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ESG Performance, Financial Pressure, and Corporate Tax Avoidance: Evidence from Taiwan before and during COVID-19

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ABSTRACT

Purpose:
This study investigates the relationship between environmental, social, and governance (ESG) performance and corporate tax avoidance, and further examines whether financial pressure induced by the COVID-19 pandemic affects firms' tax avoidance behavior. Using Taiwan as an emerging-market context, this research aims to clarify whether ESG engagement reflects ethical commitment or strategic opportunism.

Design/methodology/approach:
The study employs panel data from 5,668 firm-year observations of listed and OTC companies in Taiwan between 2017 and 2020. ESG performance is measured using a comprehensive proprietary ESG index constructed from TEJ data, covering environmental, social, and governance dimensions. Corporate tax avoidance is proxied by book–tax differences (BTD) and permanent book–tax differences (PBTD). Multiple regression models, including robustness tests with random-effects models, subsample analyses, and alternative tax avoidance measures, are applied.

Findings:
The empirical results reveal a significant positive association between ESG performance and corporate tax avoidance, supporting the strategic or opportunistic ESG perspective. All three ESG dimensions—environmental, social, and governance—are positively related to tax avoidance. Moreover, firms exhibited higher levels of tax avoidance during the COVID-19 pandemic, suggesting that heightened financial pressure incentivized more aggressive tax planning. Overall, the findings indicate that ESG initiatives may coexist with, rather than constrain, opportunistic financial behavior.

Research limitations/implications:
This study focuses on Taiwanese listed firms, which may limit the generalizability of the results to other institutional settings. Additionally, while BTD and PBTD are widely used proxies for tax avoidance, they may capture elements beyond intentional tax planning. Future research could incorporate cross-country comparisons, alternative ESG measures, or qualitative analyses to further explore the motivations underlying ESG engagement.

Originality/value:
This study contributes to the literature by providing emerging-market evidence on the ESG–tax avoidance relationship and by incorporating the COVID-19 pandemic as an exogenous financial shock. It offers new insights into how financial pressure shapes corporate tax behavior and highlights the potential misuse of ESG practices as a strategic tool rather than a purely ethical commitment.

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1. Introduction

In recent years, the global discussion on corporate sustainability has gradually shifted from the broader notion of Corporate Social Responsibility (CSR) to the more structured and measurable framework of Environmental, Social, and Governance (ESG). While CSR traditionally encompasses a wide spectrum of ethical and social expectations,

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ESG provides a more standardized set of indicators used by investors, regulators, and stakeholders to evaluate firms' non-financial performance. For this reason, and consistent with global trends, this study adopts ESG—rather than CSR—as the operational definition for assessing corporate sustainability performance.

Among the three ESG dimensions, tax governance has emerged as a central issue within the governance pillar. As corporations are expected not only to comply with tax regulations but also to contribute fairly to public finance, tax avoidance has increasingly been viewed as both an ethical concern and a risk management issue. Consequently, the relationship between ESG (or CSR) performance and tax avoidance has become a prominent topic in the literature. Existing studies present two competing views. One perspective argues that firms with strong ESG commitments avoid aggressive tax strategies to maintain legitimacy and long-term reputation (Hoi et al., 2013; Lanis & Richardson, 2015; Wang & Tsai, 2016). The alternative view suggests that ESG activities may serve as a façade associated with opportunistic managerial behaviour., including aggressive tax planning (Sikka, 2010; Davis et al., 2016; Benlemlih et al., 2023). These mixed findings highlight the need for further empirical evidence, particularly from emerging markets where regulatory environments and institutional pressures differ from those of developed countries.

Taiwan provides a unique context for such investigation. As an export-oriented emerging economy deeply embedded in global supply chains, Taiwan has progressively strengthened ESG-related regulations, including mandatory sustainability reporting and governance disclosure requirements. At the same time, international tax reforms—such as the OECD BEPS initiatives and Taiwan's implementation of Controlled Foreign Corporation (CFC) rules—have imposed stricter constraints on tax avoidance behavior. The coexistence of rising ESG expectations and tightening tax enforcement creates potential trade-offs for firms, making Taiwan an important setting to study the ESG–tax avoidance relationship.

The COVID-19 pandemic adds further complexity to this relationship. The pandemic generated severe financial pressure for many firms, intensifying concerns over liquidity and operational resilience. Prior research has shown that ESG performance may help firms mitigate crisis-related risks (Lins et al., 2017; Poursoleyman et al., 2024) but may also increase agency problems when managers use ESG initiatives strategically (Pagano & Volpin, 2005; Masulis & Reza, 2015). At the same time, evidence indicates that during periods of economic hardship, firms are more likely to engage in tax avoidance as the benefits outweigh the associated costs (Richardson et al., 2015; Athira & Ramesh, 2023). Additionally, CSR- or ESG-related spending may itself introduce financial pressure, which could further motivate tax avoidance (Davis et al., 2016; Hou et al., 2017). Therefore, financial stress represents a key mechanism linking ESG activities and tax avoidance, and the COVID-19 pandemic provides a natural setting to examine this mechanism.

Despite the relevance of these issues, few studies have simultaneously considered ESG performance, tax avoidance, and the role of pandemic-induced financial pressure, especially within emerging markets. To address this gap, this study investigates whether ESG performance and the COVID-19 pandemic influence corporate tax avoidance among Taiwanese listed and OTC firms. This paper makes three primary contributions. First, it adopts a comprehensive ESG index suited to the Taiwanese institutional context, providing a more robust measurement of sustainability performance. Second, it contributes to comparative international literature by offering evidence from an emerging market facing simultaneous pressures of ESG compliance and anti-tax-avoidance regulations. Third, it incorporates the COVID-19 pandemic as an economic shock to examine how financial stress influences tax avoidance, thereby providing new insights into corporate behavior in times of crisis.

The empirical findings support the view that some firms engage in ESG activities primarily for opportunistic reasons and reveal that the pandemic has had a positive impact on tax avoidance—suggesting that companies intensified tax planning efforts under pandemic-related financial pressures.

The remainder of this paper is organized as follows: Section 1 presents the research motivation, objectives, and contributions. Section 2 reviews the relevant literature and develops the research hypotheses. Section 3 outlines the research design, including model specification and variable definitions. Section 4 reports the empirical results. Section 5 concludes the paper and provides policy recommendations based on the findings.

2. Literature Review and the Development of the Research Hypotheses

2.1 ESG Performance and Corporate Tax Avoidance

The relationship between ESG/CSR performance and corporate tax avoidance has received extensive scholarly attention, yet empirical findings remain mixed. Two major theoretical perspectives help explain the divergent

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empirical results: (1) the ethical ESG/CSR perspective, which argues for a negative association between ESG and tax avoidance, and (2) the strategic ESG/CSR perspective, which posits that ESG may coexist with or even facilitate tax avoidance.

(1) Ethical ESG/CSR Perspective: ESG/CSR reduces tax avoidance

Under the ethical view, firms committed to ESG/CSR principles are less likely to pursue aggressive tax strategies because tax avoidance contradicts social responsibility and risks damaging corporate reputation. Studies in developed markets provide support for this argument. Hoi et al. (2013) found that firms engaging in irresponsible CSR activities tend to exhibit higher levels of tax sheltering and larger book-tax differences. They emphasized that corporate culture plays a critical role—when CSR is embedded in the firm's core values, it can reduce external costs and disincentivize tax avoidance. Similarly, Lanis and Richardson (2015) demonstrated that firms with better CSR performance, particularly in terms of transparency and disclosure, were less inclined to avoid taxes. They advocated for stronger corporate governance frameworks to ensure legal and ethical compliance. Evidence from Asian emerging markets also supports this perspective. For example, Muller and Kolk (2015) examined Indian multinational firms and discovered that companies with higher CSR ratings tend to have higher effective tax rates, suggesting lower tax avoidance risks. Wang and Tsai (2016), using Taiwanese data, found a negative association between CSR and book-tax differences in firms that received the "Corporate Citizenship Award", indicating that CSR was perceived and practiced as an extension of corporate ethics. Rakia et al. (2023), analysing Malaysian firms, also found that higher CSR scores were associated with lower levels of tax avoidance.

Collectively, this strand of research suggests that ESG-aligned firms prioritize long-term legitimacy and stakeholder trust, reducing the incentives and tolerance for aggressive tax planning.

(2) Strategic ESG Perspective: ESG/CSR may coexist with or conceal tax avoidance

An alternative perspective views ESG/CSR as a strategic instrument for risk management, reputation building, or even camouflage. From this standpoint, ESG/CSR engagement does not necessarily reflect genuine ethical commitment. Instead, ESG/CSR activities may be deployed selectively to divert attention from questionable financial practices.

Studies in developed markets provide support for this argument. Sikka (2010) argued that CSR initiatives may serve as a disguise for tax avoidance, allowing firms to enhance public perception while reducing their tax burden. This reflects a form of opportunism, where CSR becomes a means to shift attention away from questionable financial practices. Preuss (2010) found that firms headquartered in tax havens tended to be more active in promoting CSR, indicating that such engagement may serve more as a marketing tool than a genuine ethical commitment. Although these OFC-based firms claimed to engage in responsible business practices, their commitments to key stakeholders were, in most cases, weaker than those made by comparable U.S. firms. Davis et al. (2016) posited that due to resource constraints, firms must strategically allocate capital to maximize returns. In such cases, companies may use financial gains from tax avoidance to fund CSR activities, creating an appearance of social responsibility while still engaging in aggressive tax planning. Evidence from Asian emerging markets—such as Hou et al. (2017), using data from Taiwan, found that firms with strong financial performance were more willing to disclose CSR information but simultaneously had greater flexibility to engage in tax avoidance.

Benlemlih et al. (2023) added nuance to the strategic perspective by showing that consumer awareness can moderate this opportunistic behavior. Their findings suggest that while CSR may be used as a reputation shield, external pressures from stakeholders can serve as an informal governance mechanism that reduces the gap between CSR and ethical behavior.

The literature thus provides conflicting predictions on whether ESG/CSR performance reduces or facilitates tax avoidance. The divergence largely depends on institutional settings, stakeholder monitoring, and the degree of financial pressure faced by firms. Given Taiwan's status as an emerging economy with evolving ESG regulations and increasing anti-tax-avoidance enforcement, the relationship is especially worthy of empirical investigation. The following hypothesis is proposed:

H1: Ceteris paribus, ESG performance affects corporate tax avoidance.

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2.2 ESG Performance and Tax Avoidance during the COVID-19 Pandemic

The COVID-19 pandemic introduced unprecedented financial pressures, liquidity constraints, and operational uncertainty for firms worldwide. Although the pandemic differs from past economic crises, the mechanisms underlying corporate financial distress remain similar.

Richardson et al. (2015), examining Australian firms during financial crises, find that when firms experience financial distress, the expected benefits of tax avoidance often exceed reputational or regulatory costs. Athira and Ramesh (2023), focusing on COVID-19, confirm a positive association between pandemic-related financial pressure and tax avoidance, highlighting firms' increased reliance on tax savings to maintain liquidity. These studies suggest that during periods of heightened financial stress, tax planning becomes a strategic resource for survival.

In times of crisis, a related and often debated question is whether companies should increase or reduce their EGS activities. The crisis literature provides two conflicting perspectives.

(1) Risk-mitigation perspective: ESG improves resilience

ESG may buffer firms against economic shocks. Lins et al. (2017) show that during the global financial crisis, high-CSR firms enjoyed greater investor trust and mitigated valuation losses. Poursoleyman et al. (2024) demonstrate that ESG provides insurance-like protection during COVID-19 across 5,000+ global firms. These studies imply that strong ESG firms may experience less financial pressure and thus less need to increase tax avoidance.

(2) Agency perspective: ESG becomes a tool during crises

Agency theory posits that ESG investments may serve as a vehicle for managerial entrenchment, particularly when firms face declining performance. Pagano and Volpin (2005) and Masulis and Reza (2015) argue that managers may use socially responsible expenditures to pursue personal or political interests rather than shareholder value. Karaibrahimoğlu (2010) finds that firms often reduce CSR commitments during crises—suggesting that ESG activities may be deprioritized when resources are scarce.

Combined with evidence that financial pressure encourages tax avoidance, this perspective implies that even ESG-oriented firms might increase tax planning during crises. Based on the above discussion, the following hypothesis is proposed:

H2: Ceteris paribus, the COVID-19 pandemic has a positive effect on corporate tax avoidance.

3. Research Model and Variable Definition

3.1 Data sources and sample selection

The samples in this study were from listed/OTC companies in Taiwan from 2017 to 2020. The financial data was obtained from the Public Information Observatory and the TEJ Finance database of the Taiwan Economic Journal (TEJ), and the ESG data was obtained from the CSR module constructed by TEJ. Originally, a total of 1,770 companies were obtained. After deducting 43 companies with special operating conditions such as finance, securities, and financial holdings, 6,893 observations were obtained. After removing incomplete data, a total of 5,668 annual observations were gathered. Industry categories were based on TEJ's classification.

3.2 Data sources and sample selection

The first objective of this research was to explore the effects of ESG performance on tax avoidance (H1). The Model (1) is as follows:

$$BTD_{i,t} = \beta_0 + \beta_1 ESG\_SCORE_{i,t} + \beta_2 IVE_{i,t} + \beta_3 PPE_{i,t} + \beta_4 INTANG_{i,t} + \beta_5 RD_{i,t} + \beta_6 ROA_{i,t} + \beta_7 DY18_{i,t} + \beta_8 IND_{i,t} + \varepsilon_{i,t} \quad (1)$$

where:

i is the individual company

t is the period

BTD is the book-tax differences, which is a proxy of corporate tax avoidance

ESG_SCORE is the comprehensive performance of ESG

IVE is the degree of corporate financial leverage

PPE is the intensity of fixed assets

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INTANG is the intensity of intangible assets

RD is the research and development expense ratio

ROA is the return on total assets

DY18 is the income tax rate increased for profit-seeking enterprises

IND is the industry category.

The second objective of this research was to investigate the effect of the COVID-19 pandemic on tax avoidance. To test H2, we established Model (2) as follows:

$$BTD_{i,t} = \beta_0 + \beta_1 ESG\_SCORE_{i,t} + \beta_2 COVID_{i,t} + \beta_3 IVE_{i,t} + \beta_4 PPE_{i,t} + \beta_5 INTANG_{i,t} + \beta_6 RD_{i,t} + \beta_7 ROA_{i,t} + \beta_8 DY18_{i,t} + \beta_9 IND_{i,t} + \varepsilon_{i,t} \quad (2)$$

where:

COVID is the COVID-19 pandemic.

3.3 Variable Definition

Corporate tax avoidance: In this paper, the book-tax differences (BTD) were used as a proxy variable for corporate tax avoidance. Referring to Khurana and Moser (2013) and Ding et al. (2021), the present study divided the current income tax expense (including deferred income tax expense, but excluding the discontinued sector) by the highest statutory profit-seeking enterprise income tax rate to calculate the taxable income. Then, BTD was measured using:

$$\frac{\text{pre-tax book income - the taxable income}}{\text{total assets}}$$

ESG performance (ESG_SCORE): This study used the CSR module of TEJ as the data source and employed the KLD's method to evaluate ESG performance as the benchmark. A total of 19 items were included to measure the ESG performance, and the full score was 19 points. The 19 items were categorized into: environmental protection performance (ESG_E), social responsibility performance (ESG_S), and corporate governance performance (ESG_G). If the item was represented by a numerical value, it was divided into ten percentile scores (If the value ranks 18% in the total sample data of this item, the company gets 0.2 points; the highest is 1 point and the lowest is 0 point, and so on), and the scoring mechanism was adjusted according to the positive and negative indicators (for example, the higher the carbon emission, the lower the score of the enterprise, which is a negative indicator; the higher the corporate governance evaluation level, the higher the score of the enterprise, which is a positive indicator). The details of the calculation of ESG performance are shown in Table 1.

Table 1: Calculation of ESG performance

Item	Inverse indicator	Scoring
Environmental protection (E)		
Carbon emissions	yes	Divide into 10 percentiles and give points in order
Enterprise water consumption	yes	Divide into 10 percentiles and give points in order
MIT product mark		1 if the stamp is obtained, 0 otherwise
Environmental label		1 if the stamp is obtained, 0 otherwise
Social responsibility (S)		
Enterprises employing people with disabilities		Divide into 10 percentiles and give points in order
Employee turnover	yes	Divide into 10 percentiles and give points in order

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Employee educational background		Doctor = 4 points, Master = 3 points, University = 2 points, below high school = 1 point, after calculating the weighted average, divide into 10 percentiles and give points in order
Salary difference between executives and lower-level employees	yes	Divide into 10 percentiles and give points in order
Enterprises that violate the Labor Standards Law	yes	It is 1 if there is no occurrence in the current year, otherwise it is 0
Employee applying for parental leave		Divide into 10 percentiles and give points in order
Gender composition of employees		Divide into 10 percentiles and give points in order
Employee occupational injuries	yes	It is 1 if there is no occurrence in the current year, otherwise it is 0
Social responsibility news	yes	It is 1 if there is no occurrence in the current year, otherwise it is 0
Corporate donations		1 when there is an occurrence in the year, 0 otherwise
Gender composition of directors		Divide into 10 percentiles and give points in order
Corporate governance (G)		
Corporate governance assessment		Divided into 5 levels to give points in order
CSR disclosure situation		1 for voluntary disclosure, 0 for compulsory disclosure or no disclosure
CSR assurance situation		1 if there is third-party assurance, 0 otherwise
ISO series certification		1 if the stamp is obtained, 0 otherwise

Financial leverage (IVE): Chen et al. (2010) argued that companies with high debt ratios are less likely to engage in active tax avoidance because they can reduce tax expenditures through the tax shield generated by the tax law. Meanwhile, Graham (2000) suggested that companies can use the interest expenses generated by debt to deduct taxable income, thereby reducing the tax liability. In this paper, financial leverage was included as a control variable and was measured by the debt ratio.

Fixed assets intensity (PPE): Differences arise between financial accounting and tax laws due to varying depreciation expenses recognized for fixed assets, leading to financial and tax disparities. Mills (1998) indicated that enterprises may increase depreciation expense used to reduce the tax burden, but Chen et al. (2010) believed that depreciation expense itself constitutes a tax deduction, and companies no longer need to use tax avoidance to achieve their goals. In this paper, fixed asset intensity was included as a control variable and was measured by dividing the real estate, plant, and equipment by the total assets.

Intangible assets intensity (INTANG): Intangible assets, similar to fixed assets, are subject to distinct amortization recognition regulations under general accounting principles and tax laws. Steijvers and Niskanen (2014) studied the relationship between Finnish family businesses and tax avoidance and indicated that the amortization of intangible assets may cause the effect of the tax shield. Hence, intangible asset intensity was included as a control variable and was measured by dividing the intangible assets by the total assets.

Research and development expense ratio (RD): Under Taiwan's Income Tax Law, enterprises have the opportunity to declare a specified portion of their Research and Development (R&D) expenses as deductions during income tax settlement. Additionally, they may avail themselves of further tax concessions through other applicable regulations. This paper included the R&D expense ratio as a control variable, which was calculated by the R&D expenses divided by the operating income.

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Return on total assets (ROA): Gupta and Newberry (1997) indicated that companies with higher profitability may have to pay more taxes according to tax law. Chen et al. (2010) also found that the higher the profitability of family businesses, the higher the effective tax rate. Frank et al. (2009) believed that high-profit enterprises that have to pay more taxes have greater incentives to engage in tax avoidance activities. Therefore, this paper measured profitability by dividing pre-tax net income by the total assets.

Raising the income tax rate for profit-seeking enterprises (DY18): In 2018, the Taiwanese government raised the tax rate of income tax for profit-seeking enterprises from 17% to 20% to adjust the tax structure. Raising the nominal interest rate has an impact on the measurement of tax avoidance (Richardson and Lanis, 2007). Therefore, this paper set up a dummy variable to proxy the change in tax rate to control for its impact on tax avoidance. The period before 2018 was set to 0 and the period after 2018 was set to 1.

Industry (IND): Due to industry-specific tax regulations, different sectors are subject to varying tax laws, resulting in disparities in effective tax rates across industries. For instance, the 2010 Taiwan government budget assessment report pointed out that the electronics industry has become the largest beneficiary of tax concessions under the "Statute for Industrial Innovation"; the "Biotechnology Medical Industry Development Regulations" was established to promote the development of the biotechnology medical industry. Hence, an industry dummy variable was included as a control variable. If the enterprise belongs to the electronics industry or the biotechnology medical industry, the dummy variable was set to 1; otherwise, it was set to 0.

The COVID-19 pandemic (COVID): To explore the influence of the COVID-19 pandemic on tax avoidance, this paper sets up a dummy variable for the COVID-19 pandemic. The pre-epidemic period (2017-2019) is set to 0, and the post-epidemic period (2020) is set to 1.

4. Empirical Results

4.1 Descriptive Statistical Analysis

Table 2 Panel A shows the descriptive statistics of the study variables. The mean of BTD (book-tax differences) for measuring tax avoidance was -0.011, and the median was -0.005. On average, the BTD of sample companies was small, indicating that the degree of tax avoidance is low. The mean of ESG_SCORE (ESG performance) was 5.306, which was far below the ESG performance benchmark of 19 points set in this paper. The means for ESG_E (environmental protection), ESG_S (social responsibility), and ESG_G (corporate governance) were 0.276, 4.219, and 0.812, respectively. These scores were also lower compared to the full scores of each ESG dimension, indicating that the sample companies still need to actively engage in ESG activities to meet social expectations. The mean of ROA was 0.086, suggesting that most of the sample companies are profitable. The median of DY18 was 1, indicating that more than half of the sample observations belong to the period of raising the income tax rate for profit-seeking enterprises. The median of IND was 1, meaning that more than half of the sample companies belong to the electronics and biotechnology medical industries. Table 2 Panel B shows the industry distribution of all the samples, indicating that over 50% of the samples belong to the electronics and biotechnology medical industries.

