and the inputs it uses. The analysis is carried out with efficiency measures oriented at minimising inputs and constant return to scale (CRS model). The measures are calculated using Performance Improvement Management Software (PIM-DEA, version 3). We define inputs as environmental resources consumed (energy and water) and pollutants generated (carbon dioxide and waste). We took the Environmental Pillar Score as the output. From the DEA perspective, the outlays incurred as a result of environmental efficiency should be as small as possible, which translates into greater environmental efficiency.

In the next stage of our research, we assess the impact of environmental efficiency on market value using a regression analysis based on the Ohlson Valuation Model (OVM). The model shows that a company's market value can be estimated based on financial and non-financial information (e.g., ESG). In our version of the OVM, we use the environmental efficiency calculated by the DEA method as an explanatory variable. This is a novelty and an innovative approach which creates a theoretical framework for assessing a company's 0market value through economic and environmental efficiencies using the DEA method.

The research sample includes public companies listed on the stock exchanges in the 27 EU Member States (as of May 1, 2024) that were headquartered in a given country. For the study of environmental and economic efficiencies, the Refinitiv database[1] is used, which contains financial and non-financial data (ESG). The initial research sample included 4,547 companies listed in 27 European markets during the period 2003–2023. Given the low quality of the reported data and the increase in ESG disclosure in recent years, we limited our final study to the last ten years (2014–2023). As a result, our final sample comprises 411 companies.

The paper is structured as follows. In the first section, we provide an overview of the research on environmental efficiency perceived as minimising the consumption of natural resources. In the next section, we describe the recent studies on the relationship between economic and environmental efficiencies and the possible impact of ESG performances on market value. In section 3, we present the research sample, the data used, and the methodology, while the results are given in section 4. Section 5 provides conclusions.

1. Environmental efficiency

In general, efficiency is defined as the relationship between the effects achieved by a company and the inputs it incurs. In the case of environmental efficiency, the key inputs and/or effects of actions relate to the natural environment in the company's activities. Environmental efficiency refers to the ability to produce goods and services while having less impact on the environment (Silva and Magalhães, 2022). This concept was introduced in 1992 by the Business Council for Sustainable Development (since 1995, the World Business Council for Sustainable Development (WBCSD)) in its publication "Changing Course". It was based on the idea of creating more goods and services while continuously reducing the ecological impacts of production, using fewer resources, and creating less waste and pollution.

Environmental efficiency is also called eco-efficiency or ecological efficiency (Dyckhoff and Allen, 2001). These three concepts can almost be seen as synonyms, although there are differences. Eco-efficiency is defined as the general goal of creating value while decreasing environmental impact, measured by the ratio between environmental impact and economic cost or value (Huppes and Ishikawa, 2005). Meanwhile, ecological efficiency refers to achieving a high level of human well-being while reducing emissions and consumption of

[1] On December 1, 2023, Refinitiv's name was changed to LSEG (a name associated with the London Stock Exchange Group). Given the greater recognition of Refinitiv than LSEG, we use the name Refinitiv.

natural resources. More generally, it refers to the environmental impact of humanity (Tamburino and Bravo, 2024). Apostu et al. (2022) synthesised the definitions of other authors to indicate that ecological efficiency can be understood as increasing production while using few resources or value generation reported per unit of environmental influence.

In our research, environmental efficiency is defined as the expected minimisation of a company's environmental outlays, seen as the relatively low consumption of environmental resources and emissions of waste in a group of companies in a given country. This efficiency is measured using the company's aggregated Environmental Pillar Score (E-score).

The growing social awareness of the environmental damage caused by companies, coupled with the increase in the costs of using natural resources, has prompted companies to adopt pro-ecological strategies and implement technologies that reduce both resource consumption and environmental pollution. This change is also due to stricter environmental reporting regulations in many countries, as well as the change in the attitudes of consumers (the recipients of goods and services) and investors (capital donors), who expect companies to be environmentally responsible and publish information in this area. Environmental information is published in non-financial reports and enables companies that provide data (e.g., rating agencies) to produce collective summaries in which each company is assigned measures that illustrate its environmental performance. We hypothesise that a company's high environmental efficiency, achieved through minimising energy and water consumption, as well as carbon dioxide emissions and waste production, directly translates into lower operating costs. This reduction in costs should lead to increased profitability and a higher market valuation.

