The Impact of Environmental, Social, and Governance on Corporate Financial Performance: A Cross-Industry Perspective

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Abstract

Environmental, social, and governance (ESG) influences corporate financial performance (CFP), though the effectiveness varies notably across industry sectors. Employing multiple linear regression and multi-period differences-in-differences (DID), this paper empirically examines the differential impacts by comparing European chemical and software industries. Our framework distinguishes between actual ESG performance metrics and voluntary ESG disclosure, and reveals distinct pathways through which sustainability practices and reporting affect CFP outcomes. We find that actual ESG performance impacts CFP more in the chemical industry than in software. Conversely, ESG disclosure, even when not reflecting true performance, provides immediate and sustained market value benefits to software companies. Despite earlier and more comprehensive non-financial reporting by chemical companies, no significant financial effects emerged in the immediate four years. Multiple robustness tests are employed to address the potential selection problem inherent in economic observational data, and the model results are interpreted with due caution. The empirical findings further advance the understanding of ESG–CFP mechanisms by revealing the complex balance between regulatory compliance, sustainability investments, and financial

outcomes.

Managerial Relevance Statement: This study provides several managerial insights for managers to tailor ESG strategies based on industrial ESG sensitivities and regulatory exposure. First, in the chemical industry, managers can better balance regulatory compliance, sustainability investments, and financial outcomes by allocating resources across environmental and social pillars. Second, employing long-term strategies to build reputational assets helps to mitigate the conflict between environmental initiatives and profitability, and strengthen the link between ESG disclosure and market value. Third, for managers in the software industry, the findings suggest that prioritizing transparency and strategic communication of sustainability efforts rather than concentrating solely on ESG score optimization can more effectively enhance financial performance. Fourth, policymakers are also urged to assess the disclosure quality in software industry rather than focusing solely on ESG ratings compliance. Our findings offer actionable insights for ESG strategy formulation and support more informed cross-industry regulatory decision-making. This paper contributes to the following UN SDGs: SDG_{11}, SDG_{12}, SDG_{13}.

Keywords: ESG ranking, ESG disclosure, corporate financial performance, nominal indicator, real indicator, industry heterogeneity

1. Introduction

Corporate environmental, social, and governance (ESG) initiatives are not just about social welfare and environmental protection – they are essential for a company's survival and development [1-4]. The increasing frequency of social and environmental issues has introduced unforeseen risks with significant corporate financial performance (CFP) consequences [5-9]. For instance, in 2024, it cost Shell and Dow Chemical $230 million to settle claims over water well contamination caused by their products.[1] In 2025, DWS, an asset manager owned by Deutsche Bank, was fined $27 million for misleading ESG claims.[2] ESG-related risks have been further compounded by the recent COVID-19 pandemic, which caused severe supply chain disruptions and resulted in a 20% cost increase in construction[3] and a 15% production decline in automotive manufacturing. As indicated, ESG controversies are not just ethical failures but also significant financial risks as well.

Despite the growing literature on ESG and CFP, no agreed consensus has been reached on the mechanisms through which ESG impacts. It is suggested that ESG enhances competitive advantage and financial performance [10-13]. DasGupta [14] analyzed the relationship between ESG score and corporate performance shortfalls based on return on assets and found that strong ESG performance can signal regulatory compliance while reducing survival crisis. Conversely, a few research highlights potential drawbacks. For instance, Buallay [15] found that ESG investments may

[1] https://www.fresnobee.com/news/local/article290692809.html
[2] https://www.reuters.com/sustainability/german-asset-manager-dws-fined-25-mln-eur-greenwashing-case-2025-04-02/
[3] https://www.quigggolden.com/publications/the-material-shortage-crisis/

increase governance costs and weaken short-term profitability. Gregory [16], using ESG scores and free cash flow as indicators, found that ESG activities may reduce short-term liquidity, negatively impacting CFP.

This paper adopts a broad definition of CFP, which is the economic outcomes achieved by a firm through its activities over a given period [7, 9]. Mixed findings on the relationship between ESG and CFP may be attributed to differences in how ESG and CFP are measured. Orlitzky, et al. [17] pointed out that CFP is typically measured using three main sources: market-based, accounting-based, and survey-based measures. La Torre, et al. [18] and Iazzolino, et al. [19] empirically examined by selecting various CFP indicators. La Torre, et al. [18] found that ESG scores exhibited a weak negative relationship with market-based indicators and no significant impact on accounting-based measures in the banking industry. However, they focused solely on CFP indicators without considering the role of different ESG variables.

This motivates us to systematically categorize ESG and CFP measurement approaches to analyze how indicator selections influence the ESG-CFP relationship. We adopt two types of CFP measurements: accounting-based CFP to match actual ESG performance, and market-based CFP to correspond with nominal ESG disclosure. As Orlitzky, et al. [17] further explained that market indicators reflect shareholder satisfaction, while accounting indicators capture internal efficiency. By comparing the results from these two types of indicators, we are able to observe the pathways through which ESG affects CFP.

The ambiguous relationship between ESG and CFP also reflects industry heterogeneity, as different sectors may produce mixed results even when using the same research indicators and methodologies. Rojo-Suárez and Alonso-Conde [20] examined four industries (i.e., banks, industrial, insurance, and other financial industries) in the Eurozone and found that ESG had no significant short-term effects, but only strongly explaining return on equity in the insurance sector. Similarly, Chen and Zhang [21] found that ESG scores positively influence firm value in the construction industry but negatively affect the coal and oil sectors. However, research on the industry-specific variations in the ESG-CFP relationship remains insufficient, with most studies focusing on either single industries or mixed-industry samples. Therefore, this study incorporates an analysis of industry heterogeneity into the context of ESG-CFP relationship.

The chemical and software industries are chosen as representative due to their contrasting ESG sensitivities.[4] The chemical industry is a typical high-pollution and high-compliance-cost sector, which relies heavily on resource management and cost control. Higher ESG scores do not necessarily translate into higher CFP in short term, as the industry requires a longer period to build intangible assets like market reputation [22]. In contrast, the software industry, characterized by intangible assets and knowledge-based services [22], faces less environmental pressures but must navigate governance challenges like data ethics and cybersecurity compliance. Bamiatzi, et al. [23] highlighted the role of corporate social responsibility in mitigating the financial impact of data breaches. However, in reality, ESG return mechanisms across the chemical and software industries are far more complicated. For instance, Palantir

[4] We follow the Thomson Reuters Business Classification industry classification standard, and blockchain and cryptocurrencies are not included in the software industry.

Technologies, an IT company, was rated 452nd out of 943 companies in its industry by Sustainalytics in 2025. Yet, the company's market value increased by 83% compared to the end of 2024. In contrast, Arkema, a chemical company, ranked 102nd out of 581 in its industry in the same ESG rating system. Despite its relatively strong ESG performance, Arkema has experienced a continuous decline in both market value and total revenue since June 2024. These contrasting outcomes underscore the need to understand the mechanisms of ESG returns in industry contexts. Therefore, this study aims to identify differences in ESG mechanisms across industries with varying pollution issues and market competition (i.e., the chemical and software industries). Specifically, we aim to answer the following research questions:

1. How do improvements in ESG practices enhance a firm's operational efficiency?

2. To what extent does greater transparency of ESG information yield higher market value benefits?

3. Do the impacts of ESG improvements and transparency on operational efficiency and market outcomes vary across industries?