Table 2: Descriptive statistics and sample industry distribution

Panel A Descriptive statistics (n=5668)

Variable	Mean	Standard deviation	Minimum	Median	Maximum
BTD	-0.011	0.052	-0.643	-0.005	0.550
ESG_SCORE	5.306	1.240	3.200	5.100	11.300
ESG_E	0.276	0.460	0.000	0.000	2.800
ESG_S	4.219	0.899	0.500	4.200	7.700
ESG_G	0.812	0.851	0.000	0.400	4.000
IVE	0.435	0.180	0.004	0.438	0.998
PPE	0.251	0.174	2.68E-05	0.228	0.957
INTANG	0.015	0.052	2.52E-07	0.002	0.939
RD	0.026	0.030	0.000	0.016	0.132
ROA	0.086	0.071	-0.118	0.080	0.283
DY18	0.760	0.426	0.000	1.000	1.000
IND	0.540	0.498	0.000	1.000	1.000
COVID	0.250	0.436	0.000	0.000	1.000

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Panel B Sample industry distribution

	Industry	Num.	%	Industry	Num.	%
Electronics & Biotechnology Medical (n=3061)	Biotechnology Medical	339	5.98	Optoelectronics	394	6.95
	Semiconductor	376	6.63	Communication Network	292	5.15
	Computer and Peripherals	374	6.60	Electronic components	733	12.93
	Electronic channel	133	2.35	Information service	99	1.75
	Other electronics	321	5.66	**Total**	**3061**	**54.00**
Non-Electronics & Biotechnology Medical (n=2607)	Cement	28	0.49	Food	104	1.83
	Plastic	91	1.61	Textile	181	3.19
	Motor machinery	354	6.25	Electrical cable	64	1.13
	Chemical	159	2.81	Glass ceramic	20	0.35
	Paper	24	0.42	Iron	173	3.05
	Rubber	37	0.65	Auto	106	1.87
	Cultural and creative	55	0.97	Agricultural Science and Technology	13	0.23
	E-commerce	18	0.32	Building materials construction	308	5.43
	Shipping	103	1.82	Tourism	145	2.56
	Oil, electricity and gas	43	0.76	Trade department store	132	2.33
	Other	449	7.92	**Total**	**2607**	**46.00**

Notes: BTD (book-tax differences, a proxy for tax avoidance); ESG_SCORE (ESG performance); ESG_E (environmental protection performance); ESG_S (social responsibility performance); ESG_G (corporate governance performance); IVE (financial leverage); PPE (fixed assets intensity); INTANG (intangible assets intensity); RD (research and development expense ratio); ROA (return on total assets); DY18 (raising the income tax rate for profit-seeking enterprises); IND (industry); COVID (COVID-19 pandemic).

4.2 Correlation Analysis

The Pearson correlation analysis between the variables is listed in Table 3. It can be seen that ESG_SCORE and BTD had a positive relationship; thus, the higher the ESG performance, the greater the degree of tax avoidance. The IVE and BTD were found to have a negative relationship, meaning that the higher the corporate debt ratio, the smaller the degree of tax avoidance. Furthermore, the results showed that ROA and BTD have a positive relationship, indicating that the higher the return on total assets, the higher the degree of tax avoidance. INTANG had no significant relationship with BTD. COVID and BTD had a positive relationship, indicating that the degree of tax avoidance increased after COVID-19. Additionally, the VIF value of all variables was below 10, indicating that there is no serious collinearity problem among the independent variables.

Table 3: Correlation analysis

	BTD	ESG_ SCORE	ESG_E	ESG_S	ESG_G	IVE	PPE	INTANG	RD	ROA	DY18	IND	COVID
BTD	1												
ESG_ SCORE	.085**	1											
ESG_E	.038**	.456**	1										
ESG_S	.048**	.497**	-.246**	1									
ESG_G	.053**	.684**	.384**	-.199**	1								
IVE	-.109**	.027*	.062**	-.067**	.077**	1							
PPE	-.063**	-.051**	.047**	-.176**	.086**	0.004	1						
INTANG	.000	.095**	.029*	0.011	.111**	.066**	-.076**	1					

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RD	-.036**	.035**	-.079**	.090**	-0.001	-.192**	-0.006	0.007	1				
ROA	.251**	.104**	-0.002	-0.021	.175**	-.180**	.101**	.046**	.060**	1			
DY18	.057**	.247**	0.012	.313**	0.022	.038**	-0.01	-0.003	0.013	0.024	1		
IND	-.065**	0.018	-.151**	.107**	-0.006	-.107**	-.146**	0.005	.425**	.066**	-0.005	1	
COVID	.050**	.106**	-.029*	.115**	.049**	.047**	-0.021	0.006	0.014	0.004	.326**	-0.002	1

Notes: BTD (book-tax differences, a proxy for tax avoidance); ESG_SCORE (ESG performance); ESG_E (environmental protection performance); ESG_S (social responsibility performance); ESG_G (corporate governance performance); IVE (financial leverage); PPE (fixed assets intensity); INTANG (intangible assets intensity); RD (research and development expense ratio); ROA (return on total assets); DY18 (raising the income tax rate for profit-seeking enterprises); IND (industry); COVID (COVID-19 pandemic). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.3 Results and Discussion

This study employed multiple regression analysis to test the proposed hypotheses. Table 4 presents the estimation results for Model (1), which examines Hypothesis 1. As shown in COL. (1) of Table 4, the coefficient for ESG_SCORE is positive (0.0022) and statistically significant at the 1% level, indicating a significant positive relationship between ESG performance and tax avoidance (BTD). In other words, firms with higher ESG performance tend to engage in greater tax avoidance. This finding supports the strategic ESG perspective, which views ESG initiatives as driven by opportunistic motives rather than ethical considerations. This aligns with prior studies such as Sikka (2010), Preuss (2010), and Davis et al. (2016), who argue that CSR and tax avoidance can coexist or even substitute for one another. Thus, Hypothesis 1 is supported: ceteris paribus, ESG performance affects corporate tax avoidance.

Regarding the control variables, IVE (debt ratio) exhibits a significant negative relationship with BTD, suggesting that higher leverage is associated with lower tax avoidance, consistent with the tax shield argument proposed by Chen et al. (2010). PPE (fixed asset ratio) also shows a negative effect, implying that asset-heavy firms are less likely to avoid taxes—again echoing Chen et al. (2010). RD (R&D expenses) has a significant negative impact on BTD, indicating that firms investing more in innovation are less aggressive in tax planning. In contrast, ROA (return on assets) is positively associated with BTD, supporting Frank et al. (2009)'s argument that more profitable firms have stronger incentives for tax avoidance. DY18 (tax rate) is positively associated with BTD, indicating that higher statutory tax rates motivate greater tax avoidance. IND (industry dummy) has a negative effect, reflecting that firms in the electronics and biotech industries may benefit from tax incentives, thus reducing their need for tax avoidance. The coefficient of INTANG (intangible assets) is not statistically significant.

To further examine the specific dimensions of ESG, this study analyzes ESG_E (environmental responsibility), ESG_S (social responsibility), and ESG_G (corporate governance). The results, shown in columns 2 to 4 of Table 4, reveal that all three components are positively and significantly associated with BTD. These findings reinforce the opportunism hypothesis, suggesting that firms undertake ESG activities for strategic benefits rather than altruistic motives.

Table 4: Influence of ESG performance on tax avoidance

	COL.(1)		**COL.(2)**		**COL.(3)**		**COL.(4)**	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-0.0178	-4.80***	-0.0090	-3.28***	-0.0152	-3.62***	-0.0084	-3.09***
ESG_ SCORE	0.0022	3.87***						
ESG_E			0.0037	2.55**				
ESG_S					0.0018	2.24**		
ESG_G							0.0015	1.89*
IVE	-0.0236	-6.15***	-0.0234	-6.11***	-0.0224	-5.83***	-0.0237	-6.17***
PPE	-0.0300	-7.71***	-0.0311	-8.00***	-0.0294	-7.45***	-0.0314	-8.05***
INTANG	-0.0186	-1.43	-0.0152	-1.17	-0.0144	-1.11	-0.0168	-1.28
RD	-0.0005	-2.11**	-0.0005	-1.96*	-0.0005	-2.09**	-0.0005	-2.00**

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ROA	0.0018	19.06***	0.0019	19.53***	0.0019	19.63***	0.0018	18.91***
DY18	0.0049	3.06***	0.0064	4.10***	0.0053	3.19***	0.0064	4.10***
IND	-0.0097	-6.53***	-0.0093	-6.19***	-0.0100	-6.66***	-0.0098	-6.55***
Adjusted R^2	0.09		0.09		0.09		0.09	

Notes: Dependent variable is tax avoidance which is measured by BTD (book-tax differences). ESG_SCORE (ESG performance); ESG_E (environmental protection performance); ESG_S (social responsibility performance); ESG_G (corporate governance performance); IVE (financial leverage); PPE (fixed assets intensity); INTANG (intangible assets intensity); RD (research and development expense ratio); ROA (return on total assets); DY18 (raising the income tax rate for profit-seeking enterprises); IND (industry). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Observations are 5668.

Table 5 presents the results for Model (2), which tests Hypothesis 2, proposing that the COVID-19 pandemic positively affects corporate tax avoidance. As shown in columns 1 to 4 of Table 5, the COVID-19 variable is positive and statistically significant at the 1% level across all specifications, confirming that tax avoidance increased during the pandemic. This supports Hypothesis 2.

The findings are consistent with Athira and Ramesh (2023), who reported a positive association between the pandemic and tax avoidance. During COVID-19, many firms faced substantial financial pressures such as declining revenues and disrupted cash flows. To preserve liquidity and sustain operations, firms were incentivized to intensify tax avoidance efforts as a strategic response.

These results may also be interpreted through the lens of the risk management view of ESG. While some firms may have maintained or even increased ESG activities during the crisis to preserve reputation and stakeholder trust (Lins et al., 2017; Poursoleyman et al., 2024), limited resources during economic downturns may have prompted other firms to prioritize financial survival, including cost-saving strategies such as tax avoidance. Thus, the pandemic served as a stress test, revealing firms' strategic behavioral shifts under extreme conditions.

Overall, the empirical findings support both hypotheses and provide new evidence in favor of the view that ESG activities may be driven more by opportunism than ethics. Moreover, the results underscore the significant influence of external shocks such as COVID-19 on corporate tax strategies.

Table 5: Influence of the COVID-19 pandemic on tax avoidance

	COL.(1)		**COL.(2)**		**COL.(3)**		**COL.(4)**	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-0.0175	-4.71***	-0.0089	-3.24***	-0.0149	-3.56***	-0.0083	-3.03***
ESG_ SCORE	0.0021	3.80***						
ESG_E			0.0039	2.65***				
ESG_S					0.0018	2.21**		
ESG_G							0.0014	1.77*
COVID	0.0043	2.68***	0.0046	2.87***	0.0044	2.74***	0.0043	2.69***
IVE	-0.0239	-6.25***	-0.0239	-6.23***	-0.0228	-5.94***	-0.0241	-6.26***
PPE	-0.0298	-7.67***	-0.0309	-7.95***	-0.0292	-7.40**8	-0.0312	-7.99***
INTANG	-0.0186	-1.43	-0.0153	-1.18	-0.0144	-1.11	-0.0167	-1.28
RD	-0.0005	-2.16**	-0.0005	-2.01**	-0.0005	-2.14**	-0.0005	-2.05**
ROA	0.0018	19.06***	0.0019	19.53***	0.0019	19.62***	0.0018	18.93***
DY18	0.0035	2.08***	0.0049	2.95***	0.0038	2.20***	0.0050	3.01***
IND	-0.0097	-6.51***	-0.0093	-6.15***	-0.0099	-6.65***	-0.0097	-6.53***
Adjusted R^2	0.09		0.09		0.09		0.09	

Notes: Dependent variable is tax avoidance which is measured by BTD (book-tax differences). ESG_SCORE (ESG performance); ESG_E (environmental protection performance); ESG_S (social responsibility performance); ESG_G (corporate governance performance); COVID (COVID-19 pandemic); IVE (financial leverage); PPE (fixed assets intensity); INTANG (intangible assets intensity); RD (research and development expense ratio); ROA (return on total assets); DY18 (raising the income tax rate for

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profit-seeking enterprises); IND (industry). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Observations are 5668.

4.4 Robustness Tests

4.4.1 Controlling for firm effects

To account for unobserved firm-specific heterogeneity, we attempt to estimate a firm fixed-effects (FE) model. However, the FE regression fails due to a singular design matrix. As an alternative, we estimate a firm random-effects (RE) model to control for time-invariant firm attributes. COL. (1) of Table 6 presents the estimation results for Model (1), which examines Hypothesis 1. The coefficient for ESG_SCORE is positive (0.0017) and statistically significant at the 1% level, indicating a significant positive relationship between ESG performance and tax avoidance (BTD). COL. (2) of Table 6 presents the results for Model (2), which tests Hypothesis 2, proposing that the COVID-19 pandemic positively affects corporate tax avoidance. The COVID-19 variable is positive and statistically significant at the 1% level. The RE regression results remain economically and statistically aligned with the baseline, indicating that the observed relationships are not driven by omitted time-invariant firm characteristics. These robustness findings confirm that incorporating firm-level effects does not materially alter the study's inferences and provides additional confidence in the empirical validity of the results.

Table 6: Controlling for firm effects- random-effects (RE) model

	COL.(1)		**COL.(2)**	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-0.0162	-3.70***	-0.0156	-3.54***
ESG_SCORE	0.0017	2.65***	0.0016	2.52**
COVID			0.0048	3.66***
IVE	-0.0304	-6.29***	-0.0314	-6.50***
PPE	-0.0281	-5.52***	-0.0274	-5.40***
INTANG	-0.0191	-1.12	-0.0191	-1.12
RD	-0.0006	-1.91*	-0.0007	-2.02**
ROA	0.0022	19.29***	0.0022	19.33***
DY18	0.0052	3.84***	0.0037	2.63***
IND	-0.0094	-4.56***	-0.0093	-4.51***
Adjusted R^2	0.084		0.085	

Notes: Dependent variable is tax avoidance which is measured by BTD (book-tax differences). ESG_SCORE (ESG performance); COVID (COVID-19 pandemic); IVE (financial leverage); PPE (fixed assets intensity); INTANG (intangible assets intensity); RD (research and development expense ratio); ROA (return on total assets); DY18 (raising the income tax rate for profit-seeking enterprises); IND (industry). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Observations are 5668.

4.4.2 Sample Selection: Top and Bottom 25% of BTD

As shown in Panel A of Table 2, the median value of BTD was -0.005, indicating that approximately 50% of the sampled companies had positive book-tax differences. This is noteworthy given the overall low level of BTD in the dataset. Various factors may contribute to an increase in book-tax differences, and it cannot be conclusively attributed solely to active corporate tax avoidance.

To address this concern, a sensitivity analysis was conducted using a subsample consisting of firms in the top and bottom 25 percent of the BTD distribution (n = 2,834 observations). The results are reported in Table 7. COL. (1) presents the estimation results for Model (1), which tests Hypothesis 1. ESG_SCORE remains significantly and positively associated with BTD, consistent with the findings in COL. (1) of Table 4. The coefficients of the control variables also align closely with the baseline results, suggesting that a portion of BTD in the sample is indeed attributable to tax planning behavior. These results reinforce the validity of using BTD as a proxy for tax avoidance and support the interpretation that firms exhibiting higher ESG performance may do so with an opportunistic motive.

COL. (2) displays the results for Model (2), which examines Hypothesis 2 regarding the impact of the COVID-

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19 pandemic on tax avoidance. The coefficient on the COVID-19 indicator is positive and statistically significant at the 5 percent level, indicating that pandemic-induced financial pressure heightened firms' propensity to engage in tax avoidance. These findings provide robust support for Hypothesis 2.

Table 7: Sample Selection: Top and Bottom 25% of BTD

	COL.(1)		**COL.(2)**	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	-0.028	-3.28***	-0.023	-3.15***
ESG_SCORE	0.003	2.90***	0.003	2.79***
COVID			0.008	2.41**
IVE	-0.047	-6.32***	-0.048	-6.43***
PPE	-0.038	-5.04***	-0.038	-5.04***
INTANG	-0.018	-0.71	-0.017	-0.68
RD	-0.056	-1.23	-0.001	-1.26
ROA	0.274	16.43***	0.003	16.43***
DY18	0.009	2.99***	0.007	2.11**
IND	-0.015	-5.28***	-0.015	-5.31***
Adjusted R^2	0.14		0.14	

Notes: Dependent variable is tax avoidance which is measured by BTD (book-tax differences). ESG_SCORE (ESG performance); COVID (COVID-19 pandemic); IVE (financial leverage); PPE (fixed assets intensity); INTANG (intangible assets intensity); RD (research and development expense ratio); ROA (return on total assets); DY18 (raising the income tax rate for profit-seeking enterprises); IND (industry). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Observations are 2834.

4.4.3 Alternative Measure: Permanent Book-Tax Differences (PBTD)

Permanent book–tax differences (PBTD) are calculated by subtracting temporary book–tax differences from total BTD. Following Frank et al. (2009), PBTD serves as a more relevant measure of corporate tax planning because temporary differences may primarily reflect short-term earnings management by current management. Consistent with their approach, temporary book–tax differences in this study are estimated by dividing deferred income tax expense by the statutory tax rate and then deducting the resulting value from total BTD. The regression results are presented in Table 8.

COL. (1) reports the estimation results for Model (1), which examines Hypothesis 1. ESG_SCORE remains significantly and positively associated with PBTD, consistent with the findings reported in COL. (1) of Table 4. This result provides further evidence that higher ESG performance is linked to greater tax avoidance behavior.

COL. (2) presents the results for Model (2), which tests Hypothesis 2. Although the coefficient on the COVID-19 indicator is positive, it does not reach statistical significance at the 10 percent level. This suggests that, when using PBTD as an alternative measure of tax avoidance, the effect of the pandemic on tax planning remains directionally consistent with expectations but lacks statistical support.

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Table 8: Alternative Measure: Permanent Book-Tax Differences (PBTD)

	COL.(1)		COL.(2)	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	-0.154	-14.42***	-0.153	-14.38***
ESG_SCORE	0.004	2.73***	0.004	2.71***
COVID			0.004	0.86
IVE	0.020	1.80*	0.019	1.77*
PPE	-0.039	-3.50***	-0.039	-3.49***
INTANG	0.065	1.74*	0.065	1.74*
RD	0.102	1.40	0.001	1.39
ROA	0.263	9.51***	0.003	9.52***
DY18	0.014	2.93***	0.012	2.52**
IND	0.029	6.26***	0.027	6.27***
Adjusted R^2	0.05		0.04	

Notes: Dependent variable is tax avoidance which is measured by PBTD (permanent book-tax differences). ESG_SCORE (ESG performance); COVID (COVID-19 pandemic); IVE (financial leverage); PPE (fixed assets intensity); INTANG (intangible assets intensity); RD (research and development expense ratio); ROA (return on total assets); DY18 (raising the income tax rate for profit-seeking enterprises); IND (industry). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Observations are 5668.

5. Conclusion and Recommendations

This study investigates the relationship between ESG performance, financial pressure, and corporate tax avoidance using a comprehensive dataset of Taiwanese listed firms before and during the COVID-19 pandemic. ESG performance is measured using a proprietary index developed for this research, while book–tax differences (BTD) and permanent book–tax differences (PBTD) are used as primary proxies for tax avoidance. The empirical evidence consistently demonstrates a significant and positive association between ESG performance and corporate tax avoidance, supporting the strategic or opportunistic view of ESG. Rather than engaging in ESG activities solely as a reflection of ethical commitment, firms may adopt ESG practices as part of a broader strategic framework designed to enhance financial outcomes, including minimizing tax burdens.

Analyses of disaggregated ESG dimensions further reinforce this interpretation. Environmental (E), social (S), and governance (G) performance each exhibit a positive and statistically significant relationship with tax avoidance, consistent with the results derived from the aggregate ESG index. These findings suggest that, across all ESG domains, firms may employ ESG initiatives as instruments that complement tax-related incentives, thereby aligning ESG engagement with strategic economic motivations rather than purely normative or value-driven objectives.

This study also examines the role of financial pressure by exploring the impact of the COVID-19 pandemic on firms' tax behavior. The results show that tax avoidance increased significantly during the pandemic period. This finding aligns with the risk-management and financial-constraint perspectives, which propose that firms adopt more aggressive tax strategies as a means of preserving liquidity and ensuring business continuity in times of crisis. When confronted with revenue disruptions, heightened uncertainty, and operational instability, firms may view tax avoidance as a viable mechanism to mitigate financial pressures. The interaction between ESG performance and the pandemic context further highlights the complex interplay between sustainability practices and corporate financial decision-making under stress.

Based on these findings, several policy and managerial implications emerge:

Strengthening regulatory oversight and disclosure quality: Policymakers should consider enhancing ESG disclosure standards and tax transparency requirements to prevent the misuse of ESG initiatives as a façade for

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aggressive tax planning. Standardized, comparable, and audited ESG reporting—combined with stricter enforcement of tax regulations—can reduce information asymmetry and limit opportunistic behavior.

Improving corporate governance mechanisms: Firms should strengthen governance structures to ensure that ESG strategies are aligned with long-term organizational values rather than short-term gains. Enhancing board independence, establishing clearer accountability mechanisms, and integrating ethical considerations into executive compensation plans can help align ESG practices with genuine sustainability objectives.

Embedding ESG into long-term strategic planning: Companies should treat ESG not as a symbolic or reputational tool but as an integral component of long-term strategic development, risk management, and stakeholder engagement. Doing so can reduce the incentive for opportunistic ESG behavior and promote more authentic and sustainable organizational practices.

Enhancing transparency and credibility in ESG communication: High-quality ESG disclosures that are verifiable, consistent, and performance-based can improve stakeholder trust and mitigate concerns about the true motivations behind ESG initiatives. Transparent communication can help build legitimacy and foster stronger, more credible relationships with investors, regulators, and the public.