Currently, the most recognised global providers of ESG data are Bloomberg, Morningstar, MSCI, Refinitiv, and S&P Global. However, the lack of standardised non-financial reporting standards raises a significant problem regarding the comparability of this data and the reliability of the assessments they publish (Escrig-Olmedo et al., 2010; Amel-Zadeh and Serafeim, 2018; Boffo et al., 2020). We have used the Refinitiv Eikon database, which provides the most comprehensive analysis of companies' activities (Garcia et al., 2017; Huber et al., 2017). Refinitiv's ESG indicators are available both at the aggregate (ESG) and the individual level (E, S, and G). Our primary focus is on the E-score, whose components are presented in Table 1.

Table 1. Pillars, categories, calculations, and measures on the Refinitiv E-score

Pillars/ Number of measures	Categories/ Number of measures	Category definitions	Category weights	Themes
Environmental/ 68	Emissions/ 28	Measures a company's commitment and effectiveness towards reducing environmental emissions in its production and operational processes.	0.10	Emissions Waste Biodiversity Environmental management systems
	Innovation/ 20	Reflects a company's capacity to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes or eco-designed products.	0.08	Product innovation Green revenues/R&D/ capex
	Resource use/ 20	Reflects a company's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management.	0.10	Water Energy Sustainable packaging Environmental supply chain

Source: based on Refinitiv Eikon.

In most research, only the aggregated E-index is extracted from the ESG index (e.g., Albertini, 2013; Dixon-Flower et al., 2013; Trumpp and Guenther, 2015; Manrique and Martí-Ballester, 2017; Hang et al., 2019; Gao and Wan, 2023). Very few break down the E-index into its components, i.e., the consumption of natural resources (water and energy) and the production of pollutants (carbon dioxide and waste). We disaggregate the environmental measure and consider the components that relate to the consumption of key resources (energy and water) and the emission of key pollutants (carbon dioxide and waste).

2. Environmental and economic performance

The relationship between companies' economic and environmental performance has been the subject of research for years, yet the conclusions are varied. Some studies do not confirm the positive impact of increasing environmental efficiency on economic performance. Our article focuses on a selected aspect of economic performance: corporate financial performance (CFP). CFP is a general term that includes different financial ratios that characterise a company's financial situation.

The vast majority of studies investigated the relationship between ESG and CFP. Cheng et al. (2014), Ting et al. (2020), Ahmad et al. (2021), and Bukari et al. (2024) confirmed that ESG initiatives have a positive impact on firm performance and CFP. However, Naimy et al. (2021) found that the ESG–CFP relationship depends on the ESG pillar or the sector under study. Meanwhile, Rohendi et al. (2024) showed that ESG disclosure did not affect firm value; however, the situation changed when the competitive advantage was included as an additional variable, and the research showed a significant positive direction toward firm value.

A positive relationship was not confirmed in a few studies, such as Singh et al. (2022), which found a negative correlation between ESG and CFP. Friede et al. (2015) analyzed over 2,000 studies that looked for a link between ESG criteria and CFP. 5H3Y found that not only did roughly 90% of studies confirm a non-negative ESG–CFP relationship, but the large majority of them confirmed a positive relationship.

In our study, however, we only deal with one of the ESG components, i.e., the E-score. We hypothesise that companies with a higher E rating have a better CFP thanks to reducing environmental costs. However, as with studies on the relationship between ESG and CFP, the results of the previous studies on the relationship between E and CFP are mixed. For example, Al-Tuwaijri et al. (2004) found that positive environmental performance is significantly associated with positive economic performance. Nakao et al. (2007), Albertini (2013), Manrique and Martí-Ballester (2017), and Li et al. (2017) confirmed the positive relationship between a company's environmental performance and its financial/economic performance. However, Trumpp and Guenther (2015) were among the few to point out a negative relationship between environmental performance and CFP, but only for companies with low environmental performance. For companies with high environmental performance, this relationship was positive.

According to Horváthová (2010), the likelihood of finding a negative link between environmental and financial performance significantly increases when using simple correlation coefficients instead of more advanced econometric analysis. Equally ambiguous conclusions were obtained by King et al. (2001). This time, the direction of the relationship did not result from the adopted research method but from the sector in which the company operates. They showed that a company's environmental performance is relative to its industry, and it can be associated with higher financial performance.

Elsayed and Paton (2005) reached interesting conclusions. They stated that environmental performance has a neutral impact on firm performance. Their explanation is based on theoretical premises, which show that firms invest in environmental initiatives until the point where the marginal cost of such investments equals the marginal benefit. Al-Issa et al. (2022) indicated that a company's environmental responsibility alone cannot be enough to enhance its value, and stakeholders are more concerned about the company's social engagement, which should be communicated.