To address these research questions, we employ the following structured analytical approach. First, we employ a multiple linear regression model to examine whether improvements in ESG practices enhance a firm's operational efficiency. A composite score, derived through factor analysis from seven accounting indicators representing profitability, solvency, turnover, and liquidity, serves as the dependent variable, while individual ESG pillar scores act as independent variables. Next, we adopt a multi-period differences-in-differences (DID) model to assess the impact of ESG disclosure on corporate market value. Firms that initiated ESG reporting serve as the treatment group, while non-disclosing firms form the control group. Finally, we analyze industry heterogeneity in the ESG-CFP relationship by applying both the multiple linear regression and multi-period DID models to sample data from chemical and software industries. This comparative analysis allows us to identify potential differences in the effects of ESG practices and disclosure across the two industries. To ensure the robustness of our findings, various diagnostic tests are conducted, including residual normality tests, goodness-of-fit tests, parallel trend tests, and placebo tests.

This study explores the relationship between ESG and CFP in two industries with distinct ESG sensitivities. The uniqueness of this study lies in three aspects. First, the study distinguishes between actual variables (i.e., ESG ranking and accounting-based financial indicators) and nominal variables (i.e., ESG disclosure and market-based financial indicators) to reveal how different measurements choices affect the ESG-CFP relationship. Second, principal component analysis (PCA) is used to construct a composite measure representing profitability, solvency, turnover, and liquidity, rather than relying on a single indicator to assess corporate operational efficiency. Additionally, we use the timing of ESG report disclosure to mitigate the impact of disclosure quality on research findings. Third, we compare the chemical industry, which is more sensitive to environmental factors, with the software industry, which is more sensitive to social factors, to highlight industry-specific characteristics of the ESG-CFP relationship.

The rest of the paper is organized as follows. Section 2 reviews the relevant literature, while Section 3 presents the study's hypotheses. The data collection process and methodology are detailed in Section 4. Section 5 presents the empirical results, followed by robustness checks in Section 6. Section 7 discusses the results, and Section 8 concludes the paper. Additional preliminary materials are included as Online Appendices.

2. Literature review

This paper develops on three key streams of the extant literature: ESG ratings and corporate operational efficiency; ESG transparency and market valuation; and industry-specific heterogeneity in the ESG-CFP relationship.

2.1 ESG ratings and corporate operational efficiency

The relationship between ESG ratings and corporate operational efficiency represents one of the most extensively studied yet highly debated research streams in the field [24]. Two dominant theoretical perspectives – shareholder primacy theory and stakeholder theory – offer contrasting views on the ESG-CFP nexus. Shareholder primacy theory argues that ESG initiatives impose financial burdens on firms, thereby reducing profitability [25]. Rahi, et al. [24] analyzed the impact of ESG dimensions and overall ESG scores on return on invested capital, return on equity, return on assets, and earnings per share, finding that only governance had a positive effect on return on assets.

In contrast, stakeholder theory contends that engaging with multiple stakeholders enhances corporate reputation, lowers capital costs, and reduces stock price volatility [26]. The focus of this research stream is whether ESG improvements can enhance financial performance by reducing costs, mitigating risks, and strengthening stakeholder relationships. Existing studies predominantly focus on ESG's effect on profitability, whereas we adopt a more comprehensive approach by examining the broader impact of ESG on corporate operational efficiency. Specifically, we employ a set of financial indicators that collectively represent profitability, solvency, asset turnover, and liquidity to assess ESG performance's overall effect on corporate efficiency.

Our results differ from the existing findings. Xu and Wan [27] found that optimizing environmental management enhances brand value, indirectly improving operational efficiency and mitigating risks. Similarly, Chung, et al. [28] demonstrated a positive link between ESG rankings and firms' operational capacity in the real estate and hospitality industries. However, our empirical findings suggest that environmental performance negatively affects overall financial performance in the chemical industry. This implies that firms may be overinvesting in ESG compliance to meet regulatory requirements, potentially compromising financial performance. Such imbalances in financial structure can threaten corporate sustainability, underscoring the complex trade-offs between legal compliance, short-term financial performance, and long-term sustainable growth.

2.2 ESG transparency and market valuation

Another closely related research stream examines the impact of ESG transparency on market valuation. Firms increasingly view ESG disclosure as a value-enhancing tool, with greater ESG transparency associated with benefits such as reduced capital costs

[29] and lower default risks [30]. However, Pinnuck, et al. [31] conducted content analyses and found that due to the absence of mandatory disclosure requirements and standardized reporting frameworks, ESG disclosure may suffer from selective omissions, bias, and the use of emotionally charged language, potentially misleading stakeholders.

Some studies have attempted to correct for potential biases in ESG disclosure by comparing the relative positioning of ESG scores and disclosure with industry peers [32]. However, this approach has inherent limitations, as ESG scores and ESG disclosure are not entirely independent. Many ESG rating agencies rely on firms' self-reported disclosure, introducing potential endogeneity issues due to information asymmetry. In an effort to mitigate the influence of disclosure quality on results, Chen and Xie [33] suggested using the timing of ESG rating disclosure instead of ESG disclosure content. However, this approach overlooks the potential impact of ESG ratings on firms' fundamentals and subsequent market valuations.

Our paper addresses this gap by using the timing of ESG report disclosure rather than ESG rating announcements to assess whether increased ESG transparency yields additional market benefits. The empirical findings reveal that in the software industry, the publication of ESG reports has an immediate and sustained positive impact on market valuation. This suggests that software firms can enhance their competitive positioning through improved ESG transparency and strategic communication. Additionally, these findings highlight the importance for investors to critically assess ESG disclosure quality rather than relying solely on ESG scores.

2.3 Industry-specific heterogeneity in the ESG-CFP relationship

A growing body of literature investigates the heterogeneity of the ESG-CFP relationship, emphasizing how firm characteristics and external business environments shape ESG's financial impact. Prior studies suggest that factors such as firm age, media coverage [33], national culture, and institutional environment [34], influence ESG mechanisms. Our research extends this literature by comparing industries with differing ESG sensitivities. We find that in the low-pollution software industry, investors prioritize ESG transparency over actual ESG performance. Moreover, while ESG disclosure in the chemical industry exhibit significant lag effects on market valuation, their impact in the software industry is both immediate and persistent. These insights underscore the need for chemical firms to improve the transmission speed of non-financial information, ensuring that market participants can accurately assess ESG-related risks and opportunities in a timely manner.

3. Hypotheses

Built on literature review, this study proposes four hypotheses to explore the relationship between ESG performance, ESG disclosure, and corporate financial performance, across different industry contexts.

The relationship between ESG and corporate operational efficiency remains largely unexplored. Operational efficiency refers to a firm's ability to maximize output using limited resources [35]. This concept is not a single indicator but a comprehensive framework that is most conceptualized through multidimensional financial indicators.

ESG's association to corporate profitability has been previously explored [26, 27, 36]. ESG contributes to improve asset turnover [19], optimize capital structure [14], balance liquidity [37], and enhance profitability [36] through mechanisms such as strengthening market reputation and increasing customer loyalty [26, 27]. Given the positive effects of ESG on multiple individual financial indicators, we expect that ESG also to be critical for operational efficiency, which represents a comprehensive outcome of several financial metrics. Activity ratios, solvency ratios, liquidity ratios, and profitability ratios directly reflect the financial outcomes associated with ESG in accounting terms and are therefore selected as the four subdimensions of operational efficiency in this study. Based on this, we propose Hypothesis 1 as follows.