In conclusion, this study provides robust empirical evidence that ESG performance is positively associated with corporate tax avoidance and that financial pressure—exemplified by the COVID-19 pandemic—intensifies firms' reliance on tax avoidance strategies. These findings contribute to the growing body of literature on ESG, corporate behavior, and crisis management by highlighting the strategic nature of ESG engagement and its interaction with firms' financial incentives.

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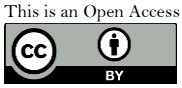

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Cooperative versus Commercial Banks in Greece: A Comparative Analysis of Credit Policy

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ABSTRACT

This study compares the credit policies of Greek cooperative and commercial banks using firm-level balance-sheet data for more than 20,000 companies drawn from the ICAP database over the period 2014–2016. We examine how lending differs by sector, firm size, and financial robustness. Descriptive evidence shows that cooperative banks primarily serve small and medium-sized enterprises (SMEs). We then estimate a logit model in which the dependent variable indicates whether a firm is financed exclusively by commercial banks, using financial ratios capturing coverage, activity, profitability, and liquidity. The results suggest that firms with stronger financial fundamentals—especially higher interest coverage—are more likely to be financed by commercial banks, while cooperative banks tend to serve financially weaker firms. These findings are consistent with the relationship-based role of cooperative banks during the crisis period in Greece.

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1. Introduction

In Greece, cooperative banks play a much smaller role than commercial banks in terms of deposits and loans. Beyond their limited market share, it is often argued by practitioners and policymakers that cooperative banks differ in governance and credit allocation, relying more on relationship lending and supporting local small and medium-sized enterprises (SMEs).This has also been supported in the past by official statements, such as those made by the Deputy Governor of the Bank of Greece during his speech at the E.S.T.E. conference on "The New Banking Landscape and the Role of Cooperative Banks" on July 10, 2018 (Bank of Greece, 2018).

This paper investigates whether such differences are reflected in actual lending outcomes. Using firm-level data from the ICAP database for the period 2014–2016—a time characterized by deep recession and severe financial stress—we compare the clients of cooperative and commercial banks in terms of sectoral allocation, firm size, and financial robustness. The descriptive evidence on how lending across productive sectors relates to the structure of the Greek economy is summarized in Section 3, while the detailed sector–GDP alignment analysis is reported in **Appendix**.

The international and Greek-focused literature contains extensive research on non-performing loans (NPLs). NPLs contribute to financial instability (Makri et al., 2014), and despite numerous empirical studies, the phenomenon remains a persistent issue (Naili & Lahrichi, 2020). Evidence further suggests that banks with smaller balance sheets are more vulnerable to elevated NPL ratios (Louzis et al., 2012), and a negative relationship has been documented between bank size and NPLs (Salas & Saurina, 2002). Additionally, a negative relationship appears to exist between ownership concentration and impaired loans (Shehzad et al., 2010).

Regarding loan evaluation criteria, prior research indicates that small banks rely more on relationship-based factors and soft information when screening borrowers (Uchida, 2011; Stein, 2002). The literature further suggests that large banks are less efficient in collecting and utilising soft information, whereas relationship banking implemented by smaller banks mitigates information asymmetry (Boot, 2000). Cooperative banks have therefore been argued to possess a comparative advantage in relationship lending (de la Torre et al., 2008). However, studies also report that credit risk management (CRM) systems are not widely adopted by Cooperative banks (Aduda & Obondy, 2020), and their absence has even been cited as a contributing factor to institutional failures (Mugo, Muathe &

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Waithaka, 2019). Conversely, case evidence from Banca di Credito Cooperativo (BCC) di Napoli demonstrates that Cooperative banks can successfully combine hard and soft information in their lending decisions (Caldarelli et al., 2015).

Our analysis addresses three questions. First, does the share of firms financed by cooperative banks reflect their small market presence in Greece? Second, do cooperative banks primarily serve SMEs and professionals, in line with their statutory objectives and with the sectoral patterns of Greek economic activity (see **Appendix**)? Third, and most importantly, are firms financed by cooperative banks financially weaker than those financed exclusively by commercial banks?

To answer the last question, which constitutes the main empirical focus of the paper, we estimate a logit model using standard accounting ratios associated with credit risk. By doing so, we provide evidence on whether the observed differences in loan portfolio quality between cooperative and commercial banks can be linked to the financial characteristics of their borrowers.

The remainder of the paper is structured as follows. Section 2 describes the methodology and the econometric specification. Section 3 presents the data and the main descriptive patterns, with supplementary sectoral evidence in **Appendix**. Section 4 discusses the empirical results. Section 5 concludes, offering policy implications and directions for future research.

2. Methodology

We employ a logistic regression (logit) model to analyze the relationship between firm financial characteristics and the type of bank financing they receive. The dependent variable is binary and defined as: $Y_i = 1$ if firm i is financed exclusively by commercial banks; $Y_i = 0$ if firm i has any exposure to cooperative banks.

Firms with multiple banking relationships that include at least one cooperative bank are classified in the cooperative-exposed group. With this definition, odds ratios greater than one indicate a higher likelihood of exclusive commercial bank financing.

The estimated model is:

$$P(Y_i = 1) = \Lambda(\beta_0 + \beta_1 \ln(\text{Coverage}_i) + \beta_2 \ln(\text{Activity}_i) + \beta_3 \ln(\text{Profitability}_i) + \beta_4 \ln(\text{Liquidity}_i))$$

where $\Lambda(.)$ denotes the logistic cumulative distribution function.

The ratios are defined as:
Coverage = EBITDA / Financial expenses (main variable),
Activity = Sales / Total assets (control variable),
Profitability = Earnings after tax / Total assets (control variable),
Liquidity = Cash / Current liabilities (control variable).
All ratios are expected to be positively related to firm sustainability.

These ratios are widely used in the credit risk literature (e.g., Beaver, 1968; Altman and Sabato, 2007; Doumpos et al., 2019) and are expected to be positively related to firm sustainability. Hence, if cooperative banks tend to finance weaker firms, higher values of these ratios should be associated with a greater probability of exclusive commercial bank financing (i.e., positive coefficients or odds ratios above one).

3. Data and Descriptive evidence

3.1 Data

The dataset is drawn from the ICAP database and includes balance-sheet information for more than 20,000 Greek firms with bank loans over 2014–2016. Firms operate across all productive sectors of the economy. Each firm is classified according to whether it is financed by cooperative banks, commercial banks, or both.

3. 2 Distribution of firms by bank type

Examining our research questions sequentially, it arises for our first question that, based on the data we draw from the ICAP database, Cooperative banks finance approximately 1.44% of the sample of 20,000 Greek businesses, while the remaining large percentage (98.56%) draws loans from Greek Commercial banks as shown in Table 1.

Table 1. Distribution of financed companies among Banks

	Number of Companies	Percentage (%)
financing from cooperative bank	290	1,44
financing from commercial bank	19912	98,56
Total	20202	100

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This aligns with the real-world economic scenario and the market shares that Greek Cooperative banks manage to gather compared to Commercial banks. As seen in Table 2, Cooperative banks' market shares in granted loans are very small and significantly lower than those of Cooperative banks operating in the European context (EACB,2022).

Table 2. Market Shares of Cooperative Banks in granted Loans in Europe

Country/ Year	*2014*	*2015*	*2016*
GERMANY	20,10	20,70	21,10
SPAIN	6,61	6,80	7,10
FRANCE	59,00	59,00	59,20
GREECE	**0,8**	**0,8**	**0,8**
ITALY	7,30	7,20	7,20
AUSTRIA	33,74	35,80	32,90
PORTUGAL	3,70	4,20	4,50
FINLAND	32,80	34,30	35,40
BULGARIA	3,30	4,00	4,30

3. 3 Sectoral allocation and firm size

Commercial banks finance firms across sectors in proportions broadly aligned with each sector's contribution to Greek GDP. Cooperative banks, in contrast, exhibit a stronger focus on the secondary sector and on SMEs, consistent with their statutory mandate to support artisans, small manufacturers, and local professionals (see **Appendix**).

Large enterprises (sales above €50 million) are almost exclusively clients of commercial banks. Only four (4) of such firms in the sample have any cooperative bank exposure, and even then within multiple-bank relationships dominated by commercial lenders.

3. 4 Crisis context

The period under study coincides with severe financial distress in Greece, characterized by a prolonged recession, declining investment, and a rapid deterioration in bank asset quality. Non-performing loans in business portfolios exceeded 50% by 2016, constraining banks' capacity to extend new credit and forcing a strong focus on balance-sheet repair.

Based on records from the Bank of Greece regarding NPLs of business loans, the following table emerges (Bank of Greece, 2023):

Table 3. Non-performing business loans in Greek banking system

DATE	NPLs
DEC/2014	43,20%
MAR/2015	43,70%
JUN/2015	45,50%
SEP/2015	47,10%
DEC/2015	50,60%
MAR/2016	51,10%
JUN/2016	51,40%
SEP/2016	51,90%
DEC/2016	51,20%
MAR/2017	51,40%

Additionally, according to the deputy governor of the Bank of Greece, the NPLs of Cooperative banks are significantly higher than those of Commercial banks. Thus, in March 2017, the NPLs of Cooperative banks reached 57.60% and those of Commercial banks 45.20%. This fact indicates a lag in the quality of the loan portfolio of Cooperative banks. This lag can partly be explained by the fact that the clients of Cooperative banks are predominantly SMEs and small professionals, categories that follow higher NPL rates than usual, as we will see in the following table.

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Table 4. Ratios of non-performing loans by customer category in the Greek banking system

Client/Date	Sep/2015	Mar/2017
S.M.E	58,20%	59,00%
Professional	66,50%	68,00%
Business loan	47,10%	51,40%

It is understood that based on the examination of NPLs of Greek banks, and separating them into those held by Cooperative banks on one side and those held by Commercial banks on the other, there is a noticeable difference exceeding 10 percentage points.

In this paper, we will use a logit regression.Through the logit regression, we will try to prove whether the lag in the loan portfolio of Cooperative banks, as suggested by the statements of official Bank of Greece officials, can be based on numerical data derived from published financial statements of a large sample of Greek businesses.

The ratios we use in our model are drawn from articles dealing with the credit risk of businesses. In simple terms, credit risk refers to the likelihood that a borrower (obligor) will not meet future debt obligations in accordance with the terms agreed when credit was provided by a lender (Doumpos et al., 2019). Thus, models that include ratios are used for prediction. One disadvantage that should be mentioned is the fact that, as argued by Altman and Sabato (2007), models used for credit risk tend to be more accurate if they incorporate qualitative variables of the businesses under examination, a fact that was not possible in our model as such information was not available in our database.

Our main variable, ebitda/financial expenses, is defined as the coverage of financial expenses and is a coverage ratio. According to Andrews, McGowan, and Millot (2017), the higher this ratio for a business, the more sustainable the business is. In their article titled: "The walking dead? Zombie firms and productivity performance in OECD countries," non-viable businesses are defined as those with a financial expenses coverage ratio of less than one for three consecutive years. This ratio is also used by Altman and Sabato (2007).

Continuing, the ratio Sales/Total Assets, which is characterized as an activity ratio, has a positive correlation with the efficiency of the business, as its increase indicates a stronger business. According to Georgopoulos and Benos (2010), it measures the ability of the business to use its assets to generate sales. Apart from the article: "Evaluation of Creditworthiness of Listed Companies: A Comparative Analysis" by the above authors, this ratio is also used in other studies such as Doumpos et al. (2019), which examine the techniques for evaluating credit risk, and in the credit policy manual for the business portfolio of Piraeus Bank (2023).

The ratio of earnings after tax/total assets is a coverage ratio and has a positive correlation with the sustainability of the business. It is used by Altman and Sabato (2007) for the credit risk of SMEs in the USA, as well as by Beaver (1967) and Edmister (1972).

Finally, the ratio Cash/Current liabilities, encountered as the Quick ratio in Doumpos et al. (2019), is a liquidity ratio that, according to Georgopoulos and Benos (2010), measures the ability of the business to use its cash to cover its short-term liabilities. It also has a positive relationship with the sustainability of the business.

Summarizing regarding the ratios used in the model, the following table emerges:

Table 5. Categorization of model variables and their correlation with business sustainability

Ratio	Ebitda/financial expenses=x1	Sales/total assets=x2	Earning after tax/total assets=x3	Cash/current liabilities=x4
Accounting ratio category	coverage	activity	Profitability coverage	Liquidity
Relation to sustainability	positive	positive	Positive	Positive

3. 5 The Impact of 2015 Capital Controls of Greek Commercial and cooperative banks

In June 2015, the Greek government imposed capital controls following heightened sovereign risk and massive deposit outflows from the banking system. These measures included limits on cash withdrawals, restrictions on domestic and international transfers, and a temporary bank holiday. The imposition of capital controls had a profound impact on banks' liquidity positions and lending behavior, further tightening credit conditions in an already fragile economy (Bank of Greece, 2016; ECB, 2015).

For commercial banks, which were heavily exposed to government bonds and dependent on Eurosystem funding, capital controls coincided with a sharp contraction in new lending, particularly to small and medium-sized enterprises (SMEs). Credit supply became increasingly selective, with banks prioritizing larger and more creditworthy firms and focusing on balance-sheet repair amid rapidly rising non-performing loans (Bank of Greece, 2017; Gibson et al., 2019).

Greek cooperative banks, although much smaller in scale, were also affected by the controls. Their deposit bases were constrained, and access to wholesale and central bank funding was limited compared to systemic banks. At the

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same time, their strong local orientation and relationship-based business model meant that many cooperative banks continued to support existing SME and professional clients, often rolling over credit lines rather than expanding new lending (Mitrakos, 2018; EACB, 2016). However, this strategy exposed them disproportionately to weaker borrowers during the downturn, contributing to persistently higher non-performing loan ratios relative to commercial banks in the subsequent years.

The capital controls episode is therefore critical for interpreting our empirical results. The tendency of cooperative banks to finance financially weaker firms during 2014–2016 may reflect not only their statutory mission but also their role as lenders of last resort for local SMEs facing severe credit constraints from commercial banks. Consequently, the estimated relationships between firm financial ratios and bank type should be understood within this exceptional institutional and macroeconomic environment.

4. Empirical results

Table 8 reports odds ratios from the logit regressions estimated separately for each year from 2014 to 2016. The dependent variable equals one when a firm is financed exclusively by commercial banks.

The results show that the **coverage ratio (EBITDA/financial expenses)** has odds ratios significantly greater than one in 2014 and 2015. This indicates that firms with stronger ability to service interest expenses are more likely to be financed exclusively by commercial banks. In other words, cooperative banks tend to serve firms with weaker interest coverage.

The **liquidity ratio (cash/current liabilities)** exhibits odds ratios below one and is statistically significant in several specifications, suggesting that firms with lower liquidity are less likely to be financed exclusively by commercial banks and more likely to have cooperative bank exposure.

Profitability is positive and significant in some years, while the activity ratio is generally not statistically significant.

Overall, the evidence supports the view that cooperative banks, during the period examined, tended to finance financially weaker firms relative to those served exclusively by commercial banks. This pattern is consistent with the relationship-based model of cooperative banking and with their focus on SMEs during a period of economic stress.

Table 8. Logit Regression Results

Y	Odds Ratio	p-value
Logx1/2014	1.234454	0.000*
Logx2/2014	0.9569841	0.658
Logx3/2014	0.9425927	0.470
Logx4/2014	0.8298681	0.002*
Logx1/2015	1.156269	0.010*
Logx2/2015	0.9094078	0.488
Logx3/2015	1.179179	0.037*
Logx4/2015	0.7680285	0.001*
Logx1/2016	1.116647	0.206
Logx2/2016	1.015092	0.940
Logx3/2016	1.249859	0.045*
Logx4/2016	0.7277158	0.017*

5. Conclusions and policy implications

This study compares cooperative and commercial banks in Greece using firm-level data for 2014–2016. The descriptive analysis confirms that cooperative banks primarily serve SMEs and professionals and hold a very small share of total lending. The econometric results provide evidence that firms financed by cooperative banks are, on average, financially weaker than those financed exclusively by commercial banks, particularly in terms of interest coverage and liquidity.

These findings are consistent with the higher non-performing loan ratios observed for cooperative banks during the same period and suggest that portfolio quality differences partly reflect borrower characteristics rather than solely bank-level practices.

Policy Implications

Cooperative banks play an important role in providing credit to financially constrained SMEs, especially in times of crisis. Preserving this role is essential for local economic development. At the same time, the evidence suggests that cooperative banks could benefit from strengthening their screening and monitoring processes, for example through greater adoption of CRM systems and the integration of quantitative credit-scoring tools, while maintaining relationship lending advantages.

From a regulatory perspective, proportional supervision and targeted technical assistance could help cooperative banks upgrade risk management without undermining their cooperative mission.

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Limitations and Future Research

A key limitation is that our analysis focuses on the crisis period of 2014–2016, including the episode of capital controls. Therefore, the results should be interpreted as crisis-specific. Future research should extend the analysis to post-restructuring years (e.g., 2017–2020 or later) to assess whether these patterns persist under more stable conditions.

Moreover, incorporating qualitative information—such as firm age, management quality, and relationship length—could further improve understanding of credit allocation. Exploring multinomial models that distinguish exclusive and multiple banking relationships would also be a fruitful avenue for future work.

Appendix. Sectoral Alignment between Bank Lending and Greek GDP

This appendix provides supplementary descriptive evidence on the alignment between the sectoral distribution of bank-financed firms and the structure of the Greek economy, as measured by sectoral contributions to gross domestic product (GDP). The purpose is to assess whether cooperative and commercial banks allocate credit across sectors in proportions consistent with overall economic activity.

1 Sectoral Structure of Greek GDP

Table 3 reports the contribution of the primary, secondary, and tertiary sectors to Greek GDP for the period 2014–2016, based on ELSTAT data.

Table 3. Participation of the productive sector of the Greek economy in its GDP

Year/Sector	Primary	Secondary	Tertiary
2014	4,00%	15,90%	80,10%
2015	4,30%	16,40%	79,30%
2016	4,00%	16,60%	79,40%

The Greek economy is clearly dominated by the tertiary sector, which consistently accounts for around 80% of GDP, while the secondary sector contributes about 16% and the primary sector around 4%.

2 Sectoral Distribution of Bank-Financed Firms

Table 4 presents the shares of firms financed by cooperative and commercial banks in 2016 across the same productive sectors. The percentages represent shares within each bank-type sample.

Table 6. Shares of financed firms within each bank type sample, 2016

Bank/Sector	Primary	Secondary	Tertiary
Cooperative	6,50%	38,30%	55,20%
Commercial	3,90%	26,00%	70,10%

3 Discussion

A comparison of Tables 3 and 4 reveals notable differences in sectoral orientation between cooperative and commercial banks. Commercial banks' lending is more closely aligned with the structure of Greek GDP, particularly in the dominant tertiary sector, which accounts for about 80% of output and roughly 70% of commercial-bank-financed firms.

In contrast, cooperative banks display a pronounced emphasis on the secondary sector, which represents only about 16–17% of GDP but accounts for more than 38% of cooperative-bank-financed firms. Cooperative banks also allocate a smaller share of lending to the tertiary sector relative to its weight in the economy. This pattern suggests a stronger focus on manufacturing, small-scale industry, and artisan activities, consistent with the statutory objectives and regional development role of Greek cooperative banks.

The primary sector, although small in terms of GDP contribution, receives a slightly higher share of cooperative bank financing than commercial bank financing, reflecting the local orientation of cooperative institutions toward agriculture and rural activities.

Overall, the appendix supports the view that cooperative banks do not mirror the aggregate structure of the economy in their sectoral credit allocation, but instead concentrate on specific productive activities and SMEs. This reinforces the interpretation in the main text that cooperative banks pursue a differentiated, relationship-based lending strategy rather than broad market coverage.

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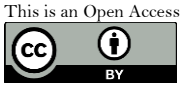

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AI and Integrated Marketing Communication Tools to Promote, Educate and Explain the Benefits of Sustainability and the Hydrogen Economy: The Cases of Cyprus and Peru

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ABSTRACT

Purpose: This study investigates how Artificial Intelligence (AI)-enhanced Integrated Marketing Communication (IMC) can accelerate the adoption of hydrogen technology in two contrasting national contexts—Cyprus and Peru.

Design/methodology/approach: A qualitative conceptual research design is employed, structured around a four-phase analytical framework that integrates IMC theory, behavioral psychology, and AI-driven marketing technologies. A 'most-different systems' comparative strategy underpins the case selection.

Findings: The proposed AI-IMC Nexus framework demonstrates that the primary barrier to hydrogen adoption is communicative rather than purely technological. AI tools—including predictive analytics, programmatic advertising, and natural language processing—can operationalize the Mere Exposure Effect to reduce stakeholder anxiety and build informed acceptance. The Strategic Segmentation, Targeting, and Positioning (STP) model, when AI-enhanced, enables real-time micro-segmentation tailored to distinct socio-economic contexts.

Research limitations/implications: As a conceptual study, the framework requires empirical validation through primary data collection, including expert focus groups and pilot communication projects.

Practical implications: The study provides a scalable, context-specific communication roadmap for policymakers and energy sector practitioners seeking to deploy hydrogen technologies in divergent regulatory and economic environments. Originality/value: This paper offers the first interdisciplinary synthesis of AI-driven IMC and energy transition communication, grounded in behavioral psychology, within a comparative framework spanning an EU island economy and an emerging South American market.