Cheng et al. (2023) examined both the relationship between ESG and CFP, as well as between the individual E, S, and G components. They found that disclosing ESG-related information significantly increases firm value. When considering the E, S, and G components, only the environmental score significantly affects company value and the social and governance scores.

Research covering both the relationships between ESG and CFP, as well as between the E, S, and G components and CFP, was also conducted by Thamid et al. (2022). They demonstrated that the ESG score has a significant and positive impact on companies' value and performance. As far as firm value is concerned, the G-score is statistically insignificant; conversely, the S-score and E-score are positively significant. This means that a company's ESG initiatives, such as reusing resources, innovating, and reducing emissions to improve its public image, improve its value.

To sum up, research on the impact of the E-score on CFP is conducted much less often than on the relationship between ESG and CFP. Most studies confirm the positive impact of the E-score on CFP, including the company's value. Thus, from the company's perspective, conducting business in a way that considers its impact on the natural environment should be positively reflected in the development of its market value.

3. Material and methods

Our research sample includes public companies listed on the stock exchanges in the 27 EU Member States (as of May 1, 2024) that were headquartered in a given country. The Refinitiv database is used, which contains financial and non-financial data (ESG). As Refinitiv's ESG database includes companies from key European stock exchange indices (e.g., SMI, DAX, CAC, FTSE, S&P, NASDAQ, etc.) only from 2003, the annual data from 2003–2023 were reviewed. The initial research sample included 4,547 companies listed in 27 European markets. Firstly, we assessed the quality of environmental reporting, that is, the number of periods for which ESG data were available in at least three, five or ten years, as well as throughout the twenty-one-year research period (see Table 2).

Unfortunately, the total number of companies reporting ESG data over different time spans was as follows: 1,215 companies reported data for at least three years, 841 for at least five years, 428 for at least ten years, and 174 for 21 years. For the 389 companies listed on the stock exchanges in Bulgaria, Croatia, Estonia, Latvia, Lithuania, Malta, and Slovakia, no ESG data were published in at least three years.

Table 2. ESG reporting of public companies in the EU Member States, 2003–2023

EU Member States	Number of companies	ESG data: for 3 years and more		for 5 years and more		for 10 years and more		for all 21 years	
		Number of companies	Share (%)	Number of companies	Share (%)	Number of companies	Share (%)	Number of companies	Share (%)
Austria	66	35	53.0	33	50.0	15	22.7	6	9.1
Belgium	121	45	37.2	42	34.7	23	19.0	11	9.1
Bulgaria	209	0	0.0	0	0.0	0	0.0	0	0.0
Croatia	67	0	0.0	0	0.0	0	0.0	0	0.0
Cyprus	83	1	1.2	1	1.2	1	1.2	0	0.0
Czech Republic	23	3	13.0	3	13.0	2	8.7	0	0.0
Denmark	151	59	39.1	43	28.5	23	15.2	11	7.3
Estonia	27	0	0.0	0	0.0	0	0.0	0	0.0
Finland	180	73	40.6	34	18.9	23	12.8	11	6.1
France	570	166	29.1	135	23.7	78	13.7	34	6.0
Germany	476	195	41.0	135	28.4	61	12.8	27	5.7
Greece	145	25	17.2	24	16.6	15	10.3	7	4.8
Hungary	40	7	17.5	6	15.0	4	10.0	0	0.0
Ireland	24	16	66.7	14	58.3	10	41.7	3	12.5
Italy	413	115	27.8	82	19.9	31	7.5	14	3.4
Latvia	12	0	0.0	0	0.0	0	0.0	0	0.0
Lithuania	29	0	0.0	0	0.0	0	0.0	0	0.0
Luxembourg	15	4	26.7	4	26.7	4	26.7	0	0.0
Malta	33	0	0.0	0	0.0	0	0.0	0	0.0
Netherlands	87	51	58.6	46	52.9	25	28.7	12	13.8
Poland	550	38	6.9	37	6.7	26	4.7	0	0.0
Portugal	36	14	38.9	14	38.9	7	19.4	2	5.6
Romania	187	3	1.6	2	1.1	0	0.0	0	0.0
Slovakia	12	0	0.0	0	0.0	0	0.0	0	0.0
Slovenia	52	1	1.9	1	1.9	0	0.0	0	0.0
Spain	245	68	27.8	66	26.9	36	14.7	14	5.7
Sweden	694	296	42.7	119	17.1	45	6.5	22	3.2
Total	4,547	1,215	26.7	841	18.5	428	9.4	174	3.8

Source: own study based on Refinitiv data.