Hypothesis 1. All ESG factors have a positive impact on corporate operational efficiency.

Recent studies recognize the importance of moving beyond corporate operational efficiency to capture the market-based financial returns of ESG disclosure. In this study, we focus on firm market value, which reflects the capital market's aggregate valuation of a firm. Several disparate observations suggest that greater disclosure or more precise information lowers firms' cost of capital [38] and improves investor expectations [39], thereby supporting higher market valuations. Similarly, ESG disclosure has been shown to improve the price discovery process of firm information, thereby increasing firm value [40]. Additionally, legitimacy theory offers a complementary explanation, suggesting that a firm's survival and development depend on the recognition and acceptance of society. In the highly regulated industries such as chemical sector, legitimacy theory precisely explains firms' motives to voluntarily exceed ESG regulatory requirements. Unlike stakeholder theory, which focuses on balancing diverse interests, or signaling theory, which emphasis on reducing information asymmetry, legitimacy theory centers on securing and maintaining societal approval, aligning closely with the sector's reality of aligning corporate conduct with social norms to preserve the license to operate. Collectively, these findings suggest that ESG disclosure enhances firms' recognition and market value by improving information flow, reducing information asymmetry, and signaling positive commitment to investors.

Hypothesis 2. Disclosing ESG report has a positive impact on corporate market value.

Resource-based view emphasizes that a firm's unique resources and capabilities determine its competitive advantage within an industry [35]. The chemical industry is resource-intensive and highly polluting, while the software industry relies on knowledge-intensive processes and operates with lower environmental impact. Iazzolino, et al. [19] provided empirical evidence that the mechanism through which ESG impacts firm efficiency varies across industries. Given the distinct competitive advantages and core business models across industries, we hypothesize that the mechanism through which ESG influences firms varies by industry. Hence, Hypotheses 3 and 4 are proposed as follows.

Hypothesis 3. The ESG factors that are financially significant vary across industries.

Hypothesis 4. The impact of ESG disclosure on market value differs across

industries.

The proposed 4 hypotheses are illustrated in Figure 1.

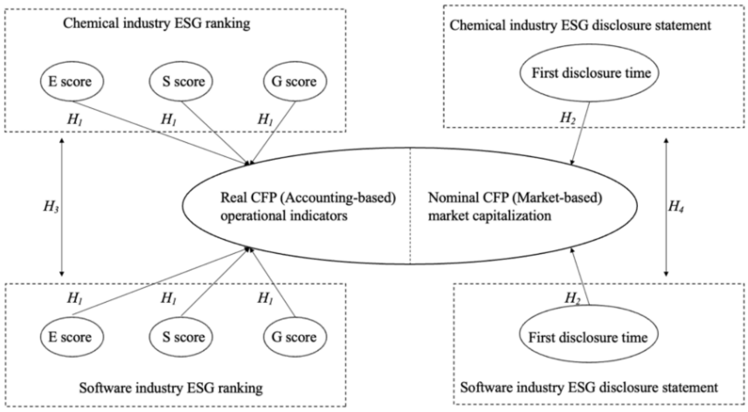

Figure 1. Proposed hypotheses.

4. Data and methods

4.1 Sample and data

The data used in this study are sourced from the Refinitiv database, which is widely recognized as one of the most reliable financial and ESG data provider and extensively used in academic research, such as Brinette, et al. [13] and Iazzolino, et al. [19]. Given the availability, the initial sample is limited to data of all listed companies in the chemical and software industries in the European region from 2014 to 2023.

Europe provides an ideal environment due to its advanced institutional framework and early adoption of non-financial reporting, unlike many emerging economies. Europe underwent significant amendments on the Non-Financial Reporting Directive in 2018, which encouraged companies to voluntarily disclose such information. This initiative has since evolved, with the European Union launching the Corporate Sustainability Reporting Directive in 2022 to enhance the integrity and transparency of

ESG reporting.[5]

The sample is constructed as follows. First, select the European region. Second, choose the industries "Chemicals and Metals[6]," "Mining Sectors[7]," "Software[8]," and "IT Services Sector[9]". Notably, the industry classification in this study follows the standard of Refinitiv Business Classification (TRBC), with the Software and IT Services sector excluding high energy-consuming areas like cloud computing, blockchain, and cryptocurrency. Third, exclude all observations with missing data.

The selected variables are categorized into four types, each corresponding to the following indicators: real ESG performance, nominal ESG performance, market-based financial performance, and accounting-based financial performance.

Real ESG performance indicators: These include the environmental, social, and governance pillar scores. The study selects the individual pillar scores, rather than the overall ESG score, based on the research question. The hypothesis is that different ESG factors have a positively impact on CFP, with the significance of these factors varying across industries. Therefore, individual pillar scores are chosen as the indicators of a company's real ESG performance.

Nominal ESG performance: This is measured by the time when a company

[5] https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en#legislation

[6] Chemicals sector includes "Commodity Chemicals", "Agricultural Chemicals", "Specialty Chemicals", and "Diversified Chemicals".

[7] Mining sector includes "Non-Gold Precious Metals & Minerals", "Iron & Steel"," Aluminum, Specialty Mining & Metals", "Gold", "Mining Support Services & Equipment", and "Diversified Mining".

[8] Software sector includes "Software (NEC)", "System Software", "Application Software", "Enterprise Software", "Mobile Application Software", "Mobile System Software", "Programming Software & Testing Tools", "Server & Database Software", and "Security Software".

[9] IT Services sector includes "IT Services & Consulting (NEC)", "Computer Programming", "Computer Training", "Technology Consulting & Outsourcing Services", "IT Testing Services", "Cloud Computing Services", and "Machine Learning & Artificial Intelligence (AI) Services".

begins to disclose ESG reports. According to the Refinitiv database, a company is considered to disclose an ESG report if it "publish a separate CSR/H&S/Sustainability report or include a section on CSR/H&S/Sustainability in its annual report." Using the disclosure start time as a variable captures the company's response to market and regulatory dynamics while minimizing the impact of discrepancies in disclosure quality across companies. Existing literature suggests that the decision to initiate continuous ESG reporting is often driven by external pressures from institutional investors, regulatory requirements, or industry best practices [41]. However, compared to financial statements, the content of ESG reports is more controllable [31]. Therefore, this study chooses the timing of disclosure rather than the content of the reports as the key research variable.

Accounting-based financial performance: As explained in Section 3, four subdimensions of operational efficiency are considered: activity ratios, solvency ratios, liquidity ratios, and profitability ratios. Activity ratios reflect the speed of a firm's resource turnover, solvency ratios indicate a firm's ability to meet long-term debt obligations, liquidity ratios reflect its ability to meet short-term debt obligations, and profitability ratios capture the firm's ability to convert revenue into profit. Following a quantitative method [42], this study selects representative financial indicators from these four dimensions. The specific indicators are provided in Table 1.

Table 1. Accounting-based financial indicators.