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1. Introduction

With the European Union (EU) and other international actors setting ambitious goals for reaching climate neutrality by 2050 (European Commission, 2020), the move to a low-carbon economy has become a major global problem. Known for its flexibility as an energy carrier, hydrogen has become a vital part of this change because it can lower carbon emissions in places where it is hard to use electricity, like in heavy industry and transportation (International Energy Agency [IEA], 2023). Despite the growing potential of adopting technology, a major barrier to hydrogen acceptance is the lack of knowledge, understanding, and trust among key players in the sector (Ball and Weeda, 2015). Two good instances for research are Cyprus and Peru. With 60% of contributions coming from the European Union (Philenews, 2025), Cyprus, a tiny Eastern Mediterranean island nation, has recently approved the creation of its first hydrogen refueling station in Larnaca with support of 7.5 million euros. The national hydrogen strategy, which was

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approved by the Ministry of Energy, Commerce, and Industry, lays out a step-by-step plan that focuses on harmonizing rules, using hydrogen in heavy vehicles, and educational initiatives by the year 2030 (Government of Cyprus, 2025). Meanwhile, Peru—a country with great renewable energy potential from hydroelectric, solar, and wind sources—is gradually exploring hydrogen to help to advance sustainable industrial development and raise energy security (ICONE29 Proceedings, 2021).

Encouraging adoption requires a clear and efficient means of communication. Marketing theory emphasizes that people's perceptions of technology, their degree of education, and their level of trust in it—not only expenses and efficiency—all affect its adoption. By providing a systematic way to match messages across several channels, Integrated Marketing Communication (IMC) guarantees they are consistent and supportive of one another (Keller, 2016). Artificial Intelligence (AI) enhances Integrated Marketing Communication (IMC) by enabling extremely tailored targeting, sophisticated predictive analysis, and quick feedback cycles (Chatterjee et al. , 2020).

The link between artificial intelligence, integrated marketing communication, and hydrogen promotion is explored in this study.

2. Review of Literature

Under a 'most-different systems' strategy, Cyprus and Peru were chosen as main case studies. This approach enables the assessment of AI-driven IMC tactics over two different socio-economic contexts: Cyprus, a small, rich European economy subject to EU regulations, and Peru, a huge, resource-rich developing nation in South America. Examining these different examples helps the study to find universally applicable communication 'drivers' and 'barriers' that go beyond local peculiarities, so improving the suggested framework's generalizability.

2.1 Energy Potential of Cyprus and Peruvian coastal- Cyprus coastal resources

The comparative study of Peru and Cyprus is based on a "most-different systems" approach. This strategy is used to show how the suggested AI-IMC framework can be modified for very different economic settings: Cyprus as a small, heavily regulated EU member state and Peru as a big, emerging South American country with varied industrial issues. This guarantees worldwide relevance of the results. This infrastructure development in Cyprus offers a great 'target' for the AI-driven IMC technologies examined in Phase 3, in which tailored information can be used to educate particular stakeholder groups (local engineers) to lower suspicion.

Cyprus is among the sunniest places in Europe as it has plenty of sunshine. With an average global horizontal irradiation (GHI) ranging from 1,900 to 2,100 kWh/m2 per year, the island gets roughly 2,700 to 3,500 hours of sunlight every year. Daily solar energy generation of around 5–6 kWh/m² made possible by this abundance of sunlight can result in notable photovoltaic (PV) power generation. Studies show that Cyprus has a lot of potential for solar energy, especially in the north of the country. In this region, GHI values are about 2,100 kWh/m² each year.
Cyprus is also working on building up its marine energy potential. The Eastern Mediterranean has a rather calm wave energy climate; wave hotspots are noted as the western and southern coasts of Cyprus. Along the western coast, the mean wave power density ranges from 6 to 7 kW per meter of the wave front. Even if this number is less than that of ocean regions, it can still be very useful for wave energy converters in coastal communities. Energy plans include Cyprus also has the potential for offshore wind energy, as the Eastern Mediterranean Sea experiences steady winds good for wind farms. Currently, however, there are no offshore turbines in place.

Moreover, "blue energy," which includes wave, tidal, and offshore wind energy, is still mostly unexplored in Cyprus, pointing to a great possibility for renewable energy source development on the island. Cyprus also has useful mineral and fuel reserves in its seas and geological formations. The island has been mined for copper for a long time, and people are still looking for gold and other metals. Cyprus is close to new Eastern Mediterranean natural gas finds; the Aphrodite gas field is thought to contain about 3. 6 trillion cubic feet of gas. Aphrodite is being developed to turn Cyprus into an energy producer and draw attention to its hydrocarbon resources. While offering vital materials required for renewable energy infrastructure, these minerals and gas resources have geopolitical importance and economic potential.

Peruvian coastal (Latin America) resources

Given their geography and climate, Peru's coastal areas—similar to Cyprus—have enormous solar energy potential. With an average of over 6. 0 kWh/m² daily, the southwest desert regions—especially in Arequipa, Moquegua, Tacna, and Ica—are comparable to other leading solar resource sites like the Sahara. Just roughly 2% of the estimated 25 GW of usable solar electricity is now being used. Peru's 3,000-kilometer Pacific coastline also has a lot of marine energy resources. Wave energy density ranges from 20 to 25 kW per meter, while tidal energy potential is low. As part of a plan for sustainable energy, the government is investigating marine renewables.

Peru's coastal regions also have abundant mineral resources that promote energy growth. With newly found significant lithium deposits, the nation is a top copper producer and will be a future supplier of lithium required for batteries in solar and electric vehicles. Furthermore, deep-sea mining is possible because the coastline is close to international waters full of minerals that are worth a lot of money. Peru's coast provides a variety of renewable energy choices and vital mineral resources needed worldwide to enable the change to clean energy.

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2.2. Hydrogen as an Eco-Friendly and Cost-Competitive Fuel: The Future for Industry and Consumers

Hydrogen seems to be the most promising future energy source since it benefits businesses as well as customers. Because of its wide use and generation from clean energy sources, it is seen as a sustainable energy carrier that supports the world's move toward renewable energy and climate neutrality (Parliament of New South Wales, 2022). RSC, 2020) hydrogen is becoming more and more seen as a basic part of the growing "hydrogen economy," which is a system where hydrogen is a versatile and environmentally friendly way to make electricity, heat, move people, and use it in industry. As governments and business investors see its promise for long-term decarbonization, the International Energy Agency underlines the remarkable worldwide development in hydrogen production (IEA, 2019). In general, the environment gains advantages from consumer and corporate adoption of hydrogen. If major steps are taken to lower carbon emissions, the International Renewable Energy Agency (IRENA, 2021) projects hydrogen might account for as much as 25% of world energy demand by the year 2050.

Hydrogen, the most common element in the cosmos, is not found naturally on Earth. Electrolysis—the process by which electricity separates water into hydrogen and oxygen—should produce it most efficiently (IEA, 2019). Hydrogen that is stored can later be compressed, converted into a liquid, or used in innovative materials. Hydrogen is among the most appealing future fuels because of its properties. In challenging-to-address sectors, it is obviously flexible and may lower carbon emissions. To realize its potential, the sector ought to spend money on infrastructure and technology; governments have to set supportive regulations and incentives. If businesses commit, customers will benefit from more easily available and cleaner applications; society will see notable changes in the environment. Existing studies in the literature and global initiatives view hydrogen as a basic component of the world's energy transition.

2.3 The role of Artificial Intelligence in Marketing Communication to promote the benefits of Hydrogen in energy

In the energy sector, AI is not merely a tool for efficiency but a mechanism for de-risking. As noted by Aritzis (2025), the 'trust gap' in hydrogen adoption stems from a lack of technical familiarity. AI-driven IMC addresses this by utilizing the 'Mere Exposure Effect'—the psychological phenomenon where people develop a preference for things merely because they are familiar with them. By using AI to deliver repeated, low-anxiety educational touchpoints, we can transform public perception from 'fear of the unknown' to 'informed acceptance'.

Greater customization, sophisticated targeting based on predictions, and quick campaign modifications made possible by artificial intelligence (AI) are transforming marketing. Natural language processing, recommendation systems, and programmatic advertising—among other artificial intelligence technologies—improve Integrated Marketing Communication's (IMC) effectiveness and accuracy (Chatterjee et al., 2020). While chatbots and virtual assistants provide thorough educational support, predictive analytics help firms to anticipate stakeholder concerns and modify their content to satisfy these demands (Davenport and Ronanki, 2018). Discussions of sustainability have shown how artificial intelligence may improve the relevance and validity of communications, hence increasing engagement among both technical and management interested parties (Jarek and Mazurek, 2019).

In the hydrogen economy, artificial intelligence serves as a means of de-risking rather than only a tool for efficiency improvement. Through predictive analytics, artificial intelligence can pinpoint particular stakeholder worries (including as explosion risks or high costs) and provide focused educational material tackling those precise issues, therefore meeting the IMC's 'consistency' need.

2.4 Integrated Marketing Communication (IMC)

IMC is defined as the coordinated use of promotional techniques to provide a consistent message across all marketing channels (Keller, 2016). Advertising, public relations, direct marketing, and sales promotion make up the most often used IMC tools. The application of digital tools and AI-enhanced customizing to boost memory retention and engagement is a recent development (Porcu et al., 2019). Regarding hydrogen, IMC can manage public initiatives, business identities, and educational programs to build confidence and dispel concerns (Fill and Turnbull, 2019). Dealing with new technology especially depends on integrated marketing communication (IMC) because unclear or contradictory messages can increase ambiguity (Kitchen and Burgmann, 2015).

2.5 Segmentation, Targeting, and Positioning: The STP Framework

Among strategic marketing practitioners, the STP model is still among the most often used systems (Kotler and Keller, 2016). Targeting finds the most promising segments by segmentation, which splits the market into distinct groups according to shared qualities, and positions the brand or technology in the eyes of those groups. People who watch hydrogen split into groups of engineers, politicians, business leaders, and environmental non-governmental organizations (NGOs). Senior technical and managerial staff members—including electrical engineers, business leaders, and government officials in Peru and Cyprus—make up the intended audience for this study. Promoting hydrogen's use depends critically on putting it as a cost-effective, ecologically friendly energy source (Ball and Weeda, 2015).

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2.6 Psychological Perspectives of Adoption and Persuasion

According to persuasion psychology, our preferences and decisions are shaped by repeated exposure. Zajonc (1968) introduced the idea of the "mere exposure effect," which states that regular contact with a stimulus makes it more appealing. In the realm of marketing, being exposed to a message at least six times has been linked to better memory retention and a higher probability of buying something (Schmidt and Eisend, 2015). Since consistent messages produced by artificial intelligence across several channels can help to establish hydrogen as a viable and accepted solution, this concept is essential for communicating the benefits of hydrogen. Supporting ideas such as social proof (Cialdini, 2001) and the diffusion of innovations model (Rogers, 2003) underline that adoption depends mostly on trust, peer recommendations, and progressive application.

2.7 Energy Transition and Sustainability Communication

Research in sustainability communication emphasize how crucial it is to be open, honest, and inclusive (Carvalho and Peterson, 2012). Studies reveal that effective communication should strike a compromise between technical accuracy and simplicity of understanding to encourage knowledge among many audiences (Moser, 2016). When talking about hydrogen, it's very important to show it in a certain way. Hydrogen can be shown as a clean alternative to fossil fuels, and it can also be shown as a way to store energy and make things more secure (IEA, 2023). Relating these events to local contexts, such energy independence in Cyprus or industrial growth in Peru, maximizes the power of the message (Philenews, 2025; ICONE29 Proceedings, 2021).

2.8 Hydrogen Policy Background in Peru and Cyprus

Supported by major EU financing, the first hydrogen station in Cyprus was given building permits in 2025 with the aim of generating 150 tons annually (Philenews, 2025). The national hydrogen plan, which the Ministry of Energy approved, emphasizes the need of transportation uses, coordination with rules, and public awareness campaigns by 2030 (Government of Cyprus, 2025). As part of its long-term energy diversification plan, Peru has been evaluating the growth of hydrogen generation using its renewable resources for maybe green hydrogen exports (ICONE29 Proceedings, 2021; ASEPA, 2024). Both countries underline the dual difficulty of growing infrastructure and informing audiences, hence stressing the need of integrated marketing communication plans combining AI technology with specifically designed educational initiatives.

2.9 Public Awareness Initiatives and Behavior Change

Many actual case studies demonstrate the ability of STP programs to rapidly change public attitudes and behavior toward hydrogen.

For instance, the Vattenfalls 2023 "Industrial Emissions Face Mist" campaign featuring hydrogen as a main skincare item and well-known climate activist model Cara Delevigne helped to spread hydrogen's advantages to consumers and the general public (Sustainable Brands, 2023). Such comparable initiatives may change public opinion toward hydrogen and inform it.

2.10 Best Practices for Integrating AI-Driven Outreach into Hydrogen Rollout Strategies

AI is not just a hypothetical idea in hydrogen communication strategy; it's an actual practice that is shown by a lot of real-world projects that show how well data-driven outreach can help people and professionals accept clean energy technologies more quickly. For the environments of Cyprus and Peru, three case studies are especially enlightening.

The first is the German government's National Hydrogen Strategy communication campaign (Bundesministerium für Wirtschaft und Klimaschutz, 2020–2023), which used AI-enhanced content to reach engineers, industrial managers, and municipal planners on professional digital platforms. Through LinkedIn and networks of industry associations, the campaign provided technical white papers, interactive ROI calculators, and regulatory compliance manuals that segmented groups by sector and region. Iterative content improvement was informed by campaign engagement data, therefore illustrating the feedback-loop benefit of AI-mediated IMC over static broadcasting. The German example is immediately applicable to Cyprus, where a similarly welcoming environment exists for EU regulatory alignment and a technically competent professional class.

For the manufacturing and transportation industries, the second case—the Japanese Ministry of Economy, Trade and Industry (METI) hydrogen literacy programme (METI, 2021)—targeted B2B communication combined with public education campaigns. Using artificial intelligence-driven sentiment analysis, public opinion on hydrogen safety was tracked and corrective information was sent in practically real-time when negative stories appeared on social media and professional sites. Of special relevance to Peru, where institutional trust in new technologies has traditionally been weaker and disinformation risks are high (ASEPA, 2024), is this proactive 'narrative hygiene' feature—using artificial intelligence to identify and fight false information before it becomes entrenched suspicion.

The third case is the European Hydrogen Valleys collaboration project (Fuel Cells and Hydrogen Joint Undertaking [FCH JU], 2022), which clearly applied IMC ideas including consistent multi-channel messaging, stakeholder segmentation according to regional industrial profile, and ambassador-led peer communication to increase uptake momentum across eleven regional hydrogen clusters across Europe. Rogers' (2003) diffusion of innovations logic is operationalised at the community level by the 'Regional Hydrogen Champion' model of the programme, whereby local engineers and municipal employees were trained and resourced as communication advocates. The geographically

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dispersed industrial areas of Peru and the island environment of Cyprus both may find straight application from this model.

These cases taken together set up three practical best practises for hydrogen communication strategy: first, include artificial intelligence (AI) feedback systems in campaign design from the beginning so that real-time content may be changed based on stakeholder involvement data; second, fund proactive narrative monitoring and quick-response corrective communication to stop false information from spreading; and third, make peer-advocate programmes at the regional level institutionalised so that the credibility of local voices is combined with the reach and accuracy of AI-driven targeting.

2.11 Convergence in the Hydrogen Economy: Artificial Intelligence and Psychological Communication

Including artificial intelligence into the IMC framework marks a fundamental change from mass communication towards algorithmic persuasion. While traditional IMC ensures that messages are consistent, artificial intelligence (AI) systems such as programmatic advertising, predictive analytics, and sentiment monitoring expand this consistency to include personalised, dynamically adjusted content that directly targets the psychological barriers unique to each stakeholder group. This convergence is especially important for the hydrogen economy, where the main reason why people don't want to use it is that they aren't familiar with it (Aritzis, 2025). AI turns communication from a mass media tool into a precision instrument for behavioural modification rather than just extending reach.

3. Research Methodology and Conceptual Framework

This study adopts a qualitative conceptual research design, moving beyond mere description to provide a theoretical synthesis of interdisciplinary fields. The methodology is structured around a four-phase analytical framework designed to ensure both theoretical depth and practical applicability.

3.1 Research Design and Methodological Phases

The research was conducted through the following sequential phases:

1. Contextual Document Assessment: A systematic review of national hydrogen strategies and policy reports from Cyprus (Government of Cyprus, 2025) and Peru (ASEPA, 2024), establishing the socio-economic baseline for energy transition.
2. Theoretical Synthesis: Integration of Integrated Marketing Communication (IMC) frameworks with behavioral psychology (Zajonc's Mere Exposure Effect) and AI-driven marketing technologies to address stakeholder skepticism.
3. Framework Development: The construction of an interdisciplinary model—the AI-IMC Nexus—that connects marketing theory with the specific sociotechnical challenges of the hydrogen economy.
4. Comparative Validation: Testing the model's scalability by aligning the proposed strategies with the divergent energy contexts of Cyprus (an insular EU economy) and Peru (an emerging South American market).

3.2 The Proposed Conceptual Framework: The AI-IMC Nexus

The framework posits that successful hydrogen uptake relies on a dual approach: infrastructure development and the behavioral transformation of key stakeholders. The "education-to-adoption" route is operationalized through four core pillars:

- AI-Driven Algorithmic Persuasion: Utilizing predictive analytics and natural language processing to deliver scalable communication. AI ensures that the correct audience receives the right message at the optimal time to reduce "technological anxiety" (Davenport & Ronanki, 2018). Instead of generic broadcasting, AI-driven content focuses on high-impact visualizations and technical simulations that demonstrate cost-saving and safety benefits.
- Integrated Marketing Communication (IMC) Consistency: AI enhances IMC by guaranteeing message uniformity across multiple digital touchpoints (e.g., LinkedIn, industry webinars, and professional networks), reducing cognitive dissonance among technical and political actors (Porcu et al., 2019).
- Strategic STP Application: Segmentation identifies high-influence groups (electrical engineers, regulators); Targeting focuses on those most likely to influence policy; and Positioning defines hydrogen as a cost-competitive and environmentally essential fuel.
- Psychological Reinforcement: The framework utilizes the "Mere Exposure Effect" (Zajonc, 1968) through programmatic advertising to normalize hydrogen technology via repeated, non-threatening exposure across professional digital environments.

3.3 Research Objectives

To validate the framework, the study addresses three primary objectives:

1. To determine how AI-driven IMC tools can mitigate public and professional fear regarding hydrogen technology.

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2. To apply the STP framework specifically to the energy sector's decision-makers in Cyprus and Peru.
3. To provide sensible policy recommendations for communication strategies tailored to different national contexts.

3.4 Limitations

As a conceptual study, the framework relies on theoretical synthesis and policy analysis rather than primary empirical data. While it provides a robust strategic roadmap, further empirical testing through focus groups with industry experts and pilot communication projects is recommended to validate the framework's real-world efficacy in specific energy markets.

4.Analysis: Applying the AI-STP Model in Cyprus and Peru

Using the global power of algorithmic persuasion, the suggested AI-STP framework has to be implemented locally taking into account the socio-economic specifics of every case study.

4.1 Segmentation and Positioning Plan

Although a conventional STP is usually stationary, an artificial intelligence-enhanced STP lets for real-time "micro-segmentation."

In Cyprus: The main groups targeted for segmentation are policymakers and maritime managers. Given Cyprus's important position as a shipping hub, positioning should stress "EU Green Deal Compliance" and "Energy Security" (Government of Cyprus, 2025).

In Peru, segmentation gives regional community leaders and large industrial mining corporations top priority. South American economic drivers (ASEPA, 2024) cause the positioning focus to change toward 'Industrial Autonomy' and 'Long-term Cost Efficiency.

4.2 Developing Messages Based on Psychology

To get past the "Trust Gap," the framework uses three psychological pillars that AI backs up:

Mitigating Loss Aversion: Stakeholders sometimes worry more about initial transition expenses than they do about future climate hazards. Showcases of phased pilot projects supported by artificial intelligence (Kahneman & Tversky, 1979) aim to guard against financial losses.

The Mere Exposure Effect: AI manages the quarterly delivery of 6–10 educational touchpoints. Normalizing hydrogen technology is achieved by regular, low-intensity exposure via professional networks (Zajonc, 1968; Schmidt & Eisend, 2015).

AI finds and highlights comments from respected engineers and standards bodies in the business (Cialdini, 2001).

4.3 B2B Stakeholder Journey: A Four-Stage Roadmap

First Phase: Awareness (Developing the Knowledge Center)

The Ministry of Energy in Cyprus ought to set up a central digital platform, maybe HydrogenCyprus.gov.cy. Targeting bilingual keywords (e.g., "green transition EU funding") with AI-enhanced SEO guarantees that first-quality, open information gets to doubting people first.

Stage 2: Assessment (Experiential Learning)

Moving from awareness to trial entails regional pilot studies. Using sentiment analysis from social media and expert forums, artificial intelligence tools assess which areas—for example, rural Nicosia or industrial Lima—most welcome innovation (Thaler & Sunstein, 2008).

Stage 3: Engagement - personalizing the story

Personalization driven by artificial intelligence matches psychographic segments with specially crafted messages.

Eco-pragmatists, ages 30 to 50, were mostly concerned with cost-benefit studies.

Industrial Managers: Targeted using ROI-focused simulations and technical white papers.

Phase 4: Advocacy - Strengthening Local Legitimacy

"Opinion leaders," according to Rogers (2003), drive the spread of innovation. AI monitoring technologies enable local ambassadors—educators, municipal employees, and engineers—to find and fix errors in real-time.

The following matrix table 1 operationalizes the AI-STP framework, identifying the specific deliverables, stakeholders, and technological tools required for each stage of the hydrogen economy's adoption.

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4.4. Operational analysis of the matrix

The matrix's application has to be seen in the light of the AI-IMC nexus if it is to be more than just a theoretical creation.

During the Awareness Phase, which is stage 1: The outcome is an AI-optimized, centrally controlled digital environment. In Cyprus, natural language processing (NLP) systems are used to translate difficult technical data into easily understood regional languages; in Peru, artificial intelligence (AI)-SEO techniques give EU-funded green projects visibility top priority. The "Mere Exposure Effect" (Zajonc, 1968), in which high-frequency, low-intensity exposure develops fundamental familiarity, takes centre stage in this phase.