The same low quality of ESG reporting was observed in Cyprus, the Czech Republic, Hungary, Luxembourg, Romania, and Slovenia, with data available for only a few companies. Given the low quality of the reported data and the increase in ESG disclosure in recent years, we limited our study to the last ten years (2014–2023). We also included only those countries where the number of companies reporting non-financial data was at least ten. As a result, our research sample comprises 411 companies listed on the stock exchanges in 13 EU Member

States: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Poland, Spain, and Sweden.

Our environmental efficiency and market value analysis consist of two stages. In the first stage, we investigate the environmental efficiency of companies with the use of the DEA method. In the second stage, we investigate its impact on the market value of companies by using a regression analysis based on the OVM.

The DEA method has been used by many authors when studying energy and environmental economics (Mardani et al., 2018), energy efficiency (Wang et al., 2018; Molinos-Senante and Sala-Garrido, 2019), energy-environmental efficiency (Vaninsky, 2018; Djordjević and Krmac, 2019), and especially environmental efficiency (Song et al., 2012; Chen et al., 2019; Hermoso-Orzáez et al., 2020; Tóth et al., 2023). Some authors also used the DEA method to estimate the relationship between corporate efficiency and ESG disclosure (Xie et al., 2019).

The DEA method was first developed in 1978 and comes from the concept of the microeconomic productivity function defined by Debreu (1951) and Farrel (1957). Building on this foundation, Charnes, Cooper and Rhodes (1978) addressed the challenge of analysing multidimensional data and created the first model to measure effectiveness, known as CCR (taken from the authors' names). This model makes it possible to measure practical efficiency using many inputs (outlays) and outputs (effects). It is defined as the quotient of the weighted sum of outputs to the weighted sum of inputs:

$$max \frac{\sum_{n}^{N} v_n y_n}{\sum_{n}^{M} u_m x_m}$$

$$max \frac{\sum_{n}^{N} v_n y_n}{\sum_{n}^{M} u_m x_m} \leq 1$$

$$v_n \geq 0, u_m \geq 0,$$

where: y_n – n-th output, x_m – m-th input, v_n – weight of the output, u_m – weight of the input, N – number of outputs, and M – number of inputs.

Not only does the DEA method determine the relationship between numerous inputs and outputs, but it also clears the path for synthetic calculations of economic efficiency. Importantly, it does not require prior knowledge of the weights that determine the importance of individual inputs and outputs because, during the calculations, weights are generated that maximise the effectiveness of each facility. The measure ranges from 0 to 1, with indicators of exactly 1 indicating fully effective objects from the DEA perspective.

The DEA method makes it possible to calculate three types of effectiveness measures: (1) input-oriented (the goal is to minimise specific inputs while keeping the outputs unchanged), (2) output-oriented (the goal is to maximise specific outputs while keeping the inputs unchanged), and (3) without orientation. Additionally, three return-to-scale models are available: fixed (CRS), variable (VRS), and non-increasing (NIRS) (Banker et al., 1984; Fäare et al., 1985).

Our choice of the input-oriented model with fixed effects of scale (CRS) aligns with our hypothesis about minimising energy use and water resources and the production of environmental pollution to achieve an effect in the form of the Environmental Pillar Score (E). As a result, our model consists of four inputs and one output (see Table 3). Based on the Refinitiv methodology, all inputs are treated as costs and divided by revenues in US dollars in millions to reflect the company's size. This method allows us to find the most environmentally efficient public companies in the EU and compare the efficiency of other companies to those leaders.

Table 3. Description of the DEA CRS model

Inputs	ENERGY	Total direct and indirect energy consumption in gigajoules divided by revenues in US dollars in millions.
	WATER	Total water withdrawal in cubic meters divided by revenues in US dollars in millions.
	CO2	Total direct and indirect CO2 and CO2 equivalents emission in tonnes divided by revenues in US dollars in millions.
	WASTE	Total non-hazardous and hazardous amounts of waste produced in tonnes divided by revenues in US dollars in millions.
Output	E	The environmental pillar measures a company's impact on living and non-living natural systems, including the air, land and water, as well as complete ecosystems.

Source: own study based on Refinitiv methodology.