Indicator Types	Indicator Name	Calculation Formula
Activity ratios	Receivable Turnover	Revenue / Average Receivable
	Total Asset Turnover	Revenue / Total Asset

Solvency ratios	Financial Leverage	Total Assets/Total Equity
Liquidity ratios	Current Ratio	Current Assets/Current Liabilities
	Cash Ratio	(Cash+Short-Term Marketable Security)/Current Liabilities
Profitability ratios	Gross Profit Margin	Gross Profit/ Net Revenue
	Net Profit Margin	Net Income/ Net Revenue
	ROA	Income Before Tax/Total Assets
	Total Assets	Total Current Assets+ Total Non-Current Assets

Market-based financial performance: This is measured by market capitalization (MC). Previous research provides a strong basis for this choice. For instance, Şerban, et al. [43] highlighted that ESG information can influence investor decisions, which in turn affects stock prices and, consequently, a company's market value.

4.2 Variables and models

4.2.1 Multivariate linear regression model

To test Hypotheses 1 and 3, we estimate the following model:

$$CFP = \beta_0 + \beta_1 * E + \beta_2 * S + \beta_3 * G + \beta_4 * SIZE + \varepsilon. \quad (1)$$

Based on the method proposed by Hassan, et al. [42], the dependent variable, CFP, is calculated using PCA with seven accounting indicators, as shown in Table 2. This approach reduces the dimensionality of the data. The independent variables are E, S, and G, with $SIZE$ as a control variable, and ε representing the error term. The data used in this model consists of cross-sectional data from 2022 for the sample companies, as the financial data for 2023 is significantly incomplete. After excluding companies with missing data, the final sample includes 43 firms from the chemical industry and 33 firms from the software industry.

Table 2. Components of the variable CFP.

Variable Types	Variable Symbol	Variable Name
Dependent Variable	CFP (CFP is derived from the Principal Component Analysis of the seven accounting financial indicators listed to the right.)	Receivable Turnover（RT）
		Total Asset Turnover(TAT)
		Financial Leverage(FL)
		Current Ratio(CuR)
		Cash Ratio(CaR)
		Gross Profit Margin(GPM)
		Net Profit Margin(NPM)

In this model, if the explanatory variables E, S, and G are statistically significant, it indicates that the ESG factors are financially important for the company. The absolute values of β_1, β_2, and β_3 reflect the sensitivity of the company's financial performance to each of the ESG factors. If β_1, β_2, and β_3 are all positive, it suggests that the company's financial performance moves in the same direction as E, S, and G, indicating that each ESG factor has a positive effect, thus supporting Hypothesis 1. If there are significant differences in the significance and the absolute values of the coefficients between the two industry samples, it implies that the financial importance of ESG factors varies across industries, thus supporting Hypothesis 3.

4.2.2 Multiperiod differences-in-differences model

To test Hypotheses 2 and 4, we estimate the following model:

$$\ln(MC_{it}) = \lambda_0 + \lambda_1 \mathrm{did}_{it} + \lambda_2 X_{it} + u_i + \gamma_t + \varepsilon_{it}, \quad (2)$$

where $did = treat_i * time_t$.

In this model, the dependent variable $\ln(MC_{it})$ represents the natural logarithm of the market capitalization of firm i in year t. u_i is individual fixed effects, and γ_t is time fixed effects. $treat_i$ is a treatment group dummy variable indicating whether a firm participates in ESG disclosure. If the firm discloses an ESG report, $treat_i$ is set to 1; otherwise, it is set to 0. $time_t$ is a time dummy variable that reflects the varying start dates of ESG report disclosure across firms, making this a multi-time-point DID model. If the fiscal year of a firm's financial data is later than the ESG report start date, $time_t$ is set to 1; otherwise, it is set to 0. X_{it} represents a set of control variables, consisting of firm financial data that changes over time, aiming to control for the impact of changes in accounting assets on market value. The selection of control variables is based on the study by Zhou and Lei [44], as detailed in Table 3. ε_{it} is the random error term. The data used in this model consists of panel data from 2014 to 2023 for the sample firms. After excluding missing values, the final sample sizes for chemical and software industries are 774 and 1093, respectively.

Table 3. Control variables in multiperiod DID model.

Variable Types	Variable Symbol		Variable Name
Control Variable	X_{it}	X_1	ROA
		X_2	Financial Leverage
		X_3	ln（Total Assets）
		X_4	Total Asset Turnover
		X_5	Current Ratio
		X_6	Cash Ratio

The coefficient λ_1 is of particular interest in this model. Its economic interpretation is the impact of initiating ESG disclosure on a firm's market value. If the did variable is significant and λ_1 is positive, it suggests that ESG disclosure has a positive impact on a firm's market value, supporting Hypothesis 2. If there are significant differences in the significance and the magnitude of λ_1 between the two industries, Hypothesis 4 is supported.

5. Empirical results

5.1 Descriptive statistic

5.1.1 Descriptive statistic for ESG ranking

The descriptive analysis of individual ESG pillar scores in Table 4 reveals two notable characteristics. First, significant differences between the two industries are observed only in the social pillar, while the environmental and governance pillars show similar distributions. Notably, in the chemical industry, social pillar scores range from a minimum of 5 to a maximum of 95, indicating substantial variation in companies' attention to social factors. The wider dispersion of social factors in the chemical industry may stem from the lack of standardized assessment frameworks. Compared to the EU's strict environmental regulations and governance systems, social factors are inherently subjective, leading to larger differences between firms. For example, evaluations of employee satisfaction and labor dignity are hard to standardize. Additionally, the chemical sector's vulnerability to safety incidents and related social issues can trigger reputational crises, further impacting social factor scores [45]. Second, in the software services industry, the distribution patterns of social and governance pillar scores are highly similar, as reflected in their closely aligned minimum, maximum, mean, and standard deviation values.

Table 4. Descriptive statistic for ESG ranking.

	Chemical Industry					IT industry				
	N	Minimum	Maximum	Mean	Std. Deviation	N	Minimum	Maximum	Mean	Std. Deviation
E	43	18	96	67.77	18.562	33	13	77	43.18	19.625
S	43	5	95	73.12	17.991	33	22	95	60.42	21.21
G	43	29	97	74.88	17.573	33	20	96	60.48	19.458

5.1.2 Descriptive statistic for ESG disclosure time

The timing of ESG disclosure differs significantly between the chemical and software industries. Surprisingly, despite being a high-pollution industry, the chemical sector generally began ESG disclosure earlier than the software sector. As shown in Figure 2, more than half of the sampled companies had already begun actively disclosing non-financial information to stakeholders even before 2018, when the European introduced the Non-Financial Reporting Directive as a voluntary policy. In contrast, the software industry only saw widespread adoption of non-financial disclosure beginning in 2020.

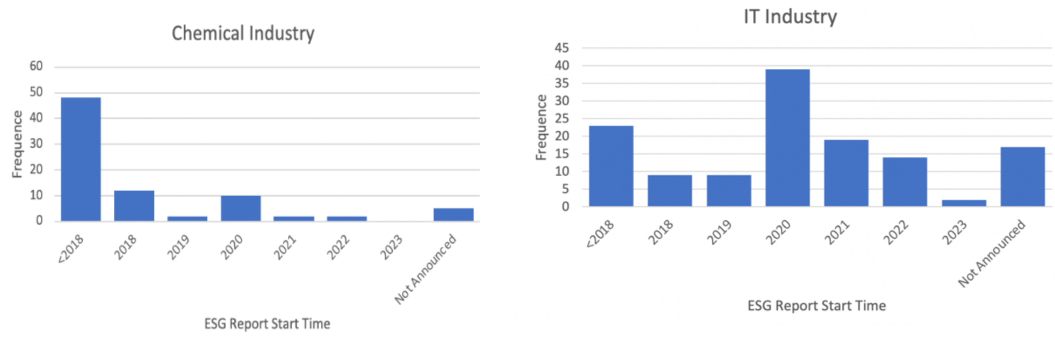

Figure 2. Distribution of ESG disclosure time.