During the Consideration Phase (Stage 2), the emphasis turns to experiential learning. AI-driven "Digital Twins" of industrial plants or hydrogen refueling facilities let Limassol or Cusco stakeholders engage with the technology in a risk-free virtual setting. By offering concrete evidence of safety and ROI before actual financial investment is made, this directly counteracts "Loss Aversion" (Kahneman & Tversky, 1979).

The Engagement Phase (Stage 3): This phase uses algorithmic persuasion. Predictive models in Peru find business leaders who value "Export Competitiveness" and provide customized white papers on how green hydrogen reduces carbon taxes for exports. The same AI reasoning in Cyprus focuses on maritime authorities using information on 'ECA (Emission Control Areas) Compliance'. Automated Integrated Marketing Communications (IMC) guarantees a uniform, non-contradictory message across all professional digital contact points (Porcu et al., 2019).

During the Adoption Phase (Stage 4), peer-to-peer promotion helps the matrix reach its maximum. Sentiment Analysis driven by artificial intelligence finds "Opinion Leaders" (Rogers, 2003) who have turned into advocates by scanning social media and business forums. These people are given specialized information to serve as local ambassadors. AI programs identify "false information" about hydrogen safety at the same time, which makes it possible to launch data-driven correction efforts right away.

4.5 Different Factors Driving Hydrogen Use

Cyprus: Being an isolated EU nation, the demand for energy independence together with legislative pressure motivates adoption. Transportation and maritime logistics take front stage.

Peru: Industrial competitiveness fuels adoption. It is fundamentally related to the decarbonization of mining and heavy transportation in far-off Andean areas.

4.6 Ethical Risks and Mitigation

AI-driven IMC brings hazards the framework has to control:

Making sure artificial intelligence systems do not discriminate against lesser participants.

Strict observance of data privacy rules in both countries.

Greenwashing Risks: AI should be used to share real data, not fake environmental statements. To guarantee long-term legitimacy, a "Transparency-First" policy is required (Moser, 2016).

Table 1 : Strategic Implementation Matrix (Cyprus & Peru)

Step	Deliverable	Objective	Responsible Entity	Target Group	Tools/Channels
Awareness	National Digital Hub	Build trust & visibility	Ministry of Energy / EU	Public & Media	AI-SEO, Predictive Analytics
Consideration	Trial Test Sites	Experiential learning	Municipalities / SMEs	Lead Engineers	IoT Feedback, Simulations
Engagement	Segmented Campaigns	Address barriers	Industry Associations	Skeptics & Youth	AI-Personalization,

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					LinkedIn
Adoption	Ambassador Program	Peer-to-peer advocacy	Local authorities	Opinion Leaders	CRM, Sentiment Analysis

5. Conclusion and Recommendations

5.1 External Hazards and Moral Dilemmas

Using artificial intelligence (AI)-driven Integrated Marketing Communications (IMC) in the sensitive area of national energy transition raises a complicated set of ethical and practical problems. These risks should be proactively handled inside the conceptual framework to guarantee long-term stakeholder confidence.

5.2 Digital Inclusion and Algorithmic Bias

An important ethical issue is algorithmic bias. Trained on historical data, artificial intelligence models could unintentionally favor wealthy groups or urban centers, therefore marginalizing rural areas in Cyprus or the Andean region of Peru.

Mitigation: The plan suggests an "Inclusive Data Protocol," which guarantees that the categorization of artificial intelligence-STP takes into account socioeconomic variety to avoid "energy poverty" by means of knowledge exclusion.

5.3 Compliance with Rules and Data Privacy

Strict compliance with international data protection rules is required when predictive analytics and behavioral tracking are used for micro-targeting.

Cyprus: Full compliance with the GDPR of the European Union is required.

Peru: Under Law No. 29733, compliance with the Law on Protection of Personal Data is necessary.

The system stresses a "Privacy-by-Design" strategy whereby stakeholder data is anonymized and openness about data use is kept via the "National Knowledge Hub."

5.4 The Threat of "Greenwashing"

There is a major risk of over-promising the near-term viability or environmental effect of the technology in the race to advance the hydrogen economy. Moser, 2016, says that if people believe that AI-enhanced campaigns are misleading, they could cause a "trust deficit" that would take years to fix.

Mitigation: Every AI-generated communication asset has to be tied to real, verifiable, real-time data from pilot projects so that "Positioning" stays based on facts.

5.5 Outside Socio-Political Factors of Danger

Beyond morality, outside elements might hinder the communication plan:

Political uncertainty: Long-term energy plans in Peru might be hampered by repeated government changes.

Resource Limitations: In Cyprus, the small amount of water that is needed for electrolysis must be talked about carefully so that people don't worry about whether there will be enough water for them.

Disinformation: "Social Listening" needs to be actively used by AI tools to find and fight anti-hydrogen stories or safety misconceptions before they spread.

5.6 Ethical Considerations

The implementation of AI-driven IMC in the hydrogen sector is not without risks. Ethical considerations regarding data privacy and the potential for 'algorithmic bias' in micro-targeting must be addressed. Furthermore, there is the risk of 'Greenwashing' if AI is used to over-promise environmental benefits without transparent data. To mitigate these, the framework proposes a 'Transparency-First' design, where AI tools are used to provide verifiable, real-time data to stakeholders, ensuring that the communication remains ethical and builds genuine long-term trust.

5.7 Future Research

There are still many ways to look at this further:

• AI- Enhanced Policy Communication: Methods in which governments can use artificial intelligence to rapidly communicate policy changes, so reducing false information.

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• The Use of Behavioral Economics in Integrated Marketing Communication: Improved persuasion among sector players by the combination of nudges and behavioral cues with AI-driven personalization.

• Comparative Analysis Throughout Nations: Evaluating the success of artificial intelligence-IMC initiatives in small island nations like Cyprus as opposed to resource-rich ones like Peru.

• Ethics and Governance: Using algorithms to set up systems for honest and open communication on sustainability.

Longitudinal Studies: Assessing how ongoing experiences using AI-based technologies affect professional attitudes and the observed hydrogen adoption rates as time goes on.

Developing these areas of study can help AI to become more important in encouraging changes toward sustainable energy and provide useful recommendations for governments and companies all over the world.

In conclusion, this study demonstrates that the success of the green hydrogen transition in divergent economies like Cyprus and Peru depends on bridging the 'communication gap' through technology. By integrating AI with IMC and STP strategies, policymakers can transform hydrogen from a complex technical concept into a socially accepted energy solution. This conceptual framework provides a scalable roadmap for global energy transition efforts.

5.8 Conclusions

In developing nations such as Peru and Cyprus, Integrated Marketing Communication (IMC) and Artificial Intelligence (AI) provide a clear structure for advancing the hydrogen economy. By using data-based targeting, forecasting analysis, and consistent messaging based on psychological principles, AI-driven Integrated Marketing Communication (IMC) can effectively address concerns among technical experts and key decision-makers.

Using artificial intelligence in Cyprus, campaigns in the transportation and energy industries may use EU funds, chatbots, and webinars to enable consumers adopt electric vehicles and energy storage more rapidly. This would fit the hydrogen policy of the nation. Artificial intelligence, clustering tools for industry participants, and reinforcement-based messaging can all help to boost hydrogen use in mining and heavy transportation in Peru, where acceptance of corporate practices is particularly crucial. E-learning has improved via these methods.

Good control of artificial intelligence (AI) systems is necessary to preserve public confidence by lowering ethical concerns including algorithmic bias, surveillance problems, and the dissemination of false information. External threats including infrastructure costs, political unrest, and water shortage call for adaptable, context-specific strategies.

In the end, AI-augmented integrated marketing communication not only disseminates information but also educates and persuades by means of repeated exposure, personalized content, and signals of expertise. Used properly, it can accelerate the adoption of sustainable hydrogen, therefore supporting to fulfill worldwide decarbonization targets and positioning both Cyprus and Peru as frontrunners in the green transformation.

The research determines that the energy transition presents a communication problem as much as a technological one. This study offers a scalable plan by bridging the divide between energy policy and artificial intelligence-driven marketing. For Cyprus, the emphasis should be on narratives of EU integration; for Peru, on industrial autonomy supported by the psychological mere exposure of hydrogen's safety.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the Author(s) used [CHATGPT] in order to [improve grammar/english]. After using this tool/service, Dr. Aritzis(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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Green M&A Deals: Do Acquirers Obtain Superior Returns?

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ABSTRACT

Purpose:
The paper aims to examine whether investors receive superior returns for participating in green mergers and acquisitions (M&As), or whether they pay a price for doing so.

Design/methodology/approach:
Using the event study research methodology, we assess whether acquirers are rewarded by the stock market in green versus non-green M&A deals, specifically in cross-border and horizontal transactions. The empirical study employs the pair-matching principle. The research is based on US market data on green and non-green acquirers listed in the US, sourced from Bloomberg, from 2010 to 2024.

Findings:
Our study results suggest that the stock market rewards the acquirer for making green M&As and provides positive cumulative abnormal returns during the short-term event window. However, as event window following the announcement of M&A transaction increases, the positive cumulative abnormal returns transition to negative ones. The results of the study suggest overpricing effects, which can be explained by the high takeover premiums when targeting sustainability-oriented deals.

Research limitations/implications:
The study implies mixed market attitudes towards sustainability-oriented M&A transactions. It supports the generally increasing interest in sustainable investments, urged by regulatory developments. However, the limited disclosure of public information on the environmental practices of companies involved in M&As makes it difficult to assess the level of adoption of sustainability practices and the possibility of greenwashing policies.

Originality/value:
This study addresses a research gap by examining green versus non-green M&As over the period from 2010 to 2024, characterized by a growing emphasis on sustainability issues within regulatory and political domains, as well as in the broader public discourse. Our results corroborate previous research indicating that investors often overstate the value of green M&As on the day of the announcement. Investors tend to assign a favourable value to cross-border environmentally oriented deals, also characterised by higher short-term volatility. Although not systematic, these overpricing effects suggest a general market optimism towards sustainability-oriented deals. The results support the notion that markets may overreact to the 'green' label of a transaction, and reinforce the argument that sustainability-oriented acquisitions involve significant information asymmetry.

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1. Introduction

Global trends in climate change sparked investment in financial markets, particularly in mergers and acquisitions transactions. Over the past ten years, there has been a dramatic increase in the emphasis placed on corporate social responsibility, socially responsible investments, and investments with specific environmental targets, in response to strong pressure from diverse stakeholder groups. The proportion of public corporations producing sustainability reports rose from 20% to 86% (Gillan et al., 2021). Financial investors targeted investments in socially and environmentally responsible corporations more frequently, though with mixed results. These trends prompted a growing academic interest.

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A substantial body of literature has examined the performance effects of socially responsible investment targets, as well as the extent to which investors can select successful stocks and recognise high-performing firms. A more specific research stream focuses on sustainability-oriented M&As. The term green M&As has emerged encompassing target company's CSR practices, socially and environmentally responsible investments. In such transactions, it is assumed that acquirers will pursue investments linked to sustainability, such as technologies or operations that are intended to create long-term sustainable value, with positive social and environmental outcomes. Previous studies show that shareholders of target companies tend to benefit from M&A transactions (Andrade et al., 2001), whereas acquirers often achieve zero or negative abnormal returns (Moeller et al., 2004). Gomes (2019) provides evidence that a firm's CSR is positively associated with its propensity to become a M&A target. Furthermore, studies conducted across multiple markets, regions and industries have not consistently demonstrated that investors in green deals experience positive abnormal returns following the announcement of green M&A transactions. As these studies mainly focus on transactions in the early stages of sustainability-oriented investments, the dramatic increase in green-focused investments calls for a revisit of the research in this field.

This paper aims to examine whether investors receive superior returns for participating in green M&As, or whether they pay a price for doing so. The study looks at the effects of announcements and the short-term performance before and after announcements. Using event-study methodology and the pair-matching principle, we investigate whether acquirers in green M&As are systematically rewarded by the stock market more than those in non-green M&As. Additionally, we examine the results in relation to cross-border deals and horizontal green M&A transactions. The study focuses on the US market given its semi-strong form of market efficiency, well-developed institutional environment, strong corporate governance mechanisms, and robust investor protection framework. It covers green M&A transactions announced between 2010 and 2024, a period characterised by growing regulatory support and investor interest in sustainability-oriented investments.

Our research focuses on the effects for the acquirer in green M&A transactions, and the results show that acquirers in such deals may earn positive cumulative abnormal returns over the short-term event window. The results suggest overpricing, however not systematic, in market reactions towards green M&A announcements. The findings point out that abnormal returns after the announcement are modest, short-lived and sensitive to the event window specification. These outcomes are consistent with previous studies that have suggested that, at the time of the announcement, investors may not fully consider the potential long-term value of sustainability-oriented acquisitions (Deng et al., 2013; Han et al., 2022). Any positive valuation effects for acquirers, if they arise, may therefore emerge gradually as information about sustainability integration and future performance becomes clearer. This pattern is consistent with earlier findings on overpricing effects and may reflect high takeover premiums in sustainability-driven investments.

The study reveals mixed market attitudes towards green M&As. Market investments driven by sustainability have been encouraged by regulatory developments and expanded. However, limited public disclosure of the sustainability practices of companies involved in M&A deals makes it difficult to assess the depth of their sustainability practices and the credibility of their environmental claims. This increases uncertainty for investors and may prevent stock market fair valuations.

We contribute to the research on green versus non-green M&As, a topic that is characterised by growing interest in scholarly literature. Previous studies (Shleifer and Vishny, 2003) proved the existence of M&A waves, with stock market valuations shaping merger activity. Our focus on the timeframe of 2010–2024 covers several M&A waves, as well as the latest significant regulatory, political and societal shifts towards environmental sustainability policies. Our approach enables to assess the influence of rising sustainability awareness on market reactions to acquisition announcements. By applying an explicit green M&A classification and integrating it into an event-study framework, our study provides new evidence on whether acquirer returns differ systematically across green and conventional M&A transactions. Our study builds on previous research indicating that investors often overstate the value of green M&As on the day of the announcement. The results support the notion that markets may overreact to the 'green' label of a transaction, and reinforce the argument that sustainability-oriented acquisitions involve significant information asymmetry.

2. Review of Literature

The backbone of M&A research lies in neoclassical theories, assuming that markets are efficient and investors are rational. Within this stream of research M&A studies focus on motives of efficiency improvement concerns, a reaction to diverse economic and industry shocks, a response to deregulation, development of large conglomerates (Andrade et al., 2001).

The understanding that transactions are driven by fair market valuations is at the core of neoclassical theories. Behavioural theories refine this approach by examining the drivers of market over- and undervaluation. Shleifer and Vishny (2003) suggested that stock markets misvalue potential participants of M&A transactions, either acquirers or target companies or both, and introduced earnings manipulation and insider selling effects into their model. Roll (1986) introduced a hubris hypothesis which attributes acquirer overpayment to managerial overconfidence rather than market inefficiency.

Scholars demonstrated that M&A waves are triggered by multiple factors, including changes in the technological, economic and regulatory environment. Technological innovations and developments are critical shifts (Gaughan,

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2017) that have a significant impact on industries and redefine them. As market competition grows, companies are motivated to merge or acquire complementary assets, including investments in innovative firms, due to concerns about industry competition. Furthermore, economic shocks drive consolidation through the horizontal and vertical expansion of companies' operations.

A significant body of academic research conducted on the effects of M&A announcements, highlighting the theoretical tension between signalling, resource acquisition, and the exploitation of synergies, particularly in environmentally oriented transactions. From a signalling perspective, M&A announcements reveal managerial expectations about future cash flows. However, empirical evidence shows that markets often respond cautiously. Kellner (2024) indicates that acquirer returns in the European Union are modest and sensitive to transaction characteristics, which is consistent with the notion that announcement signals are incomplete. The empirical evidence from the crisis period supports this. Pandey et al. (2022) show that, in times of uncertainty, investors rely more heavily on signals, resulting in abnormal return patterns that differ from typical M&A reactions. The resource-based view provides a complementary explanation, emphasising that acquisitions are a way of securing strategic assets, whether technological, environmental or operational. Studies on renewable energy and sustainability-oriented transactions (Yoo et al., 2013; Wei and Pujari, 2023) show that companies pursue green targets in order to acquire critical environmental capabilities and innovation potential. Nevertheless, market reactions remain heterogeneous, reflecting uncertainty regarding integration and the company's capacity to utilise acquired resources to gain a competitive advantage. This aligns with the findings of Wei and Pujari (2023) that green acquisitions generate positive but inconsistent stock market returns when investors perceive environmental investments as reliable indicators of long-term strategic intent. A synergy-based interpretation provides further insight into these mixed outcomes. While Salvi et al. (2018) demonstrate that sustainability-oriented deals can improve bidder performance in the post-acquisition period, realising synergies in green transactions often relies on the complex integration of environmental technologies or processes, which increases execution risk. Insights from private equity research reinforce these dynamics. Ljungqvist (2024) identifies evolving value-creation mechanisms in modern investment environments, while Indahl and Jacobsen (2019) argue that sustainability integration reduces operational risk when aligned with credible strategic execution. Jost et al. (2022) suggest that there is no significant relationship between CSR performance and M&A premia, but the interaction of governance quality and CSR negatively impacts transaction premia. Overall, the existing literature indicates that acquirer returns in green and non-green M&As depend on financial performance as well as the interaction between signalling capacity, resource absorption proficiency, and the firm's ability to realise environmental and operational synergies. This emphasises the need for further analysis of how markets interpret sustainability-oriented acquisitions.

The post-acquisition M&A performance in financial markets attracted a great deal of attention from researchers (Bettinazzi and Zolo, 2017). Multiple studies examine the abnormal returns of the target company and its bidder after the acquisition. While both engaged parties pursue the perceived benefits of M&A, studies demonstrate that the effects on each party tend to differ (Campa and Hernando, 2004). Empirical evidence indicates that target company shareholders may experience positive abnormal returns, proving that such transactions could create shareholder value for sellers of target company shares. When examining cross-border acquisitions in US Danadapani et al. (2020) recognize that shareholders exhibit statistically significant short-term abnormal return, however around the announcement of their first international acquisition. These findings indicate that gains from mergers are unevenly distributed among bidders and sellers, and that postive abnormal returns for the acquirer arise under specific conditions.

A body of research, which examines corporate governance and M&A deals, demonstrates that governance structures can impact both the decisions made around acquisitions and the subsequent distribution of merger gains. More specifically, research indicates that board composition, managerial incentives, and ownership structures impact acquirer discipline and deal quality. For example, stronger board independence and the separation of the roles of CEO and chair are associated with more value-preserving acquisitions and higher acquirer announcement returns (Datta et al., 2001; Masulis et al., 2007). Insider trading and information leakage in market transactions are extensively examined in corporate governance literature, however to a limited extent in studies on M&As. Research across different countries shows that the laws and systems in place can influence how markets respond to M&A announcements. In particular, stronger protections for investors can lead to better outcomes for the companies that are bought (Bris and Cabolis, 2008). These findings show that the quality of governance is very important for the strategy used to buy a company, the prices paid, and the market assessment of the transaction. This highlights the need to consider how different governance structures affect the returns on acquisitions.

A substantial body of research looks at the connection between CSR/ESG features and M&A performance. Firms with solid environmental management practices and a stronger commitment to CSR and sustainability tend to experience more favourable announcement returns (Jo and Na, 2012). Empirical evidence also shows that target firms with robust employment-related and social practices generate higher post-acquisition returns (Lin and Wei, 2006). Stakeholder-oriented governance influences the likelihood of acquisition as well as the distribution of merger gains (Bettinazzi and Zollo, 2017). Further research suggests that acquirers benefit from acquiring targets with strong socially reponsible investments (Aktas et al., 2011), whereas review of studies on socially responsible investment funds found mixed or negative performance in relation to benchmarks (Renneboog et al., 2008). Furthermore, stronger CSR was found to increase merger completion rates and realize higher merger announcement returns (Deng

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et al., 2013). Sector-specific studies reveal variations across industries undergoing technological disruption or regulatory transition. In the oil and gas sector, for example, M&As were found to have predictive power of energy returns and volatility within the industry (Wang et al., 2024). In the renewable energy and cleantech sectors, acquirer characteristics are negatively correlated with returns. However, for acquirers from outside the industry, positive abnormal returns were observed in the context of the financial crisis (Eisenbach et al., 2011).

Despite the extensive literature on the topic, the evidence on acquirer returns following an event announcement remains inconsistent. The variations in findings suggest that acquirer outcomes depend on such factors as environmental orientation, sectoral characteristics and the geographical context of M&As. These sources of heterogeneity of outcomes indicate that certain transaction types may generate different market reactions. It is important to note that the distinction between green and non-green M&As is insufficiently explored. Studies seldom consider environmental strategic motivation as an explanatory factor, and even fewer examine how horizontal versus cross-border green M&As affect acquirer returns following an event announcement. This limits our understanding of whether sustainability oriented transactions create distinct value and abnormal returns relative to conventional deals.

3. Methodology

3.1. Data sample

The main focus of our empirical study on M&A transactions is to test the effects on the green acquirer's stock returns. The green M&A is typically defined (Pernick and Wilder, 2007) as a transaction in which an acquirer, which utilizes renewable resources and maintains a low level of waste, acquires a majority stake in another green firm, or merges with another firm engaged in environmentally sustainable activities. Because such transactions are not separately disclosed in standard M&A reporting, a structured identification procedure is required. For data sample selection purposes, we employed data from the Bloomberg database. We applied a description text filter to the target and the acquiring firms to filter out the specific deals. The filtering words were selected based on the components of renewable and sustainable products, such as solar, hydropower, wind farm, biomass, and many more. The keywords were picked from the monthly report about cleantech M&As, which is presented by Zephyr (2013), known for its M&A database. The data sample for non-green M&As was selected based on the description of deals, where participation companies utilize non-renewable resources and exhibit high levels of waste.