In the second stage of our analysis, the calculated DEA environmental efficiency measures are used as variables that could influence a company's economic efficiency. To study economic efficiency, understood as the maximisation of a company's market value, we use the model presented by Ohlson (1995) and later promoted by Graham (2005) and Dechow and Schrand (2010). Their model posits that a company's market value (expressed as market capitalisation) is a function of three key factors: the book value of equity (BVE), net profit (NI), and information not disclosed in financial statements but relevant for predicting future above-average profits (OI; other intangibles) (Ohlson, 1999):

$$MC_{i,t} = \beta_0 + \beta_1 BVE_{i,t} + \beta_2 NI_{i,t} + \beta_3 OI_{i,t} + \varepsilon_{i,t},$$

where: MC – market capitalisation, BVE – book value of equity, NI – net income, OI – other information.

Following Guenster et al. (2011), Bajic and Yurtoglu (2018), and Torre et al. (2020), our study modifies the original OVM model by replacing BVE and NI as explanatory variables with the Return on Total Assets (ROTA). We hypothesise that high profitability of total assets is associated with the company's economic efficiency and its development on the market (Fatemi et al., 2018; Wong et al., 2021). Therefore, the market will value such companies higher than those with lower profitability. We assume a positive impact of ROTA on market capitalisation (MC).

In the OVM, the author did not specify the OI to reflect the company's future results (Ohlson, 2011). To address this gap, we include environmental performance, calculated using the DEA method, as an explanatory variable. This procedure creates a theoretical framework for assessing market value through the prism of financial and non-financial (ESG) results (Torre et al., 2020). Similar approaches have been employed in recent ESG research (Fatemi et al., 2018; Khan, 2019; Cornell and Damodaran, 2020; Pedersen et al., 2021; Wong et al., 2021; Giannopoulos et al., 2022; Naffa and Fain, 2022).

The rationale is that companies use environmental resources for their own needs. Therefore, one of their operation goals should be to minimise the use of resources and the production of unnecessary pollution to take care of the environment, leading to improved financial and market performance. Therefore, a positive relationship is expected between environmental efficiency (EEF) and MC.

As a company's market value is influenced by many additional factors, following previous research (Velte, 2017; Atan et al., 2018; Bajic and Yurtoglu, 2018; Fatemi et al., 2018; Cornell and Damodaran, 2020; Wong et al., 2021; Abdi et al., 2022; Giannopoulos et al., 2022), our model also includes the following control variables: enterprise size (SIZE), leverage (GDR), current liquidity ratio (CR), growth rate (GROW), and asset tangibility (AT).

SIZE is measured by the natural logarithm of total assets (Yang and Baasandorj, 2017). Larger companies are more stable and in a better financial condition than smaller companies, which is why investors with a higher valuation (we assume a positive impact of SIZE on MC). Some authors have also presented a positive relationship between total assets and ESG measures (Clarkson et al., 2008; Atan et al., 2018).

We also use the General Debt Ratio (GDR), defined as the book value of total debt to the book value of total assets for the company's leverage. It measures the company's capital structure and indicates its level of risk, thereby influencing its market value (Guenster et al., 2011; Zhao et al., 2018; Lee et al., 2019; Bahadori et al., 2021). The results of many studies of ESG are inconsistent. They show that a company's leverage significantly negatively or positively influences its economic and financial performance (Nollet et al., 2016; Fatemi et al., 2018; Cristache et al., 2019; Garcia and Orsato, 2020; Giannopoulos, 2022). We assume a positive leverage effect and, as a result, a positive impact of GDR on MC. In line with Iancu et al. (2023), we also use the current liquidity ratio (CR), calculated by dividing current assets by short-term liabilities, which could positively influence the market value.

GROW is calculated using the revenue growth rate. It is considered the 'purest measure' of a company's growth (Cornell and Damodaran, 2020) and reflects the process of increasing its market value (we assume a positive relationship between GROW and MC). Following Limkriangkrai et al. (2017), we also use the asset tangibility ratio (AT) as the relationship between the book value of fixed assets and the book value of total assets. Akintoye (2009) indicated that companies have smaller financial costs if they retain large investments in tangible assets, generating more revenue and positively influencing firm value. Therefore, a positive relationship is expected between AT and MC.

The analysis of companies from different sectors also requires a variable to eliminate the problem of inter-sectoral transparency and distortions in the comparability of environmental indicators. Previous studies also included a variable related to the sector or industry (Limkriangkrai et al., 2017; Xie et al., 2017; Garcia and Orsato, 2020). We use a control variable (dummy), SECTOR, which takes a value of 1 for the Financials sector and 0 for other sectors[2]. Companies from the Financials sector conduct slightly different types of business; they are subjected to additional regulations and report certain information differently. Our final version of OVM is as follows:

$$MC_{i,t} = \beta_0 + \beta_1 ROTA_{i,t} + \beta_2 EFF_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 GDR_{i,t} + \beta_5 CR_{i,t} + \beta_6 AT_{i,t} + \beta_7 GROW_{i,t} + \beta_8 SECTOR_{i,t} + \varepsilon_{i,t}.$$

Table 4 presents a description of all the variables considered in our study.