This may be related to the European Union's 2021 initiative to strengthen oversight of non-financial disclosure, highlighting the crucial role of regulatory policies in driving corporate ESG reporting. Among the sampled companies, 6.2% in the chemical industry and 12.9% in the software industry have yet to begin ESG disclosure. This indicates that non-financial disclosure in the European chemical industry not only started earlier and but also had a broader participation compared to the software industry.

5.2 Multivariate linear regression model

5.2.1 Calculate interpreted variables

First, the suitability of the seven accounting indicators listed in Table 2 is tested. The sample data for both industries passed the KMO and Bartlett's tests. As shown in Table

A1, the KMO value is 0.532 for the chemical industry and 0.516 for the software industry, both exceeding the acceptable threshold of 0.5. Moreover, the significance values for both datasets are below 0.05, indicating that the Bartlett test results are statistically significant. Therefore, PCA is appropriate for computing each company's CFP variable score.

SPSS (version 29.0.0.0(241)) is used to conduct factor analysis on the financial data samples from both industries. Principal factors are extracted based on the criterion that eigenvalues should be equal to or greater than 1. As shown in Tables A2 and A3, the total variance explained shows that the eigenvalues of the first three factors exceed 1, with a cumulative contribution rate surpassing 70%. This indicates that these three principal factors capture most of the data's information from the original seven accounting indicators, making them suitable representations for further analysis.

Table 5 displays the component score coefficient matrix for both industries, where higher loading indicates stronger explanatory power for each factor. In the chemical industry, the first factor primarily explains RT, TAT, CaR, GPM, and NPM; the second factor explains CuR, and the third factor explains FL. In contrast, the software industry exhibits a different pattern: the first factor mainly explains TAT, CuR, and CaR; the second factor explains RT, FL, and NPM; and the third factor explains GPM.

Table 5. Component score coefficient matrix.

	Chemical industry			Software industry		
	Component 1	Component 2	Component 3	Component 1	Component 2	Component 3
RT	**0.661**	0.384	-0.084	0.338	**0.76**	-0.162
TAT	**-0.608**	0.425	0.277	**0.756**	0.14	-0.365
CuR	0.591	**0.617**	-0.037	**0.797**	-0.435	0.071
FL	0.085	0.217	**0.926**	-0.046	**0.456**	0.049

CaR	**0.816**	0.492	-0.101	**0.784**	-0.413	0.252
GPM	**0.685**	-0.647	0.082	0.113	0.379	**0.876**
NPM	**0.636**	-0.53	0.305	0.366	**0.779**	-0.058

The scores for each principal factor are calculated using the corresponding coefficients of the seven accounting indicators. The following equations provide the calculation formulas, where (3), (4), and (5) correspond to the three principal factors for the chemical industry, and (6), (7), and (8) correspond to those for software industry.

$$F_{C1} = \frac{0.661 * RT - 0.608 * \mathrm{TAT} + 0.591 * \mathrm{CuR} + 0.085 * \mathrm{FL} + 0.816 * \mathrm{CaR} + 0.685 * \mathrm{GPM} + 0.636 * \mathrm{NPM}}{\sqrt{2.704}}, \quad (3)$$

$$F_{C2} = \frac{0.384 * \mathrm{RT} + 0.425 * \mathrm{TAT} + 0.617 * \mathrm{CuR} + 0.217 * \mathrm{FL} + 0.492 * \mathrm{CaR} - 0.647 * \mathrm{GPM} - 0.530 * \mathrm{NPM}}{\sqrt{1.697}}, \quad (4)$$

$$F_{C3} = \frac{-0.84 * \mathrm{RT} + 0.277 * \mathrm{TAT} - 0.037 * \mathrm{CuR} + 0.926 * \mathrm{FL} - 0.101 * \mathrm{CaR} + 0.082 * \mathrm{GPM} + 0.305 * \mathrm{NPM}}{\sqrt{1.053}}, \quad (5)$$

$$F_{S1} = \frac{0.338 * \mathrm{RT} + 0.756 * \mathrm{TAT} + 0.797 * \mathrm{CuR} - 0.046 * \mathrm{FL} + 0.784 * \mathrm{CaR} + 0.113 * \mathrm{GPM} + 0.366 * \mathrm{NPM}}{\sqrt{2.085}}, \quad (6)$$

$$F_{S2} = \frac{0.76 * RT + 0.14 * TAT - 0.435 * CuR + 0.456 * FL - 0.413 * CaR + 0.379 * GPM + 0.779 * NPM}{\sqrt{1.915}}, \quad (7)$$

$$F_{S3} = \frac{-0.162 * RT - 0.365 * TAT + 0.071 * CuR + 0.049 * FL + 0.252 * CaR + 0.876 * GPM - 0.058 * NPM}{\sqrt{1.002}}. \quad (8)$$

Based on the variance contribution rates of each principal factor in Tables A2 and A3, the comprehensive scoring formula for the dependent variable CFP in both industries are derived as follows.

$$CFP_C = 0.38626 * F_{C1} + 0.24236 * F_{C2} + 0.15047 * F_{C3}, \quad (9)$$

$$CFP_S = 0.29789 * F_{S1} + 0.27363 * F_{S2} + 0.14317 * F_{S3}. \quad (10)$$

5.2.2 Regression result

Before conducting the regression analysis, we perform the Durbin-Watson test and multicollinearity test on the sample, as presented in Tables A4 and A5, respectively. The results indicate that the Durbin-Watson statistics for both industries are close to 2, and all explanatory variables have variance inflation factor (VIF) values below 5. Therefore, the samples satisfy the prerequisite for multiple linear regression.

To test whether ESG factors have a positive impact on corporate financial performance (H1) and whether this impact varies across industries (H3), we estimate a multiple linear regression model and report the results in Table 6. Column (1) indicates that in the chemical industry, the environmental and social factors are statistically significant, with coefficients of -7.343 and 16.34, respectively. Conversely, column (2) presents that in the software industry, only the environmental factor is significant, with a coefficient of 0.129. The differences in coefficients suggest that financial performance in the chemical industry is more sensitive to ESG factors compared to the software industry.

Table 6. Regression results for multivariate linear regression model.

	(1)	(2)
Variables	CFP_C	CFP_S
E	-7.343**	0.129**
	(3.329)	(0.0555)
S	16.34***	-0.0759
	(4.257)	(0.0511)
G	-3.516	0.0565
	(2.832)	(0.0487)
SIZE	-86.85**	1.475**
	(38.05)	(0.666)
Constant	830.5***	-4.206
	(224.5)	(6.228)
Observations	43	33
R-squared	0.299	0.349

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

5.3 Multiperiod differences-in-differences model

This section evaluates the impact of corporate ESG disclosure on financial performance by constructing a multi-period DID model. A multi-period DID model not only accommodates situations in which treatment is implemented at different times across individuals and provides estimates of the policy's dynamic post-treatment effects, but also leverages the full panel dataset, thereby avoiding the sample loss and matching-related biases that may arise from other models, like PSM-DID models. Since the magnitudes of market capitalization and total assets are significantly larger than those of other variables, their logarithmic transformations are applied in this model.