According to Andrade et al. (2001), stock price trends following an M&A announcement are heavily dependent on the size of the transaction. They suggest that larger deals are more likely to attract greater investor attention. Therefore, this research only analyses transactions larger than 10 million USD. While previous studies have included completed deals, this study includes transactions that have been announced and have a sufficiently long post-announcement share price development period, but which are still pending or have been declined.

Two data samples were sourced from the Bloomberg database: green M&As and non-green M&As, covering the period from 2010 to 2024. Deals where the acquirer is listed in the United States were specifically chosen to reflect the depth and liquidity of US financial markets, as well as the extensive evidence of semi-strong market efficiency (Fama, 1991; Fama et al., 1969). The US market also exhibits high M&A activity, supported by robust disclosure standards and investor protection mechanisms (Rossi and Volpin, 2004). Acquirers in cross-border transactions often originate from jurisdictions with stronger governance frameworks than the targets, making cross-border M&A deals relevant for examining governance spillover effects.

The control sample of non-green M&A transactions was constructed using a matched-pair sampling design intended to improve comparability between treatment (green M&A) and control observations in a non-randomized empirical setting. Each green M&A announcement was matched one-to-one with a non-green transaction based on predefined observable characteristics. Non-green M&A transactions were required to occur within the same fiscal year as the corresponding green transaction (based on announcement year), thereby limiting exposure to macroeconomic and market-wide shocks. To further account for residual time-specific heterogeneity not fully eliminated through exact year matching, year fixed effects were incorporated in the subsequent regression analysis. Matching was performed within the same 3-digit NACE industry classification to reduce structural differences in operating environment and risk profiles between bidders and targets. Economic comparability of transaction size was addressed by matching deals with similar materiality relative to bidder scale, operationalized through the ratio of total deal value to the acquirer's total assets. This scaling approach enabled comparison of transactions with comparable financial significance across firms and industries.

Following the implementation of the matching criteria, the final balanced sample comprised 160 M&A announcement observations, including 80 green and 80 matched non-green transactions. The acquiring firms represented a diversified cross-section of industries, such as real estate, materials, financials, industrials, utilities, technology, consumer discretionary, and energy, with green transactions occurring most frequently among acquirers in the energy, technology, and utilities sectors. The matched design enhanced the internal comparability of the treatment and control groups and provided a structured empirical setting for estimating abnormal stock-market reactions associated with green M&A announcements, while acknowledging that unobservable firm-level heterogeneity may still influence the results.

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3.2 Research design

In order to perform the event-study, three components were defined: the event day, the event window and the estimation window. The event day is the trading day on which the green M&A announcement was made public. Accurate identification of this date was crucial as it established the basis for measuring market reactions. The event window represented the period during which the effects of the announcement were expected to be visible in stock-price movements.

Most studies examining M&A announcement returns rely on short event windows rather than long ones. Dann et al. (1977) demonstrated that security prices can adjust within minutes of an announcement, whereas McWilliams and Siegel (1997) suggested that shorter windows mitigate the impact of unrelated events. In the present study, short-term windows are employed and days prior to the announcement are also incorporated to capture potential information leakage or insider trading. Previous empirical research showed that confidential information may leak prior to public disclosure, resulting in abnormal trading activity. Accordingly, the event windows selected for analysis are [-1, 1], [-2, 2] and [-2, 5].

The estimation window is used to model each firm's normal return in the absence of an event. Prior studies commonly apply estimation windows ranging from 100 to 300 trading days. Following MacKinlay (1997), this study employs a 250-trading-day estimation window. Trading days between the end of the estimation window and the beginning of the event window are excluded to avoid contamination. Cumulative average abnormal returns (CAARs) are then calculated for each event window across the full sample of companies.

The empirical analysis follows MacKinlay (1997) and estimates the following cross-sectional OLS regression:

$$CAR_i = \alpha + \beta_1 X_{1,i} + \beta_2 X_{2,i} + \cdots + \beta_n X_{n,i} + \varepsilon_i \quad (1)$$

where CAR_i denotes the cumulative abnormal return for acquirer i; α is the intercept; β_n represents the coefficients on the independent variables $X_{n,i}$; and ε_i is the error term.

The model incorporates several independent variables and controls based on prior research. The relative size ratio, defined as total deal value scaled by the acquirer's total assets, captures the transaction's economic significance; larger transactions impose stronger effects on acquirer returns (Eisenbach et al., 2011; Alexandridis et al., 2013). The market-to-book ratio measures potential undervaluation, overvaluation, and growth expectations, all of which influence M&A motivations and outcomes (Goergen and Renneboog, 2004; Eisenbach et al., 2011). Market capitalization controls for firm size, recognizing that larger firms generally exhibit more stable price movements. The deal value–to–market capitalization ratio further controls for deal size and reduces pair-matching-related distortions.

Four dummy variables are included: year, green M&A, cross-border, and cross-industry. Year fixed effects account for variation in stock returns across merger cycles (waves). The green M&A dummy isolates differences in announcement returns between green and non-green transactions. The cross-border dummy controls for differences between domestic and international M&A transactions, which often reflect disparate regulatory regimes, political risks, currency exposure, and cultural frictions (Cao et al., 2015). The cross-industry dummy distinguishes horizontal, vertical, and conglomerate acquisitions. This distinction is essential because each type of transaction generates different synergies and implementation challenges, as documented by Gaughan (2017).

The Table 1 below provides descriptive statistics for variables of the data sample.

Table 1: Descriptive statistics

Statistics	N	Mean	Median	St. Dev	Pctl(25)	Pctl(75)	Min	Max
CAR [-1;+1]	160	-0,002	-0,004	0,059	-0,028	0,026	-0,248	0,328
CAR [-2;+2]	160	-0,002	-0,004	0,063	-0,031	0,028	-0,233	0,323
CAR [-2;+5]	160	-0,001	-0,002	0,136	-0,039	0,035	-0,676	1,194
Log(TV/TA)	160	0,183	0,178	0,776	-0,274	0,718	-2,120	2,236
Log(Market-to-Book)	160	0,726	0,703	0,841	0,358	1,117	-2,996	3,197
Log(MarketCap)	160	8,812	8,959	1,664	7,762	9,824	2,303	12,664
TV/mCAP	160	0,330	0,105	0,521	0,028	0,346	0,001	2,803
Log(TotalValue)	160	6,489	6,629	2,099	5,010	8,366	2,401	11,793

Source: (Authors' own, based on RStudio results)

The descriptive statistics describes the whole sample of companies, employed for studying of the effect of green M&A transaction announcement for acquiring companies, based on selected event study methodology.

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4. Results

The empirical study focused on testing if specific green M&As related events, the public announcement of a green M&A transactions, created an immediate positive impact on the acquirer's abnormal returns.

Firstly, following MacKinlay (1997) suggestions for the event study methodology, two types of significance tests – parametric and non-parametric – were performed. The study applied three parametric tests: a two-tailed cross-sectional t-test, a Patell z-test (Patell, 1976), Bharath and Wu, 2005), and a standardized cross-sectional (BMP) test (based on Boehmer et al. (1991). One non-parametric test, the generalized sign test (Cowan, 1992), was performed. Also, a two-tailed cross-sectional t-test was applied rather than a one-sided t-test.

Cumulative average abnormal returns of green and non-green M&A announcements were computed for all selected event windows (see Table 2 and Table 3).

Table 2: Green M&A announcements - results

Average Abnormal Returns					
Event Day	**AAR**	**T-test**	**Patell Z**	**BMP**	**Gen. Sign Test**
T-2	-0,19%	-0,993	-1,631	-0,923	-0,472
T-1	0,09%	0,482	-0,424	0,563	-0,919
T	-0,15%	-0,268	-1,872*	-0,089	0,422
T+1	0,43%	1,578	2,325**	1,166	0,869
T+2	-0,10%	-0,525	-0,92	-0,571	-1,367
T+3	0,28%	0,982	0,415	0,701	1,540
T+4	0,26%	1,400	1,677*	1,348	1,540
T+5	-0,82%	-1,156	-3,100***	-0,541	-0,919
Cumulative Average Abnormal Returns					
Event Window	**CAAR**	**Patell Z**	**BMP**	**Gen. Sign Test**	**Pos:Neg**
[T-1;T+1]	0,36%	0,896	0,002	0,199	41:39
[T-2;T+2]	0,08%	0,148	-0,723	-0,919	36:44
[T-2;T+5]	-0,20%	-0,303	-0,824	0,422	42:38

Note: *p<0,10, **p<0,05, ***p<0,01

The empirical findings do not reveal statistically robust evidence of an average stock-market reaction to M&A announcements within the examined sample. Daily average abnormal returns (AARs) fluctuate around zero throughout the event period, and although a modest positive abnormal return is observed on the first trading day following the announcement (T+1), this effect lacks persistence and is not consistently supported across alternative test statistics. Cumulative average abnormal returns (CAARs) calculated over the short-term event windows [T-1, T+1], [T-2, T+2], and [T-2, T+5] remain economically small and statistically insignificant, indicating the absence of a sustained valuation impact at the aggregate level. In addition, the nearly balanced distribution of positive and negative abnormal returns across firms suggests that the observed variation in abnormal returns reflects firm-specific heterogeneity rather than reflecting a systematic market sentiment. Overall, the results are consistent with heterogeneous transaction-specific valuation effects.

Table 3 illustrates the average abnormal returns and cumulative average abnormal returns for the selected event windows for non-green M&A announcements.

Table 3: Non-green M&A announcements - results

Average Abnormal Returns					
Event Day	**AAR**	**T-test**	**Patell Z**	**BMP**	**Gen. Sign Test**
T-2	0,460%	1,493	1,534	1,163	-0,462
T-1	-0,478%	-2,522**	-2,774***	-2,503**	-2,698***
T	0,041%	0,076	-0,245	0,023	-0,014
T+1	-0,389%	-0,980	-0,756	-0,451	-0,909
T+2	-0,035%	-0,154	-0,817	-0,124	-0,238
T+3	1,078%	0,670	-0,707	0,281	0,433
T+4	-0,095%	-0,451	0,230	-0,325	-0,685
T+5	-0,523%	-1,872*	-1,673*	-1,296	-1,356

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Cumulative Average Abnormal Returns					
Event Window	**CAAR**	**Patell Z**	**BMP**	**Gen. Sign Test**	**Pos:Neg**
[T-1;T+1]	-0,826%	-2,100**	-1,023	-1,580	33:47
[T-2;T+2]	-0,402%	-0,791	-0,774	-0,462	38:42
[T-2;T+5]	0,059%	0,061	-0,886	-1,132	35:45

Note: *p<0,10, **p<0,05, ***p<0,01

As Table 3 documents, the pattern of average abnormal returns indicates generally limited and non-systematic stock-market reactions surrounding M&A announcement dates. The only statistically significant effect is observed on the trading day immediately preceding the announcement (T-1), when the AAR equals –0.478%. This negative abnormal performance is consistently supported across multiple parametric and non-parametric test statistics, including the standard t-test, Patell Z statistic, BMP test, and the generalized sign test. In contrast, cumulative average abnormal returns computed over standard short-term event windows remain small and statistically insignificant, indicating the absence of a persistent aggregate valuation effect. The concentration of negative abnormal returns prior to the announcement may tentatively suggest the presence of anticipatory trading; however, such an interpretation should be treated with caution, as alternatively it might be related to market noise.

Table 4 presents average abnormal returns and cumulative average abnormal returns for selected event windows for horizontal green M&A announcements.

Table 4: Horizontal green M&A announcements - results

A: Average Abnormal Returns					
Event Day	**AAR**	**T-test**	**Patell Z**	**BMP**	**Gen. Sign Test**
T-2	-0,410%	-1,768*	-2,416**	-1,491	-1,358
T-1	0,221%	1,273	0,383	1,688*	-0,308
T	-0,184%	-0,247	-1,779*	-0,075	0,217
T+1	0,659%	2,058**	2,960***	1,476	1,268
T+2	-0,006%	-0,026	-0,005	-0,028	-0,570
T+3	0,515%	1,468	1,733*	0,958	3,106***
T+4	0,427%	1,836*	2,021**	1,824*	1,268
T+5	-0,930%	-0,958	-2,961***	-0,385	-0,833
B: Cumulative Average Abnormal Returns					
Event Window	**CAAR**	**Patell Z**	**BMP**	**Gen. Sign Test**	**Pos:Neg**
[T-1;T+1]	0,70%	1,537	0,406	0,743	32:26
[T-2;T+2]	0,28%	0,479	-0,237	-0,308	28:30
[T-2;T+5]	0,29%	0,395	-0,262	1,531	35:23

Note: *p<0,10, **p<0,05, ***p<0,01

The results indicate that acquirers engaged in horizontal green M&A transactions experience, on average, positive short-term abnormal stock-market reactions in selected event windows. Statistically significant positive average abnormal returns are observed primarily in the post-announcement period, particularly on trading days T+1, T+3, and T+4, indicating a delayed but favourable investor response. Although isolated negative abnormal returns emerge prior to the announcement (T−2) and toward the end of the event window (T+5), these effects are limited in magnitude and do not materially alter the overall short-term return pattern. Cumulative average abnormal returns remain modest and statistically insignificant, implying that the positive daily reactions do not translate into a persistent aggregate valuation effect. The distribution of positive versus negative abnormal returns provides tentative evidence of a mildly favourable market assessment of horizontal green M&A announcements, while also reflecting potential constraints related to sample size or event clustering.

Table 5 below provides results of average abnormal returns and cumulative average abnormal returns for the selected event windows associated with cross-border green M&A announcements.

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Table 5: Cross-border green M&A announcements - results

Green Cross-Border M&As					
A: Average Abnormal Returns					
Event Day	**AAR**	**T-test**	**Patell Z**	**BMP**	**Gen. Sign Test**
T-2	0,011%	0,046	0,041	0,049	1,171
T-1	-0,088%	-0,371	-0,973	-0,438	-1,131
T	0,725%	1,292	2,825***	0,499	1,499
T+1	0,141%	0,436	0,639	0,391	0,513
T+2	-0,342%	-1,532	-1,580	-1,747*	-2,117**
T+3	0,128%	0,519	0,061	0,556	0,184
T+4	0,296%	1,724*	1,775*	2,273**	1,828*
T+5	-0,358%	-1,625	-1,079	-2,030**	-0,473
B: Cumulative Average Abnormal Returns					
Event Window	**CAAR**	**Patell Z**	**BMP**	**Gen. Sign Test**	**Pos:Neg**
[T-1;T+1]	0,78%	1,511	0,801	0,842	21:16
[T-2;T+2]	0,45%	0,672	0,264	-0,473	17:20
[T-2;T+5]	0,51%	0,611	0,470	0,842	21:16

Note: *p<0,10, **p<0,05, ***p<0,01

The results show that the most significant positive abnormal return is on the day of the announcement (T_0), suggesting that the market responds immediately to the disclosure of cross-border green M&A transactions. Following the announcement, there are additional positive abnormal returns on selected days, although these are followed by short-lived negative adjustments. The latter may reflect uncertainty related to the strategic, regulatory, or integration challenges typically associated with international acquisitions. Despite the presence of statistically significant daily effects, cumulative average abnormal returns remain statistically insignificant, albeit consistently positive. The evidence suggests that investors tend to assign a moderately favourable value to cross-border environmentally oriented acquisitions, but the adjustment process is gradual and characterised by higher short-term variability. The findings should be interpreted with caution, as transaction-specific heterogeneity and potential constraints related to sample size may influence the observed return dynamics.

Below is provided Table 6, which presents the results of the cross-sectional analysis on cumulative abnormal returns of the observed bidders.

Table 6: Cross-sectional results of cumulative average returns for short-term window

	Dependent variable: CAR [-1; +1]								
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Green	0.012	0.012	0.012	0.012	0.011	0.011	0.012	0.009	0.009
	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)
log(Total Value/Total Assets		-0.0005						-0.001	
		(0.006)						(0.006)	
Total Value/ Market Cap			0.006						0.006
			(0.014)						(0.015)
Cross-Industry				-0.012				-0.014	-0.013
				(0.008)				(0.008)	(0.008)
Cross-Border					0.007			0.009	0.010
					(0.011)			(0.011)	(0.012)
log(Market-to-Book)						-0.001		-0.0003	-0.0005

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						(0.006)		(0.006)	(0.006)
log(Market Cap)							-0.001		
							(0.003)		
Fixed Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	160	160	160	160	160	160	160	160	160
R2	0.097	0.097	0.100	0.104	0.100	0.093	0.098	0.105	0.108
Adjusted R2	0.003	-0.004	-0.001	0.003	-0.001	-0.009	-0.003	-0.017	-0.014
Res. Std. Error	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
F Statistic	1.029	0.958	0.988	1.034	0.991	0.911	0.970	0.862	0.882

Source: (Author's construct)

The reliability of the regression estimates was evaluated through a series of diagnostic procedures addressing key Gauss–Markov conditions. Heteroskedasticity-robust (White) standard errors were applied to ensure consistent statistical inference in the presence of potential variance heterogeneity. Additional assumption checks, conducted in RStudio, examined issues related to multicollinearity, functional specification and residual properties. The Shapiro-Wilk tests indicated that all nine regression model did not meet the requirement of normality in the residuals. Therefore, skewed variables were log-transformed. Distributional adjustments were implemented to enhance the robustness of inference in a relatively limited sample setting.

The results in Table 6 indicate variation in short-term investor responses to green M&A announcements by acquiring firms. Overall, the estimated coefficients do not provide statistically significant support for generally discussed by scholars effects of pricing of green M&As and the return generation for acquiring companies.

To summarize, the consistently low explanatory power across all models suggests that short-term market reactions and variation in announcement returns is not driven by observable characteristics at deal or firm level. Instead, the evidence points to the tentative impact of unobserved factors, including information asymmetry, varied investor expectations, and strategic narratives specific to each transaction. The findings imply that sustainability-related M&As may generate value for acquirers in delayed or multi-stage adjustments. Variables traditionally emphasized in M&A literature - deal size, diversification, cross-border status, bidder valuation metrics, firm size - do not exhibit systematic significance during the 2010–2024 period. This pattern suggests that in the contemporary M&A environment classical determinants may have weaker explanatory power than historically documented.

Although the overall regression model showed limited effects, the event-study results revealed significant differences between horizontal and cross-border green deals. The findings of the study indicate that aggregate regressions may overlook important structural heterogeneity across deal types. These findings emphasise the methodological limitations of pooled cross-sectional approaches and highlight the need for subsample analyses and more refined variable construction in future research.

The absence of or limited statistical significance of results is a limitation of the study. However, it does not imply the absence of meaningful effects. The observable directional patterns across variables suggest indicative signals, that the current sample lacks sufficient power to confirm formally. Consequently, the results should be regarded as exploratory yet informative.

The absence of strong statistical relationships of the study suggests that key determinants of announcement-period returns in sustainability-oriented M&A may not be easily observable, motivating further development of empirical strategies capable of capturing the qualitative and informational dimensions of corporate transactions.

5. Discussion

The empirical study adds to the growing body of research looking at how financial markets react to sustainability-oriented mergers and acquisitions. The results indicate that acquirer returns in green M&A announcements are not consistently positive or negative, but rather exhibit short-term volatility and sensitivity to the specification of the event window. While initial optimism is evident in short-term windows, these gains often reverse in longer-term windows, suggesting a short-lived market response influenced by uncertainty and corrective price adjustments. This pattern is consistent with previous research showing that markets may overreact to the 'green' label of a transaction while underestimating the underlying financial and operational fundamentals (Cui and Docherty, 2020).

The findings also reinforce the argument that sustainability-oriented acquisitions involve significant information asymmetry. Investors have limited knowledge of companies' actual sustainability practices, their integration capacities, and the credibility of their environmental commitments. As Han et al. (2022) and Deng et al. (2013) demonstrate, the strategic benefits of environmental acquisitions tend to materialise in the long term, through cost efficiencies, innovation capacity and operational improvements. The negative immediate market reactions observed in this study are consistent with the delayed-value phenomenon.

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Acquisition premiums and risk perceptions also influence short-term market responses. Green M&As may involve higher premiums due to reputational motives or strategic urgency, which can compromise short-term acquirer value. Evidence from Gomes and Marsat (2018) study suggests that bidders in sustainability-oriented deals sometimes overpay to secure environmental capabilities or strengthen their ESG positioning. Similarly, cross-border green acquisitions may expose the acquirer to increased regulatory, cultural and geographical risks, prompting a cautious investor reactions despite potential long-run strategic benefits.

Observed patterns are also influenced by synergy expectations of M&As. Horizontal green acquisitions in the sample consistently generated positive cumulative abnormal returns across event windows, though not at statistically significant levels. This is in line with established views that horizontal deals generate tangible operational synergies through economies of scale and market consolidation (Andrade et al., 2001). However, while cross-border deals also yield positive cumulative returns, they do not trigger strong market responses. Thus integration complexity in M&As may offset anticipated returns.

Together, the dynamics suggest that markets do not treat green M&As as inherently value-enhancing in the short term. Rather, investor reactions depend on the interplay of perceived sustainability credibility, integration risk, premium levels and strategic fit. Therefore, the findings suggest the need of a more nuanced view on the expectations that green M&As automatically generate market rewards, and highlight the importance of examining both the short-term and long-term effects.

These outcomes align with prior research suggesting that investors may not fully incorporate the potential long-term value of environmentally oriented acquisitions at the announcement date (Deng et al., 2013; Han et al., 2022). Any positive valuation effects for acquirers, if they arise, may therefore emerge gradually as information about sustainability integration and future performance becomes clearer.