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[2] Refinitiv uses its own methodology (TRBC, The Refinitiv Business Classification) to classify these entities into one of 13 economic sectors (Basic Materials, Consumer Cyclicals, Consumer Non-Cyclicals, Energy, Financials, Healthcare, Industrials, Real Estate, Technology and Utilities). Financials includes Investment Holding Companies, Investment Banking & Investment Services, Banking Services, Insurance, and Collective Investments (TRBC Industry Group Names). https://www.lseg.com/content/dam/data-analytics/en_us/documents/methodology/lseg-esg-scores-methodology.pdf

Table 4. Description of variables considered in the study

Variables	Description
ROTA	Return on Total Assets, calculated as net income/average value of total assets
EEF	Environmental Efficiency – a DEA-based indicator
SIZE	Natural logarithm of total assets
GDR	General Debt Ratio, computed as the book value of total debt/book value of total assets
CR	Current Ratio, calculated by dividing current assets by short-term liabilities
AT	Assets Tangibility, computed as the book value of fixed assets/book value of total assets
GROW	Growth Rate – a percentage change in revenues over a given period
SECTOR	Dummy, 1 if companies belong to the Financials sectors

Source: authors' study.

All independent variables were winsorised at the top and bottom 1% using OLS panel data regression analysis[3]. Based on the results of the Hausmann test, it was considered justified to use fixed effects (FE), and they were selected for the FE model (Redundant Fixed Effects Test) using the Chi^2 statistic. For the redundant effects (RE), we used the Breusch-Pagan test using the Lagrange Multiplier.

4. Results

Before conducting the cross-country assessment, we analysed the average value of the inputs (ENERGY, CO2, WASTE, WATER) and output (E), from 2014 to 2023 (see Table 5).

Table 5. Average values of inputs and outputs used in the DEA method, 2004–2023

EU Member States	Inputs in USD millions				Output
	ENERGY	WATER	CO2	WASTE	E
Austria	197,670.52	12,745.94	285.52	33.03	61.87
Belgium	579,13.83	38,553.09	3,825.83	4,431.28	51.32
Denmark	2,549.00	634.27	163.90	29.71	53.40
Finland	2,314.17	36,717.84	241.60	50.78	71.42
France	1,511.83	7,033.32	137.42	48.75	73.94
Germany	2,228.10	8,302.58	302.95	173.50	66.98
Greece	9,653.44	95,613.31	477.23	65.68	47.05
Ireland	2,925.42	28,877.12	316.80	29.74	49.39
Italy	2,282.95	28,618.99	291.68	36.11	63.77
Netherlands	4,136.82	1,685.49	186.36	60.79	60.33
Poland	1,626.26	125,422.18	1,136.76	1,351.49	41.71
Spain	3,886.95	14,636.50	187.22	1,842.43	68.75
Sweden	2,987.68	10,806.55	92.14	681.74	62.85

Source: own study/calculations based on Refinitiv data.

[3] We use the EViews 10 software for all statistical and econometric analyses.

The average values of ENERGY show that public companies were not stable in total energy consumption measured in gigajoules and divided by revenues in US dollars in millions. The variables varied significantly, ranging from approx. 1.5 billion USD in France to approx. 197.7 billion USD in Austria. Companies listed in Belgium can also be considered highly energy-intensive, in contrast to those from the Warsaw Stock Exchange (Poland). However, these companies report the highest water withdrawal in cubic meters divided by revenue. The average value of WATER was approx. 125.4 billion USD. The lowest water consumption was recorded in Denmark (634.3 million USD).

The results show considerable disparities among public companies in the EU regarding their CO2 emissions in tonnes divided by revenue, ranging from 92.1 million in Sweden to approx. 3.8 billion USD in Belgium. A similar trend was observed for waste production in tonnes divided by revenue. The minimum average values of WASTE were in Ireland and Denmark (approx. 29.7 million USD) with a maximum of approx. 4.4 billion USD in Belgium. The E-ratio also varied widely – from 41.71 in Poland to 73.94 in France, giving them "C+" and "B+" ratings in Refinitiv's environmental score, respectively. This variation in inputs and output can affect differences in environmental efficiency measures from the DEA perspective.