Table 7 reports the regression results on the impact of ESG disclosure on corporate market value. Column (1) reports the estimation results without control variables or fixed effects. Column (2) adds the control variables X_{it} listed in Table 3, and Column (3) further includes year and firm fixed effects. The results show that in Columns (1) and (2), the did regression coefficients for both the chemical and software industries are significantly positive, indicating that ESG disclosure enhances firms' market value and supports Hypothesis 2. In Column (3), after accounting for fixed effects, the coefficient for the chemical industry becomes insignificant, while that for the software industry remains significantly positive, suggesting that the industry-specific difference supports Hypothesis 4.

Table 7. Regression results for multiperiod DID model.

	(1)		(2)		(3)	
Industry	Chemical	IT	Chemical	IT	Chemical	IT
Variables	MC	MC	MC	MC	MC	MC
did	2.418***	2.977***	0.216**	0.435***	0.0366	0.323**

	(0.146)	(0.127)	(0.106)	(0.0815)	(0.0820)	(0.128)
Control variables	No	No	Yes	Yes	Yes	Yes
Fixed effects	No	No	No	No	Yes	Yes
Observations	796	1211	774	1,093	774	1093
R-squared	0.258	0.311	0.741	0.758	0.694	0.747

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In summary, Figure 3 presents the empirical results of the proposed hypotheses. Specifically, H1 reports the results from the multiple linear regression model, while H2 presents the regression results from the multi-period DID model. The differences in significance levels and coefficient estimates between the chemical and software industries for H1 and H2 provide key insights into the industry-specific differences examined in H3 and H4.

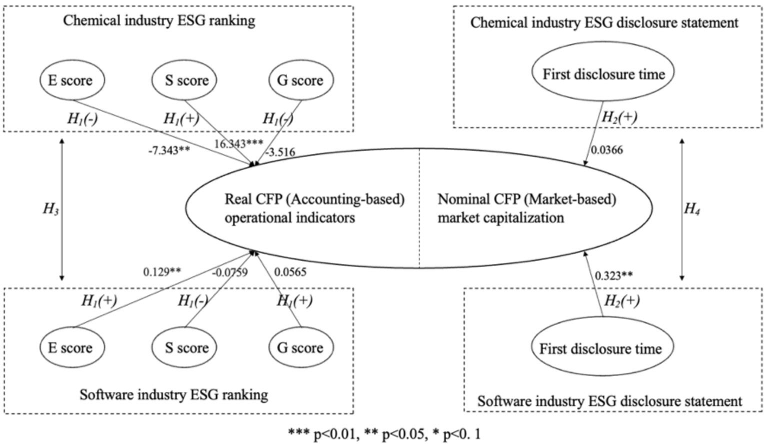

Figure 3. Proposed hypotheses (validated).

6. Robustness tests

To assess the stability and consistency of the research findings, we conduct a more in-depth reliability analysis.

6.1 Robustness test of the multiple linear regression model

6.1.1 Residual normality test

The normality of residuals is often considered a key assumption of multiple linear regression models and can be used to further examine sample characteristics. Figure 4 presents the P-P plots of standardized residuals for the two industry samples.

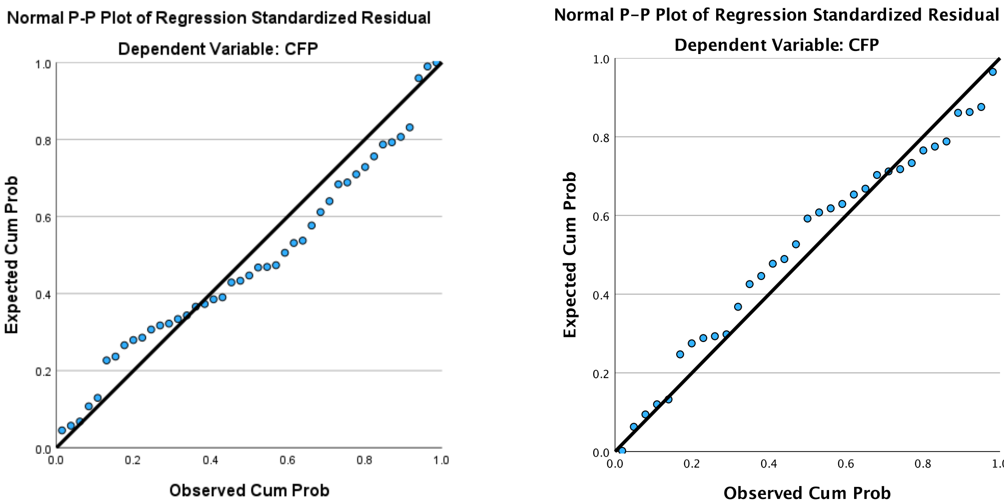

Figure 4. P-P plots.

The right-hand side of the P-P plot is for the software industry. It shows that the standardized residuals closely align with the reference line, indicating an approximately normal distribution. However, the P-P plot for the chemical industry (the left-hand side of the P-P plot) shows slightly greater deviations from the reference distribution, suggesting a weaker adherence to the normality assumption.

Given that the multiple linear regression model for the chemical industry has an R^2 value of 29.9%, implying that residuals account for approximately 70% of the variance in CFP, an approximate normal distribution remains acceptable. Therefore, the validity of the multiple linear regression analysis is maintained.

6.1.2 Goodness-of-fit test

The goodness-of-fit test assesses how well the regression model fits the data. In this study, three methods are employed to evaluate the model's goodness of fit. First, the coefficient of determination (R^2) is used to measure the proportion of variation in the dependent variable explained by the independent variables. A higher R^2 indicates a better model fit. Second, the F-statistic tests the null hypothesis that all slope coefficients are equal to zero. A value greater than 1 indicates that the slope coefficients are significantly different from zero, suggesting a good model fit. Third, the standard error of the regression (Se) measures the standard deviation of the residuals. A smaller Se indicates a better model fit, reflecting less variability in the residuals.

Table 8. Goodness-of-fit test.

	coefficient of determination (R^2)	F-statistic for the test of fit	standard error of the regression (Se)
Chemical industry	29.9%	4.05	2.652
Software industry	34.9%	3.75	5.375

The specific results of the goodness-of-fit test are presented in Table 8. In terms of the R^2 indicator, the software industry sample demonstrates a better fit, while the chemical industry sample exhibits a lower standard of error of regression (Se), indicating a better fit in terms of residual variance. The F-statistic values for both industries are similar, showing no significant difference in their performance. Overall, according to the above evaluation criteria, the goodness-of-fit indicators for both samples fall within an acceptable range.

6.2 Robustness check of the multiple time-point DID model

The insignificance of the did regression coefficient for the chemical industry after controlling for fixed effects draws our attention. This may be related to the concentrated timing of ESG report disclosure within the chemical industry. As shown in the descriptive statistics of ESG disclosure timing for the two industries in Figure 2, most chemical companies had begun disclosing ESG reports before 2018. Consequently, the time fixed effects absorb these timing effects, leaving insufficient within-company variation to support a significant estimation result. To further verify this conjecture, this study employs a parallel trend test to examine the dynamic impact of ESG disclosure.