6. Conclusions

In conclusion, this study provides new evidence on how the stock market reacts to green and non-green M&A announcements from the perspective of acquirers in the US between 2010 and 2024. This period was characterised by the rapid expansion of sustainability-oriented investment. The empirical results show that acquirers in green M&As do not systematically experience positive abnormal returns at the time of the announcement, although short-term cumulative returns may be modestly favourable. These effects dissipate over longer timeframes, suggesting either market overreaction or heightened uncertainty. However, overpricing effects, which are not systematic, follow immediately after the announcement of M&A deals, suggesting general market optimism towards sustainability-oriented investments. Previous research has argued that investors frequently undervalue green M&As on the day of the announcement (Deng et al., 2013; Han et al., 2022). The positive effect on the acquirer's stock price may be delayed due to the acquirer's long-term sustainability goals and future investments in them. Horizontal and cross-border green M&As generally produce positive returns, albeit without statistical significance, which highlights the complexity of investor interpretation in environmentally oriented transactions.

The results point out that green M&A status does not significantly influence short-term announcement returns, contradicting general consensus. This indicates that markets do not consistently reward environmental motives in M&A, at least within the immediate announcement period, and adds nuance to the scholarly debate.

The findings of the study indicate that the initial pricing of green M&As is affected by factors such as anticipated synergies, information asymmetry, integration risk, and acquisition premiums. These results are consistent with the wider body of literature documenting the delayed realisation of value in sustainability-driven acquisition strategies. Therefore, future research should explore the effects on longer-term performance, company integration outcomes, and the conditions under which environmental acquisitions generate long-lasting shareholder value.

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Credit Risk Modelling for Small and Medium-Sized Enterprises in Zimbabwe

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ABSTRACT

Purpose:
The main aim of the study was to determine a context-specific credit risk assessment framework that integrates both traditional financial metrics and alternative data sources to better evaluate the creditworthiness of Zimbabwean SMEs. It also identified key factors affecting credit risk for SMEs in Zimbabwe by incorporating both financial and non-financial data.

Design/methodology/approach:
We employed machine learning algorithms which were Logistic Regression (LR), Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Random Forest (RF), and AdaBoost (AB). The data was obtained from the loan database of an SME banking division of a commercial bank of Zimbabwe consisting of 52,750 loan applicants over the 5-year period from 2018 to 2022. The features of the credit dataset included capital structure, financial history, profitability, liquidity, growth potential, industry characteristics, management quality, social media engagement, macroeconomic environment, customer concentration, credit history, firm age, collateral availability and whether the applicant defaulted on the loan or not. We performed data preprocessing and cleaning, feature development, hyper parameter selection and cross validation. A split ratio of 80% for the training set and 20% for the testing set was used, followed by an evaluation of the model based on the following performance metrics: classification accuracy, precision, recall (sensitivity), F1-score and the Receiver Operating Characteristic - Area Under the Curve (ROC-AUC).

Findings:
We find that traditional financial indicators such as profitability, liquidity and leverage, non-financial factors—including collateral availability, cash flow stability, management quality, and macroeconomic conditions—play a significant role in shaping credit risk profiles. Non-traditional data sources such as firm characteristics, supplier–buyer relationships, and social media activity can provide deeper insights into SMEs' operational performance and risk exposure. Incorporating these data sources alongside traditional financial information can significantly enhance the prediction of defaults.

Research limitations/implications:
This study was confined to one Zimbabwean bank, this represents a narrow focus since the Zimbabwean banking industry has 343 players as at 30 September 2025, (Reserve Bank of Zimbabwe (2025)). Also, since we base our research on Zimbabwe, it implies that the findings of this study cannot be generalised to all developing countries.

Originality/value:
This study contributes to the theory by providing an enhanced credit risk assessment framework that integrates traditional financial indicators and alternative data sources for Zimbabwean banks when determining the credit risk of SMEs. This will improve access to credit by SMEs in Zimbabwe and in jurisdictions with similar economic environments as those found in Zimbabwe. By providing reliable credit risk assessment methods it increases the financial inclusion of SMEs.

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1. Introduction

Small and Medium-sized Enterprises (SMEs) form the foundation of Zimbabwe's economy, performing an important task of stimulating economic growth, employment, and social development. According to the latest government statistics, there are 1,954,202 owners of Micro, Small and Medium Enterprises (MSMEs) in Zimbabwe, employing 7.05 million individuals, generating an estimated USD 14.2 billion in annual turnover (FinScope, 2021). These enterprises span a diverse range of sectors, including agriculture, manufacturing, trade, and services, and are crucial in fostering innovation, competition, and entrepreneurship.

The significance of the SME sector in Zimbabwe is well-documented in existing literature. Dlamini and Schutte (2020) emphasises that SMEs are the primary source of job creation, with the potential to alleviate poverty and income inequality, especially in rural and marginalised communities in Zimbabwe. Similarly, Makanyeza and Dzvuke (2015) explain the importance of SMEs to the promotion of inclusive and sustainable economic development, as they are more likely to employ local resources and engage with local supply chains. Furthermore, Njanike (2020) states that a thriving SME sector can contribute to the diversification of the Zimbabwean economy, reducing its reliance on a few dominant industries and making it more resilient to external shocks since it is known that 99% of business enterprises in developing countries are SMEs. Matsongoni and Mutambara (2021) state that the informal sector which is predominantly driven by SMEs is the largest absorber of labour in Zimbabwe, implying that it is contributing towards the livelihoods of many Zimbabweans,

SMEs represent a vital sector in Zimbabwe but nonetheless it faces several challenges that prevent it attaining its full potential. A critical impediment is the lack of access to credit and finance, this is generally considered as the most restrictive inhibition that limits growth and development of SMEs in Zimbabwe (Karedza et al., 2014). Inadequate financing restricts the ability of SMEs to invest in new technologies, expand their operations, and capitalise on emerging market opportunities.

1.1 Problem Statement

The limited access to credit and finance experienced by SMEs in Zimbabwe can be attributed to a range of interrelated factors. Firstly, SMEs often lack the collateral and credit history required by traditional financial institutions to secure loans (Manyanga et al., 2023). The high-risk perception associated with SMEs, coupled with information asymmetries, makes them less attractive to lenders compared to larger, established corporates (Dhlandhlara, 2019).

Furthermore, the volatile economic and political environment in Zimbabwe has exacerbated the challenges faced by SMEs in accessing credit. Periods of hyperinflation, currency instability and policy uncertainty have heightened the risk profile of SMEs leading financial institutions to adopt more conservative lending practices (Karedza et al., 2014). In most jurisdictions including Zimbabwe there is a lack of well-developed credit infrastructure such as credit bureaus and collateral registries further compounding the information asymmetries between SMEs and lenders (Dhlandhlara, 2019; Muriithi, 2017). This financing gap has constrained the ability of SMEs to invest in innovation, expand their operations and ultimately realise their full economic potential.

Consequently, the shortcomings of the current credit risk assessment approaches have contributed to the persistent financing gap faced by SMEs in Zimbabwe. Financial institutions constrained by the perceived high risk associated with the SME segment have often resorted to conservative lending practices further reducing access to credit for SMEs in Zimbabwe. This study presents a novel, context-specific credit risk assessment framework that integrates both traditional financial metrics and alternative data sources to better evaluate the creditworthiness of Zimbabwean SMEs. This is achieved by. The model is then validated by using real-world data from Zimbabwean SMEs.

1.2 Significance of the study

By integrating both traditional and alternative data sources, this study will expand the existing theoretical and empirical understanding of credit risk modelling approaches that can effectively capture the nuances of SME lending in emerging market settings. By addressing the critical gap in existing literature this study contributes to the advancement of both academic and practitioner-oriented understandings of credit risk assessment for SMEs. The finding we have generated will inform policy decisions, guide the development of targeted interventions and ultimately support the growth and financial inclusion of the SME sector.

In this study we provide a roadmap towards implementing a machine learning based approach to credit risk assessment that incorporates alternative data by Zimbabwean banks when lending to SMEs. We also provide a comparison of the machine learning algorithms that can be used in order to provide operational guidance to banks in emerging markets, with Zimbabwe acting as a case study. Furthermore, we give several practical recommendations to policymakers, banks and SMEs that if implemented will support the growth and financial inclusion of the SME sector. To the best of our knowledge such a study has never been undertaken, hence the novelty of the present study's findings.

The rest of the paper is structured in the following manner: Section 2 presents a review of literature. Section 3 contains the methodology. Section 4 contains results and analysis including the model performance metrics. Section 5 contains the conclusions and recommendations.

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2. Review of Literature

2.1 Previous studies

Some studies have performed credit risk assessment modelling that include alternative data using machine learning. Recently, Jiang et al. (2026) utilise data about micro enterprises obtained from an internet bank to assess credit risk using alternative data. They categorise the alternative data as either historical credit data or behavioral data. They proceeded to employ a random forest model on the data categories and perform credit risk assessment. The behavioral data based models are shown to perform better than historical credit risk data based models.

In another recent study, Ahmad (2026) provides a wide ranging analysis of the uptake of credit risk assessment models that use alternative data. The aim of the study was to explore how these approaches have improved the accuracy of credit risk prediction and the broader inclusion of smaller players in the financial sector. They demonstrate that credit risk assessment via the use of alternative data should be complemented by changing its emphasis to transparency and socio-economic equity.

In their study Lee et al. (2026) demonstrate how retail transaction data can be used for credit risk assessment. The data is obtained from a Peruvian company. In their study they combine customer loyalty data with credit card repayment data and juxtapose it with each individual's financial history obtained from the Peruvian financial records. Using machine learning algorithms, they calculate credit scores for individuals with and without a credit history. Their study finds that using retail transaction data improves the credit rating of people who do not have credit histories from 16% to be approximately between 31% and 48%.

3. Methodology

3.1 Introduction

This section outlines the methodological approach used to develop and evaluate a machine learning model for credit risk prediction. An accurate and interpretable machine learning credit risk model was created that can be used by financial institutions to better assess the creditworthiness of loan applicants in Zimbabwe by SMEs.

3.1 Data collection

The data used in this study was obtained from the loan database of an SME banking division of a commercial bank of Zimbabwe. The dataset includes information on 52,750 loan applicants over the 5-year period from 2018 to 2022. The loans that were in default constituted 22% of the portfolio and 78% was fully repaid. The features of the credit dataset included capital structure, financial history, profitability, liquidity, growth potential, industry characteristics, management quality, social media engagement, macroeconomic environment, customer concentration, credit history, firm age, collateral availability and whether the applicant defaulted on the loan or not.

3.2 Data pre-processing

The first step in the data pre-processing phase involved addressing missing values within the dataset. A thorough examination revealed that several attributes had an insignificant number of missing observations, ranging from 0.5% to 2% of the total data. To handle these missing values, a combination of techniques was employed:

- For numeric variables the missing values were imputed using the mean of the available data for that feature.
- For categorical variables the missing values were imputed using the most frequent category (mode) for that feature.
- In cases where the missing data would have exceeded 25% for a particular variable, the feature was considered for removal from the analysis to avoid introducing excessive bias.

3.3 Feature development

After the initial data cleaning we conducted feature development to create additional variables that could potentially improve the predictive power of the credit risk model. This process involves the following steps:

- Derivation of Ratios: Several financial ratios were calculated from the available data, such as the current ratio, debt-to-equity ratio, and return on assets, to capture the financial health and performance of the SMEs.
- Temporal Feature Creation: Variables representing the duration of the SME's operation (firm age) and the timeliness of supplier payments (supplier payment delay) were engineered to incorporate the temporal aspects of the business.
- Categorical Variable Encoding: Categorical features, such as business sector and management experience, were encoded using one-hot encoding to enable their inclusion in the machine learning models.

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3.4 Model development

3.4.1 Variable selection

The selection of variables for the machine learning-based credit risk assessment model for Zimbabwean SMEs was informed by a comprehensive review of the existing literature on SME financing and credit risk modeling. The key variables to be considered, based on the insights from the literature, are found in Table 3.1.

- Hyperparameter selection: Hyperparameters were selected using a mix of default settings and systematic tuning. For example, SVM hyperparameters (C, gamma, kernel) were optimised using GridSearchCV, while KNN used grid search to identify the optimal number of neighbors (e.g., k=9k=9k=9). In contrast, Logistic Regression and Random Forest were largely implemented with default parameters, with feature selection applied to Logistic Regression via RFECV.
- Cross-validation approach: Beyond the initial train–test split (70/30), cross-validation was applied in specific stages. RFECV used StratifiedKFold (cv=2) for feature selection, and GridSearchCV implicitly employed cross-validation during hyperparameter tuning (e.g., for SVM and KNN). However, there was no consistent, unified cross-validation strategy applied across all models.
- Justification of model choice: The selected models—Logistic Regression, SVM, KNN, and Random Forest—provide a diverse set of learning approaches: linear (LR), kernel-based (SVM), distance-based (KNN), and ensemble methods (RF). This allows for robust comparison and captures different data structures. Additionally, SMOTE was used to address class imbalance, which is critical in credit risk classification problems.

Table 3.1: Model variables

Financial variables	• Liquidity ratios (e.g., current ratio and quick ratio) • Profitability ratios (e.g., return on assets and net profit margin) • Leverage ratios (e.g., debt-to-equity and debt-to-assets): • Cash flow measures (e.g., cash flow from operations and cash flow coverage ratio)
Non-financial variables	• Firm characteristics (e.g., firm age, industry sector, legal structure and customer concentration) • Management quality (e.g., education, experience and decision-making practices) • Collateral and guarantees • Business environment
Alternative data variables	• Digital footprint (e.g., online sales, social media activity and mobile money transactions) • Supply chain relationships (e.g., supplier payment history and customer concentration) • Entrepreneurial characteristics (e.g., owner's credit history and educational background,

Table 3.2 provides a description of the characteristics of each variable used in our models.

Table 3.2: Variable characteristics and description

Variable	Category	Type	Calculation	Additional Notes
Loan Status (Default)	Target Variable	Categorical (Binary)	1 = Default, 0 = Non-default	Dependent variable
Liquidity Ratio (Current Ratio)	Financial	Continuous	Current Assets / Current Liabilities	Measures short-term solvency

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Quick Ratio	Financial	Continuous	(Current Assets – Inventory) / Current Liabilities	More conservative liquidity measure
Return on Assets (ROA)	Financial	Continuous	Net Income / Total Assets	Profitability indicator
Net Profit Margin	Financial	Continuous	Net Profit / Revenue	Operational efficiency
Debt-to-Equity Ratio	Financial	Continuous	Total Debt / Shareholders' Equity	Capital structure risk
Debt-to-Assets Ratio	Financial	Continuous	Total Debt / Total Assets	Overall leverage
Cash Flow from Operations	Financial	Continuous	Net Cash from Operating Activities	Core cash generation
Cash Flow Coverage Ratio	Financial	Continuous	Operating Cash Flow / Total Debt	Ability to service debt
Revenue Growth Rate	Financial	Continuous	(Current Revenue – Previous Revenue) / Previous Revenue	Growth potential proxy
Firm Age	Non-Financial	Continuous (can be ordinal)	Current Year – Year Established	Proxy for stability
Industry Sector	Non-Financial	Categorical	Encoded (e.g., one-hot)	Captures industry risk differences
Customer Concentration	Non-Financial / Alternative	Continuous	% of revenue from top customers	High concentration = higher risk
Legal Structure	Non-Financial	Categorical	Encoded (e.g., LLC, Corporation)	Impacts liability and governance
Management Experience	Non-Financial	Ordinal	Years of experience or score index	Proxy for management quality
Management Education Level	Non-Financial	Ordinal	Encoded (e.g., High school=1, Degree=2, etc.)	Human capital indicator
Collateral Availability	Non-Financial	Categorical (Binary/Ordinal)	1 = Collateral available, 0 = none (or value-based ratio)	Reduces lender risk
Business Environment Index	Non-Financial	Continuous	Composite index (e.g., regulatory, market conditions)	Macro/business climate
Macroeconomic Indicator (e.g., GDP growth)	Non-Financial	Continuous	External data (e.g., % GDP growth, inflation rate)	Systemic risk factor
Credit History Score	Alternative / Financial	Continuous	Credit bureau score or repayment index	Key risk predictor

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Previous Defaults	Alternative	Categorical (Binary/Count)	1 = prior default, 0 = none (or count)	Strong predictor of default
Social Media Engagement	Alternative	Continuous	Metrics (followers, engagement rate, activity index)	Proxy for business activity
Online Sales Volume	Alternative	Continuous	Total online transaction value	Digital footprint
Mobile Money Transactions	Alternative	Continuous	Transaction volume/frequency	Financial behavior proxy
Supplier Payment History	Alternative	Ordinal	Payment timeliness score (e.g., late/on-time)	Supply chain reliability
Customer Reviews / Ratings	Alternative	Continuous/Ordinal	Average rating score	Market perception

3.2 Model validation

The following validation techniques will be employed to ensure the reliability, robustness and generalisability of the proposed credit risk model.

3.2.1 Model training

- Data loading and pre-paration:The data was loaded into a Pandas data-frame, which is a popular data structure in Python for working with tabular data. The data-frame included the 13 features (Liquidity, Profitability, Leverage, Firm Age, Management Experience, Collateral Availability, Customer concentration, Supplier Payment Delay, Industry Index, Macroeconomic Index, Business Growth Potential Index, Social Media Engagement Index, and Credit History) and the target variable 'Defaulted' (0 for non-defaulted, 1 for defaulted).
- Train-test split:The pre-processed data is split into training and testing sets using the train_test_split function from scikit-learn. The training set is used to train the machine learning model, while the testing set is used to evaluate the model's performance on unseen data. A split ratio of 80% for the training set and 20% for the testing set was used based on the requirements of this research. Stratified splitting was used to ensure that the class distribution (defaulted vs. non-defaulted loans) is maintained in both the training and testing sets, which is particularly important when dealing with imbalanced datasets.

3.2.2 Model performance

The evaluation of the model is based on a set of performance metrics. We used the following performance metrics: classification accuracy, precision, recall (sensitivity), F1-score and the Receiver Operating Characteristic - Area Under the Curve (ROC-AUC).

4 Model results and analysis

4.1 Introduction

This section presents the results and analysis for the machine learning-based credit risk model for SMEs in Zimbabwe. The section is structured as follows: exploratory analysis, feature importance analysis and model interpretation and discussion.

4.2 Exploratory analysis

To gain a comprehensive understanding of the dataset and identify potential relationships between the variables, exploratory data analysis (EDA) was conducted. The insights gained from exploratory data analysis were used in carrying out feature selection. The study was able to identify the most relevant variables, understand the underlying data characteristics, and detect any potential issues or biases within the dataset.

4.2.1 Summary statistics

The summary statistics were calculated, including mean, median, standard deviation, and range, for each numerical variable to understand their distribution and characteristics. These results are presented in Table 4.1.

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Table 4.1: Summary statistics

Variable	Mean	Median	Standard Dev	Min	Max
Current Ratio	1.78	1.65	0.82	0.32	5.21
Return on Assets	0.09	0.08	0.06	-0.15	0.33
Debt-to-Equity Ratio	1.42	1.21	0.95	0.08	6.74
Firm Characteristics	8.3	7	5.2	4	15
Management Experience (years)	11.4	10	6.8	2	35
Collateral Availability %	65.2	70	23.1	10	100
Average Monthly Online Sales	18,450.00	15,320.00	11,230.00	2,100.00	92,800.00
Supplier Payment Delay (days)	42	38	16	7	102

The descriptive statistics reveal important information about the characteristics of the SME credit data. For example, the average current ratio is 1.78, indicating that on average, SMEs in the dataset have current assets that are 1.78 times greater than their current liabilities. The average return on assets is 0.09, suggesting a moderate level of profitability among the SMEs. The debt to equity ratio has a minimum value of 0.08 and a maximum of 6.74 with an average of 1.42 an appropriate level considering the economic volatility historically prevalent in Zimbabwe.

4.2.2 Measure of skewness on the numerical variables

To assess the skewness of the numerical variables in the credit risk assessment model we calculated the skewness statistic for each variable. Skewness is a measure of the symmetry of a distribution, with a value of 0 indicating a perfectly symmetric distribution. Table 4.2 presents the skewness values for the numerical variables in the dataset.

Table 4.2

Variable	Skewness
Current Ratio	1.02
Return on Assets	0.41
Debt-to-Equity Ratio	1.78
Firm Characteristics	1.34
Management Experience (years)	0.92
Collateral Availability %	-0.59
Average Monthly Online Sales	2.51
Supplier Payment Delay (days)	0.71

Results in Table 4.2 indicate that Current Ratio has a skewness value of 1.02 which indicates a positive skew, meaning the distribution has a longer right tail. This implies that most SMEs have current ratios at the lower end of the distribution, with a few outliers having significantly higher current ratios. Also, the debt-to-equity ratio possesses a skewness value of 1.78 that represents a strong positive skew, indicating that most SMEs have low debt-to-equity ratios.

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4.2.3 Correlation analysis

Table 4.3 presents the correlation matrix for the numerical variables.

Table 4.3 Correlation matrix

	Current Ratio	Return on Assets	Debt-to-Equity Ratio	Firm Age (years)	Management Experience (years)	Collateral Availability %	Average Monthly Online Sales	Supplier Payment Delay (days)
Current Ratio	1.00	0.31	-0.45	0.21	0.18	0.29	0.24	-0.13
Return on Assets	0.31	1.00	-0.37	0.15	0.22	0.19	0.27	-0.11
Debt-to-Equity Ratio	-0.45	-0.37	1.00	-0.16	-0.13	-0.24	-0.19	0.09
Firm Age (years)	0.21	0.15	-0.16	1.00	0.34	0.12	0.17	-0.08
Management Experience (years)	0.18	0.22	-0.13	0.34	1.00	0.14	0.13	-0.07
Collateral Availability %	0.29	0.19	-0.24	0.12	0.14	1.00	0.21	-0.10
Average Monthly Online Sales	0.24	0.27	-0.19	0.17	0.13	0.21	1.00	-0.12
Supplier Payment Delay (days)	-0.13	-0.11	0.09	-0.08	-0.07	-0.10	-0.12	1.00

The results in Table 4.3 indicate a current ratio that has a moderate positive correlation of 0.31 with return on assets and a moderate negative correlation of -0.45 with debt-to-equity ratio. This suggests that SMEs with higher current ratios tend to have higher profitability and lower leverage.