To address our research objectives, we first calculated the DEA measures[4] for 411 public companies as their indexes of environmental efficiency. Table 6 presents selected statistics of environmental efficiency results for 13 EU countries using the DEA CCR method.

Table 6. Selected statistics for environmental efficiency using the DEA method

EU Member States	N	Mean	Median	Minimum	Maximum	Std. Dev.
Austria	150	31.41	8.85	0.11	100.00	36.71
Belgium	230	28.18	9.99	0.00	100.00	35.28
Denmark	230	23.98	10.74	0.07	100.00	30.25
Finland	230	35.05	17.74	0.12	100.00	36.77
France	780	12.04	2.72	0.01	100.00	23.63
Germany	610	8.16	0.90	0.00	100.00	20.32
Greece	150	42.53	27.68	0.15	100.00	38.13
Ireland	100	55.92	58.04	0.59	100.00	37.40
Italy	310	20.37	5.61	0.00	100.00	30.93
Netherlands	250	32.74	14.14	0.03	100.00	36.69
Poland	260	38.27	25.24	0.01	100.00	35.56
Spain	360	30.38	13.11	0.04	100.00	34.88
Sweden	450	31.26	17.33	0.21	100.00	33.71

Source: own study based on Refinitiv data.

[4] We use the Performance Management Improvement Software (PIM-DEAsoft-V3.0).

It is important to note that analysed companies are generally environmentally inefficient, with the average of the DEA measures for all entities being only 24.47. Only Ireland and Greece were slightly highly efficient from the DEA perspective. Their average DEA ratios were 56.92 and 42.53, respectively. Therefore, public companies listed on the Irish Stock Exchange and the Athens Stock Exchange require few changes in inputs (ENERGY, WATER, CO2, and WASTE) to achieve output (E) from the DEA perspective. Considering the variation of environmental efficiency between countries, the lowest DEA efficiency was observed in Germany and France; the average efficiency ratios were only 8.16 and 12.04, respectively. In other countries, the calculated DEA measures are also significantly below unity (below 0.4), suggesting that they should focus on strategic decisions that improve environmental efficiency by minimising resource use and pollutant emissions.

To confirm how environmental efficiency, calculated using the DEA method, affects the market value of companies, a regression analysis was carried out. Table 7 provides the descriptive statistics of the variables used in our OVM.

Table 7. Selected statistics of variables considered in the OVM

Variables	Mean	Median	Minimum	Maximum	Std. Dev.
MC*	16.038	5.789	0.003	460.801	29.897
EFF	24.468	7.320	0.000	100.000	33.180
ROTA	3.196	3.153	-29.157	72.283	10.662
SIZE*	78.947	11.023	0.006	3,039.193	252.667
GDR	0.663	0.671	0.000	0.998	0.167
CR	1.336	1.173	0.001	9.753	0.850
AT	0.458	0.429	0.002	0.993	0.309
GROW	1.751	0.934	0.001	396.874	12.351

* Given in nominal units, i.e. the value of market capitalisation and assets in billion USD (not as a logarithm).
Source: authors' study.

The analyzed companies exhibit significant variation in their financial health. The level of MC varies significantly, ranging from 0.003 to 460.801 billion USD, with an average of approx. 16 billion USD. Based on the calculated DEA measures, the EFF range ranges from 0 to 100, and the mean and median are approx. 24.5 and 7.3, respectively. One significant factor that differentiates MC is the profitability ratios (ROTA), which ranged from -29.157 to 72.283 (with a standard deviation of 10.662).

In terms of leverage and financial liquidity, these companies have adopted different policies in these areas. Several companies use a lot of debt to finance their assets, as the GDR ranges from 0 to 0.998 with a mean of 0.663. The average of CR is 1.336, while the median is slightly lower, at 1.173. However, they have problems maintaining financial liquidity or overliquidity, with CR ranging from 0.001 to 9.753. AT also varied significantly (from 0.002 to 0.993). What may differentiate MC most is the GROW ratios, which ranged from 0.001 to 396.874 (with a standard deviation of 12.351).

Table 8 presents the results of our regression analysis. The model fit reports an adjusted R-squared of 0.688.

Table 8. The impact of environmental efficiency (EFF) on firm market value (MC)

Unbalanced Panel (Fixed effects)		
Specification	Coefficient	p-Value
EFF	0.0011	0.017
ROTA	0.0342	0.000
SIZE	0.7945	0.000
GDR	0.0000	0.027
CR	0.0192	0.000
AT	0.0000	0.000
GROW	-0.0004	0.010
SECTOR	-1.5540	0.000
Intercept	4.0418	0.000
Hausman	23.859	0.002
Ch^2	23.954	0.004
Fixed effects	Yes	
F test	534.804	0.000
Adj-R^2	0.688	
N	4,110	

Source: authors' own study.