6.2.1 Parallel trend test

As shown in Figure 5, the parallel trend test result for the chemical industry is not good enough when using pre_1 as the baseline period. Before the policy implementation, the estimated values of pre_2, pre_3 and pre_6 are close to zero, with error bars encompassing zero, indicating no significant deviations in trend. However, the confidence intervals of pre_4 and pre_5 slightly deviate from zero, indicating a minor violation of the parallel trend assumption. Considering that most chemical companies disclosed ESG reports before 2018, while the panel data in this study begins in 2014, the earlier pre-periods, such as pre_4 and pre_5, contain few or no observations, leading to unstable estimates. Therefore, further tests will be conducted in Section 6.2.2.

After the policy implementation, the estimated coefficients exhibit a slight downward trend. However, the changes are not statistically significant from post_1 to post_4. This suggests that the policy's short-term impacts on ESG disclosure are weak or insignificant, with a more noticeable effect emerging only after a longer period (post_5).

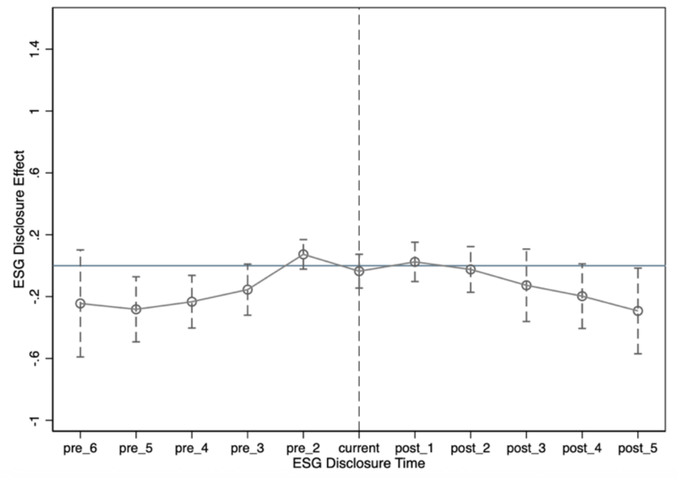

Figure 5. Parallel trend test results for the chemical industry.

Compared to the chemical industry, the software industry passes the parallel trend test with perfect alignment, as shown in Figure 6. Before policy implementation, the estimated coefficients are relatively stable, all close to zero, with error bars including zero. This indicates that, prior to the policy implementation, the trends of the treatment and control groups were generally consistent, satisfying the parallel trend assumption. Following the policy implementation, a noticeable effect emerged immediately, and this impact remained until post_2, suggesting that the policy may have a short-term effect on ESG disclosure in the software industry.

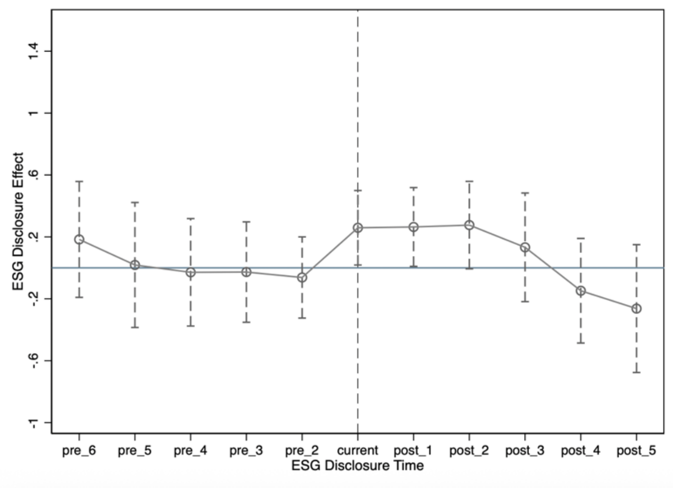

Figure 6. Parallel trend test results for the software industry.

6.2.2 Placebo test

Due to the poor performance of the parallel trend test in the chemical industry, we further examine whether the observed impact of ESG disclosure on firm market value is driven by other random factors. Following the approach of Ferrara, et al. [46], we perform 500 random samplings to construct the "pseudo-policy dummy variable" (the did variable in this model). We then re-estimate the regression and examine the distribution of the coefficients and p-values.

As shown in Figures 7 and 8, the randomly generated did regression coefficients for both industries are centered around zero. This suggests that the observed impact of ESG disclosure on firm value is not driven by other random factors. Therefore, the core conclusions of the model remain stable and robust.

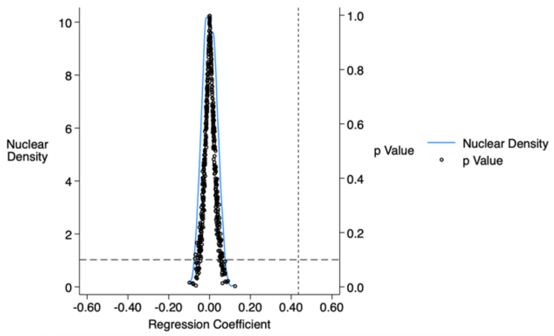

Figure 7. Placebo test of chemical industry.

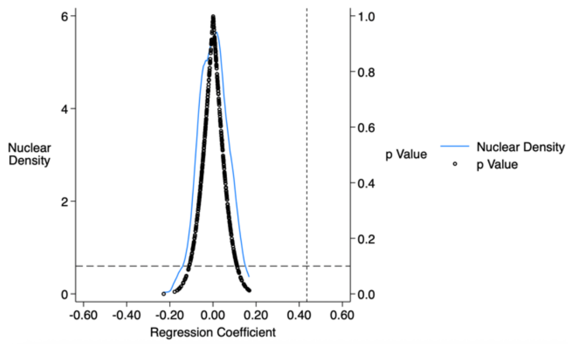

Figure 8. Placebo test of software industry.

7. Discussion

Our findings indicate that Hypothesis 1 does not hold, meaning that not all three ESG factors positively impact CFP. The results of the multiple linear regression indicate a "negative correlation" between the environmental factor and CFP in the chemical industry. This contradicts with previous research, which suggests that firms can enhance long-term competitive advantage through environmental management activities [47]. However, the lack of consensus on defining “long-term” provides a possible explanation. As Delmas, et al. [48] suggested, the relationship between financial and environmental performance may depend on the time horizon used to measure financial indicators. Since our study relies on current financial indicators, it is possible that the observed “negative correlation” is the financial benefits of environmental initiatives not yet materialize.

From an industry-specific perspective, this negative correlation reflects the inherent contradiction between the development needs of the chemical industry and the constraints of environmental resources. Marques and Machado [49] argued that the chemical industry faces sustainability challenges due to its dependence on non-renewable resources and the limited self-restorative capacity of the environment. Another factor is the heavy regulatory pressures faced by such high-pollution industries, which necessitate substantial capital investments in pollution control and compliance. Pacelli, et al. [50] noted that excessive investment into ESG factors can lead to financial structural imbalances, ultimately harming firm financial performance.