The results indicate that there is a positive correlation between environmental efficiency and market value, which is in line with our predictions. The coefficient on EFF is statistically significant at the 5% level. This finding is consistent with the previous studies that documented the positive effect of environmental performance (E) on companies' value (Guenster et al., 2011; Nollet et al., 2016; Atan et al., 2018; Bajic and Yurtoglu, 2018; Abdi et al., 2022). With respect to control variables, all coefficients are statistically significant and, except for GROW, generally consistent with our expectations. The increase in ROTA is positively associated with market value. The results are similar to other researchers (Guenster et al., 2011; Fatemi et al., 2018; Garcia and Orsato, 2020; Wong et al., 2021).

Firm size has a significant positive coefficient in OVM, suggesting that larger firms have higher market valuations. This is consistent with a number of studies that use firm size as a control variable (Clarkson et al., 2008; Limkriangkrai et al., 2017; Atan et al., 2018; Abdi et al., 2022). The effect of leverage and financial liquidity on market value is also positive, which is partially consistent with the previous studies presented, although there are also ambiguous results in this regard (Atan et al., 2018; Garcia and Orsato, 2020; Wong et al., 2021; Abdi et al., 2022; Giannopoulos et al., 2022). Asset tangibility is connected with higher market valuations. These findings are in line with Limkriangkrai et al. (2017) and Wong et al. (2021).

Firms which report higher firm GROW have lower market capitalisation. On the one hand, these findings contradict previous studies (Guenster et al., 2011; Bajic and Yurtoglu, 2018). On the other hand, some authors received similar results (Wong et al., 2021). Firms with lower asset growth opportunities, all else being equal, should have higher market value. In our sample, this may be the result of significant differences in the growth rate in the analysed companies, as mentioned earlier. The negative impact of SECTOR on market valuation is not consistent with previous empirical studies (Limkriangkrai et al., 2017; Xie et al., 2017; Fatemi et al., 2018; Garcia and Orsato, 2020). It may, therefore, be assumed that in the Financials sector, the relationship between environmental efficiency and firm market value is usually lower than in other sectors.

5. Conclusions

The unfavourable changes that are currently taking place in the natural environment are mainly a consequence of the activities of the production and service enterprise sector, so it is mainly companies that should undergo pro-environmental transformations. Financial arguments also constitute an additional incentive to undertake such actions – reducing the consumption of natural resources and the consumption of waste. Although it may initially entail additional costs (e.g., implementing pro-ecological technologies), in the long run, it should mean an increase in economic efficiency. The improvement in a company's financial situation should translate into increased investor interest and, consequently, increase its market value. Companies should, therefore, be interested in limiting their negative impact on the environment not only for image reasons but also for financial ones.

The analysis of the environmental efficiency of public companies listed on stock exchanges in the EU using the DEA method shows that they cannot be considered environmentally efficient. This finding is particularly evident in companies from countries traditionally viewed as core EU members, such as Germany and France, as well as those known for their commitment to sustainable development, such as Denmark or Sweden. The results suggest that, overall, EU companies have significant room for improvement in their environmental practices despite the numerous legal regulations and subsequent requirements adopted by the EU.

Our research has demonstrated that there is a positive relationship between environmental efficiency and market value. This means that investors may consider a company's environmental performance to be an important factor in their investment decision-making. Therefore, companies should prioritise increasing their environmental performance because it should be financially beneficial for them. Currently, the change in companies' attitudes towards disclosing environmental information and introducing pro-ecological changes mainly stems from legal EU regulations rather than a genuine belief in the profitability of such actions. The complete implementation of the EU Directive (2022) will oblige companies to undertake timely and comprehensive environmental reporting. This development will address a significant research limitation, which is the relatively small database of environmental data published by companies. All listed companies, regardless of their size, will have to present non-financial reports for 2026, i.e. full reporting will start from 2027.

The lack of due attention to a high level of environmental performance in the case of EU public companies can be explained in two ways. On the one hand, this may result from the lack of sufficient knowledge in this area. Nevertheless, it will have to be supplemented and implemented in accordance with the requirements of the EU Directive (2022). On the other hand, companies may be afraid of having to incur high costs of implementing pro-ecological solutions, which may negatively affect their financial situation in the short term and only bring the expected benefits related to investors' decisions in the long term. The latter option is worth a more detailed analysis and may become the subject of further research in the future.

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