Another noteworthy finding is that the governance factor of ESG is insignificant in both industries. This may be attributed to the research methodology, as the multiple linear regression model employed in this study can only analyze the linear relationship between the governance factor and financial performance. However, Nollet, et al. [51] suggested that the relationship between accounting-based financial indicators and corporate governance follows a U-shape, implying that the governance factor’s impact may be nonlinear. Our findings provide empirical support for their conclusions, suggesting that further investigation using non-linear models may be necessary to fully capture the effects of governance on CFP.

Hypothesis 2 holds, meaning that ESG disclosure has a positive impact on firm market value. This remains robust after a series of stability tests. Based on the results of Hypothesis 1, we find that even if the E, S, and G factors do not all enhance firms' operational efficiency, companies can still increase their market value by disclosing ESG reports to release positive signals to the market. This finding aligns with signaling theory: voluntary disclosure of ESG performance helps reduce investors' perceived risk, alleviate information asymmetry, and mitigate potential issues such as investor divestment [52], reputational damage, and stock price volatility [53]. It is also consistent with legitimacy theory: highly polluting industries often face greater risks of market sanctions, and transparent non-financial disclosure serves not only as an important mechanism for maintaining investor confidence and securing stakeholder support but also as an effective tool to avoid direct administrative penalties related to environmental issues [54]. Descriptive statistics on ESG disclosure timing further reinforce this finding, showing that compared with the software industry, the chemical industry exhibits both a higher disclosure rate and earlier adoption of ESG reporting. Although multiple robustness tests confirm that proactive ESG disclosure yields tangible market benefits, the concentration of ESG disclosure among chemical companies in 2018 and earlier poses challenges for fixed-effects estimation and weakens the explanatory power of the model. Future solutions to this issue are suggested in Conclusion.

Hypotheses 3 and 4 examine the industry-specific heterogeneity effects of ESG on CFP, confirming that ESG influences both real and nominal performance differently across industries. Firstly, the significant ESG factors differ between the chemical and software industries. In the chemical sector, both environmental and social factors significantly financial performance, whereas in the software industry, only the environmental factor is significant, with a coefficient of 0.129. Kanoo, et al. [45] compared 26 different industries and confirmed that the key ESG factors vary between the chemical and software industries, attributing these differences to the inherent nature of their production processes. Specifically, they found that governance factor performs best in the IT industry, a discrepancy that may stem from differences in ESG rating methodologies between CRISIL and Refinitiv [55]. Iazzolino, et al. [19] used the same region and database as our study but adopted a more general industry classification. Despite differences in financial indicators, they similarly found that the chemical and technology industries are highly sensitive to environmental factors, supporting the robustness of our findings. Notably, Kanoo, et al. [45] identified the banking industry as a top performer in overall ESG scores, as well as in environmental and social dimensions. However, Iazzolino, et al. [19] found that the financial industry (include bank industry) does not gain significant economic returns from ESG performance. This highlights the need to consider a broader range of industries when examining sectoral heterogeneity.

Secondly, although ESG disclosure positively affects market value in both industries, the timing of this effect differs. In the software industry, the positive impact emerges immediately and remains stable through the short-term, with a slight decline after the third year of policy implementation. In contrast, in the chemical industry, there is a noticeable time lag, during the first four periods following policy implementation, the effect remains insignificant and only becomes evident in Period 5. This lag may stem from the study's inability to capture the "maturity period" of ESG effects [56]. A lack of significant results within five years does not mean that ESG strategies are ineffective; rather, the limited availability of long-term data restricts accurate assessment of their true market impact. This timing mismatches can distort both academic evaluations and policy judgments regarding industry responsiveness. Thus, the observed lag should not be interpreted as mere market indifference but as a structural misreading of the temporal pathway through which ESG value is realized.

8. Conclusion

This study examines and compares the chemical and software industries in Europe to assess the impact of corporate ESG performance on CFP. The research framework distinguishes between actual and nominal performance variables. Specifically, a multiple linear regression model is employed to examine the effect of actual ESG performance on actual financial performance, using accounting-based financial indicators matched with ESG rankings. Then, a multi-period DID model investigates the effect of nominal ESG performance on nominal financial performance, where market-based financial indicators are matched with the timing of ESG disclosure. The dual-focus approach allows for a comprehensive assessment, investigating not only whether ESG performance directly affects financial performance but also whether it generates additional market or policy benefits.

The findings highlight the complex trade-offs between regulatory compliance, sustainability investments, and financial outcomes, particularly in the chemical industry. The observed negative correlation between environmental factor and financial performance suggests that while environmental strategies may yield long-term financial benefits, they also impose financial costs in the short term, creating survival pressures for companies. Furthermore, while ESG disclosure enhances firm market value in the chemical industry, the policy impact exhibits a notable time lag. Empirical results suggest that the positive effects of ESG disclosure only become noticeable in the fifth year after implementation.

The software industry stands in stark contrast to the chemical industry. While improvements in ESG scores have a negligible impact on financial performance, actively disclosing ESG information positively impacts market value, yielding additional market dividends. Moreover, this positive impact is immediate upon increasing ESG transparency and remains stable over a two-year period. This suggests that, while environmental factors have not yet emerged as major financial driver in the software industry, their influence is growing in response to evolving regulatory frameworks and shifting investor expectations.

There are limitations of this paper that deserve further investigation. Firstly, the reliability of the multi-period DID model for the chemical industry requires further testing. Considering the unsatisfactory results from the parallel trends test, we conducted a placebo test by replacing the policy dummy variable, confirming that the impact of ESG disclosure on company value is not driven by random factors. However, to enhance the reliability of these findings, future research could collect earlier data to reduce estimation bias caused by sample loss before policy implementation. At the same time, extending the observation window could help capture the long-term effects of the policy. To address the issue of concentrated disclosure timing in the chemical industry, the sample could be grouped to increase variation in disclosure years.

Secondly, the long-term effects of environmental factors on CFP requires further exploration. This study relies on cross-sectional data from 2022 to examine the relationship between ESG rankings and CFP, suggesting that environmental investments in the chemical industry do not yield immediate financial returns. This finding contradicts prior research suggesting that companies can improve operational efficiency by enhancing environmental management. To further understand this “negative correlation”, future research could explore whether the impact of environmental performance on financial performance is subject to a time lag or if it is attributed to the characteristics of high-pollution industries. Future studies could also consider adopting variables that better represent firms’ long-term development potential to demonstrate the long-term impact of ESG or employing additional lag periods to assess the delayed effects of environmental performance on financial performance.

The third limitation is that our classification of the software industry as a low-pollution sector is based on a narrow definition of environmental sustainability, focusing only on operational pollution. We do not account for the broader environmental concerns associated with software, such as high energy consumption in high-performance computing, the carbon footprint of data centers, or the waste generated from hardware infrastructure. As AI and big data continue to expand, these factors are becoming increasingly relevant. Future research could incorporate a more comprehensive view of sustainability that includes full-lifecycle carbon emissions and electronic waste.

Fourthly, this study focuses on a comparative analysis of ESG–CFP relationships between the chemical and software industries, without examining potential cross-sector linkages. However, it is reasonable to assume that ESG initiatives in one industry may exert spillover effects on others through shared investor perceptions, supply chain interdependencies, or systemic market sentiment. Future research could integrate network relationships, such as supply chains, to capture potential interconnections, thereby advancing our dynamic understanding of ESG–CFP relationships.

Declaration of interests: The authors report there are no competing interests to declare.

Data Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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