Firm age has a weak positive correlation of 0.21 with current ratio, of 0.15 with return on assets and of 0.17 average monthly online sales. This implies that firms with strong firm characteristics like growth potential tend to have slightly better liquidity, profitability, and online sales performance.

4.3 Feature analysis

We conducted a feature analysis for Logistic Regression (LR), Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Random Forest (RF), and AdaBoost (AB). Tables 4.4 to 4.8 display coefficients which are also referred to as feature importance values. Feature importance values greater than 0.15 identify the most important variables. The feature-important analysis identifies firm characteristics, return on assets, current ratio, and debt-to-equity ratio as the most significant predictors of credit risk. Collateral availability and average monthly online sales have moderate importance, whilst management experience and supplier payment delay the lowest importance.

Table 4.4 Logistic Regression (LR) feature importance analysis

Variable	Coefficient
Current Ratio	0.72
Return on Assets	1.34
Debt-to-Equity Ratio	-0.59
Firm Characteristics	1.51
Management Experience (years)	0.11
Collateral Availability %	0.44
Average Monthly Online Sales	0.27
Supplier Payment Delay (days)	-0.09

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Table 4.5 Support Vector Machine (SVM) feature importance analysis

Variable	Coefficient
Current Ratio	0.21
Return on Assets	0.24
Debt-to-Equity Ratio	0.18
Firm Characteristics	0.27
Management Experience (years)	0.07
Collateral Availability %	0.13
Average Monthly Online Sales	0.11
Supplier Payment Delay (days)	0.05

Table 4.6 K-Nearest Neighbors (KNN) feature importance analysis

Variable	Coefficient
Current Ratio	0.19
Return on Assets	0.22
Debt-to-Equity Ratio	0.16
Firm Characteristics	0.29
Management Experience (years)	0.08
Collateral Availability %	0.14
Average Monthly Online Sales	0.12
Supplier Payment Delay (days)	0.06

Table 4.7 Random Forest (RF) feature importance analysis

Variable	Coefficient
Current Ratio	0.20
Return on Assets	0.23
Debt-to-Equity Ratio	0.17
Firm Characteristics	0.31
Management Experience (years)	0.08
Collateral Availability %	0.15
Average Monthly Online Sales	0.13
Supplier Payment Delay (days)	0.07

Table 4.8 AdaBoost (AB) feature importance analysis

Variable	Coefficient
Current Ratio	0.18
Return on Assets	0.21
Debt-to-Equity Ratio	0.16
Firm Characteristics	0.10
Management Experience (years)	0.07
Collateral Availability %	0.13
Average Monthly Online Sales	0.11
Supplier Payment Delay (days)	0.06

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4.4 Model performance and evaluation

We now focus on the metrics of accuracy, precision, recall, and F1-score. The results for each metric are presented in Table 4.9 providing a comparison of the performance of the models.

Table 4.9 Model performance

Metric	Logistic Regression	SVM	KNN	Random Forest	AdaBoost
Accuracy	0.83	0.82	0.78	0.85	0.81
Precision	0.81	0.80	0.76	0.83	0.79
Recall	0.85	0.84	0.08	0.87	0.83
F-1 Score	0.83	0.82	0.78	0.85	0.81

4.4.1 Overall model performance

The random forest model demonstrated the best performance across all the evaluated metrics. The logistic regression and SVM models also showed strong performance, with the AdaBoost and KNN models comparatively being the weakest. Further evaluation of the model's performance using different subsets of the data or ensemble techniques may achieve improved performance.

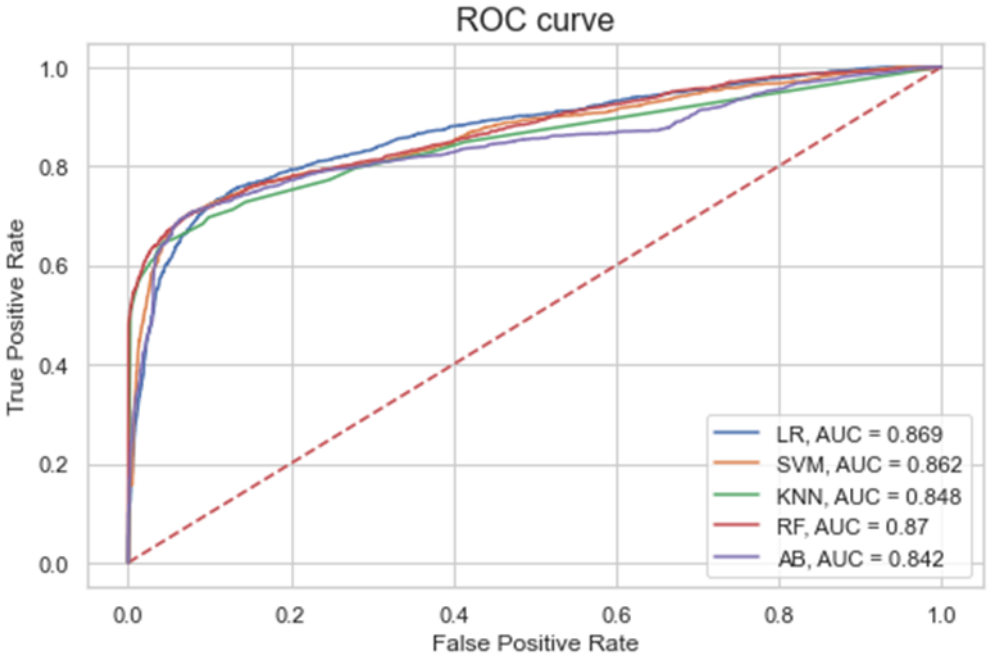
4.4.2 ROC-AUC analysis

Accuracy is often used to evaluate the performance of classification models. However, it encounters limitations when carrying out credit risk assessment. Accuracy measures the overall proportion of correct predictions but is incapable of providing a complete picture of the model's ability to differentiate between credit-worthy and high-risk borrowers (Malik et al., 2024; Dong, Liu and Tham, 2024; Wang, 2024; Wu et al., 2025).

In credit risk assessment, the cost of misclassification can be quite high. For example, incorrectly classifying a high-risk borrower as a low-risk borrower (false negative) could lead to substantial financial losses for the lender (Wang, 2024; Wu et al., 2025). Conversely, incorrectly classifying a low-risk borrower as high-risk (false positive) could result in missed lending opportunities and reduces financial inclusivity (Wang, 2024; Wu et al., 2025).

ROC-AUC when compared to accuracy is a more comprehensive metric that evaluates the model's ability to distinguish between these two classes. It is not affected by the specific classification threshold. ROC-AUC measures the trade-off between the true positive rate (sensitivity) and the false positive rate (1 - specificity) across all possible classification thresholds (Wang, 2024; Wu et al., 2025). Figure 4.1 contains the ROC curve.

Figure 4.1ROC curve



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The Random Forest model emerges as the best performer, with an ROC-AUC score of 0.87. This indicates that the ensemble nature of the Random Forest model allows it to effectively handle the complexity of the data and provide highly accurate predictions for credit risk assessment. This suggests that the model can accurately rank the instances based on their predicted probabilities of default, making it a suitable choice for credit risk assessment.

The Logistic Regression model also exhibits a strong ability to distinguish between credit-worthy and high-risk borrowers, with an ROC-AUC score of 0.869. The KNN model also demonstrates good performance in discriminating between credit risk classes, with an ROC-AUC score of 0.848. This indicates that the model can effectively capture the complex, non-linear relationships in the data and provide reliable predictions for credit risk assessment.

4.4.3 Interpretation of model findings

The results are broadly consistent with prior credit risk literature, which typically finds that ensemble methods outperform linear models (Xu, (2025), Miliūnaitė, (2023), Wang et al. (2020)). The strong performance of Random Forest aligns with studies showing that tree-based methods better capture complex borrower behavior. The superior performance of Random Forest in your analysis can be attributed to several factors.

- Non-linear relationships: It effectively captures complex, non-linear interactions between variables (e.g., between liquidity, leverage, and credit history) that linear models like Logistic Regression cannot.
- Interaction effects: Random Forest automatically models interactions between predictors without explicit specification.
- Robustness to noise and overfitting: Through bootstrapping and averaging (bagging), it reduces variance and improves generalisation. Other research studies used the random forest model when performing credit risk assessment and had similar findings (Xu, (2025); Miliūnaitė, (2023); Wang et al. (2020)).

The comprehensive analysis of the credit risk assessment model's performance using various machine learning approaches has provided valuable insights into the key drivers of credit risk management for SMEs in Zimbabwe.

4.4.4 Model interpretation and discussion

The feature importance analysis across the Logistic Regression, SVM, KNN, Random Forest, and AdaBoost models consistently identified the following variables as the most significant predictors of credit risk:

- Return on Assets: SMEs with higher profitability, as measured by return on assets, were less likely to default on their loans. This finding aligns with previous studies that have emphasised the importance of financial performance indicators in credit risk assessment (OECD, 2025).
- Current Ratio: SMEs with a higher current ratio, indicating stronger liquidity and ability to meet short-term obligations, were likely to be classified as low-risk borrowers. This supports the notion that liquidity is a crucial factor in creditworthiness (D'Amato, 2020; Rusu and Roman, 2022; Li et al., 2025; López-Gracia and Sogorb-Mira, 2008).
- Debt-to-Equity Ratio: Higher debt-to-equity ratios, which signify higher financial leverage, were associated with increased credit risk. This is consistent with the findings of other studies who highlighted the importance of capital structure in predicting SME defaults (Feng, Li and Peng 2021; Paeleman et al., 2024).

In addition to these financial performance indicators, the analysis also revealed the significance of other firm-level characteristics:

- Firm characteristics: SMEs with higher growth potential, higher customer concentration and greater firm age were found to have the lowest credit risk profile, suggesting that the longevity and experience of a business can be an important factor in credit risk assessment. This aligns with other studies who noted the role of firm age in reducing information asymmetries and improving access to credit (Pillay, 2024; Garcia-Martinez et al., 2023; Ciampi, et al., 2021; Altman, Sabato and Wilson, 2010).
- Collateral availability: SMEs with higher collateral availability were found likely to be classified as low-risk borrowers. This emphasises the importance of collateral as a risk-mitigating factor, as demonstrated in previous studies (Ciampi, 2021; Pillay, 2024). Lack of collateral is a challenge commonly faced by SMEs in Zimbabwe impeding their access to credit facilities.

Also, the alternative data source variables have a medium contribution towards credit rating. Evidence of this is the consistent middle rating of monthly online sales when compared to traditional financial and non-financial variables. However, this variable outperforms other variables such as management experience. This points to a need to include alternative data sources as a means of improving the accuracy of credit risk assessments and predictions.

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4.4.5 Credit risk assessment for SMEs with inadequate collateral in Zimbabwe

We suggest that when assessing the credit risk for SMEs applying for loans, without collateral, in Zimbabwe various firm characteristics beyond just the financial ratios of the borrower should also be taken into consideration. Factors such as firm age, growth potential, type of industry, macroeconomic conditions and customer concentration can provide important insights into the creditworthiness of the borrower.

Firm age is a significant indicator of a company's stability and creditworthiness. Older firms typically have a better track record, more established business processes and stronger relationships with suppliers and customers, making them less risky borrowers. Younger firms, on the other hand, may face higher uncertainty and a higher risk of failure which can increase the credit risk associated with lending to them (Pillay, 2024; Garcia-Martinez et al., 2023; Ciampi, et al., 2021; Altman, Sabato and Wilson, 2010).

The growth potential of a firm is also an important consideration in credit risk assessment. Companies with strong growth prospects, as indicated by factors such as industry outlook, market share, and innovation, may be better positioned to generate the cash flow needed to repay their loans, even in the absence of collateral (Abbasi and Tamoradi, 2020). Conversely, firms with limited growth potential may struggle to generate sufficient income to service their debt obligations.

The type of industry in which a firm operates can also have a significant impact on its credit risk. Some industries may be more volatile or cyclical, making them riskier investments, while others may be more stable and resilient. Incorporating industry-specific factors, such as market trends, competitive landscape and regulatory environment, can help lenders better understand the risks associated with lending to a particular company.

Macroeconomic conditions can also influence a firm's creditworthiness. Economic factors, such as GDP growth, inflation, interest rates, and unemployment, can affect a company's sales, profitability, and cash flow, thereby impacting its ability to repay its loans. Lenders should closely monitor the macroeconomic environment and adjust their credit risk assessments accordingly.

Finally, the concentration of a firm's customer base can have a significant impact when assessing credit risk. Companies with a high degree of customer concentration may be more vulnerable to the loss of a major client, which could severely impact their cash flow and ability to repay their loans. Lenders should carefully evaluate the diversity and stability of a borrower's customer base to better understand the associated risks.

By considering these firm-level characteristics in addition to financial ratios, lenders can gain a more comprehensive understanding of the credit risk associated with a particular borrower, even in the absence of collateral. This holistic approach to credit risk assessment can help lenders make more informed decisions and minimise the risk of default in their loan portfolios.

5. Conclusion and recommendations

5.1 Conclusions

The study provides a comprehensive assessment of the key factors influencing SME creditworthiness in Zimbabwe. It finds that, in addition to traditional financial indicators such as profitability, liquidity and leverage, non-financial factors—including collateral availability, cash flow stability, management quality, and macroeconomic conditions—play a significant role in shaping credit risk profiles. This highlights the importance of adopting a more holistic approach to credit risk evaluation that extends beyond conventional financial metrics.

The findings also emphasise the growing importance of alternative data in improving credit risk assessment. Non-traditional data sources such as firm characteristics, supplier–buyer relationships, and social media activity can provide deeper insights into SMEs' operational performance and risk exposure. Incorporating these data sources alongside traditional financial information can significantly enhance the prediction of defaults. At the same time, the study underscores the strong impact of Zimbabwe's macroeconomic, where inflation, and policy uncertainty can undermine SME performance and reduce the reliability of traditional credit models.

Another key issue identified is the role of information asymmetry and institutional weaknesses in limiting SME access to finance. The lack of comprehensive credit data, effective collateral registries, and well-functioning credit bureaus makes it difficult for lenders to accurately assess borrower risk. Addressing these gaps is essential to improving credit allocation. Strengthening financial infrastructure, improving data availability, and reducing information asymmetries would enable lenders to make more informed decisions and expand lending to SMEs.

Based on these findings, several recommendations are proposed. Policymakers should strengthen credit infrastructure, implement credit guarantee schemes, improve financial literacy, and create an enabling regulatory environment while promoting alternative financing mechanisms. Financial institutions are encouraged to adopt context-specific credit risk models that integrate alternative data, diversify lending products, leverage technology, and enhance engagement with SMEs. Meanwhile, SME support agencies should focus on capacity building, data collection, financial education, and fostering partnerships and networks. Collectively, these measures can improve access to finance and support the growth and sustainability of SMEs in Zimbabwe.

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5.2 Suggestions for further studies

Further studies could consider the potential of integrating qualitative data, such as management interviews, industry benchmarks and expert assessments into the credit risk assessment process to capture other soft factors that may influence SME creditworthiness in Zimbabwe. We could also conduct a longitudinal study to examine the evolution of credit risk profiles among Zimbabwean SMEs over time, capturing the impact of macroeconomic and political changes. This could boost the effectiveness of policy interventions in mitigating default risks. Another research study direction could assess the viability and potential impact of innovative financing solutions. These solutions could include crowdfunding platforms, supply chain financing schemes, and specialised SME lending programs. These can help address the credit access challenges faced by Zimbabwean SMEs.

5.3 Limitations of the study

This study was confined to one Zimbabwean bank, this represents a narrow focus since the Zimbabwean banking industry has 343 players as at 30 September 2025, (Reserve Bank of Zimbabwe (2025)). Also, since we base our research on Zimbabwe, it implies that the findings of this study cannot be generalised to all developing countries.

5.4 Declarations

All authors declare that they have no conflicts of interest. There was no breach of ethical rules and guidelines. All materials and information were not subject to confidentiality restrictions.

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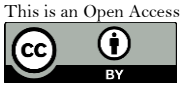

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Regulatory Intensification and Pension Fund Performance: Evidence from Pension Funds in Brazil

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ABSTRACT

Purpose: This paper evaluates the causal impact of prudential regulatory intensification on Brazilian closed pension funds classified as systemically important (EFPC-ESI). The study aims to determine whether stricter governance, reporting, and compliance requirements, implemented as an asymmetric regulatory shock in 2019, produced structural improvements in these entities.

Design/methodology/approach: The study employed an empirical strategy using annual panel time-series data from 2014–2023. It compares EFPC-ESI (treatment group) with comparable non-ESI funds (control group). The methodology combines structural break tests and interaction-based regressions to distinguish persistent regulatory effects from transitory dynamics within the same institutional environment.

Findings: The results show that regulatory intensification generated statistically significant structural changes in capital-related indicators, particularly total assets and consolidated performance. However, effects on population and sustainability measures were found to be limited or non-persistent. The evidence suggests that heightened prudential supervision acts primarily as an amplifier of existing financial trajectories rather than producing broad structural shifts.

Research limitations/implications: The findings raise relevant questions about regulatory inflation and the cost–benefit trade-offs in pension fund supervision. A potential limitation involves the specific focus on the Brazilian institutional environment, which may require further comparative studies in other emerging markets to generalize the impact of asymmetric regulatory shocks.

Originality/value: This study contributes to the literature by providing a quasi-experimental analysis of regulatory shocks within the pension fund sector. It offers a unique perspective on how "systemically important" classifications affect institutional performance, shifting the debate from simple compliance to the actual structural efficacy of prudential supervision.

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1. Introduction

Pension funds play a central role in modern financial systems by intermediating long-term savings, allocating capital, and contributing to macroeconomic stability. Because of their size, interconnectedness, and fiduciary responsibilities, large pension funds are often subject to heightened regulatory oversight, particularly when their potential failure poses systemic risks. As a result, regulators increasingly adopt differentiated supervisory regimes that impose stricter governance and compliance requirements on systemically important entities.

From an economic perspective, however, the effects of intensified prudential regulation are theoretically ambiguous. On the one hand, stronger supervision may enhance governance, reduce excessive risk-taking, and improve solvency, thereby increasing confidence among participants and beneficiaries. On the other hand, additional regulatory burdens may generate substantial compliance costs, reduce managerial flexibility, and divert resources away from productive investment activities, potentially leading to what the literature defines as regulatory or normative inflation (Stigler, 1971; Baldwin, Cave and Lodge, 2012).

This trade-off has gained renewed attention in recent empirical research. Contemporary studies emphasize that institutional and regulatory shocks rarely generate homogeneous effects, instead interacting with pre-existing

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structural characteristics of organizations and markets. Evidence from emerging economies suggests that regulatory intensity may amplify existing trajectories rather than induce broad-based structural transformation, particularly in highly regulated sectors (Andreoli, 2023; de Campos, 2023). These findings reinforce the importance of evaluating regulatory interventions through a causal and context-sensitive econometric lens.

The pension fund industry represents a particularly relevant environment for such analysis. Pension funds manage large pools of long-term savings, operate under strict fiduciary constraints, and are deeply embedded in financial markets. International regulatory frameworks, such as the OECD Core Principles of Private Pension Regulation and the G20/OECD Principles of Corporate Governance, explicitly recommend proportionality and risk-based supervision, arguing that regulatory intensity should reflect fund size, complexity, and systemic relevance (OECD, 2016; OECD, 2023). Despite these guidelines, recent studies highlight that the economic consequences of differentiated regulation remain underexplored, especially outside advanced economies (Smolski et al., 2024).

Brazil offers a unique institutional setting to address this gap. The Brazilian closed pension fund system (Entidades Fechadas de Previdência Complementar – EFPC) manages assets exceeding one trillion reais and represents a significant share of domestic long-term investment. In response to concerns related to governance failures, financial misconduct, and systemic risk, the national supervisory authority — the Superintendência Nacional de Previdência Complementar (Previc) — implemented a prudential framework that classifies a subset of large pension funds as systemically important entities (ESI). These funds became subject to enhanced supervision, stricter governance requirements, and additional reporting obligations, while other comparable funds continued to operate under the standard regulatory regime.

The consolidation of this differentiated supervisory framework around 2019 created an asymmetric regulatory shock within a homogeneous institutional environment. Systemically important pension funds were exposed to a discrete increase in regulatory intensity, whereas non-ESI funds were not. This setting enables a quasi-experimental evaluation of the economic effects of prudential regulatory intensification, isolating regulatory impacts from broader macroeconomic dynamics affecting the pension fund sector as a whole.

This paper examines whether enhanced prudential supervision of systemically important Brazilian closed pension funds generated persistent structural changes in financial and demographic outcomes. Using annual data from 2014 to 2023, we compare EFPC classified as ESI (treatment group) with comparable non-ESI funds (control group). Our empirical strategy combines structural break tests and interaction-based regressions to distinguish between transitory adjustments and lasting changes in key indicators such as total assets, performance, solvency, population, and sustainability.

By focusing on the economic consequences of differentiated regulation rather than its legal design, this study contributes to the applied literature on regulatory economics and pension fund governance. In line with recent empirical work on institutional shocks and economic performance (Andreoli, 2023; Smolski et al., 2024), the paper provides evidence on whether intensified prudential supervision enhances financial stability or primarily reinforces existing trajectories at the cost of increased regulatory burden. The findings are directly relevant for policymakers and regulators seeking to balance financial stability, governance quality, and regulatory efficiency in the supervision of large institutional investors.

2. Data and Empirical Strategy

2.1 Data and sample construction

The empirical analysis is based on annual data for Brazilian closed pension funds (Entidades Fechadas de Previdência Complementar – EFPC), obtained from official regulatory and supervisory records compiled by the Superintendência Nacional de Previdência Complementar (Previc). The dataset covers the period from **2014 to 2023**, allowing the comparison of pre- and post-regulatory intensification dynamics.

The treatment group consists of **systemically important pension funds (EFPC-ESI)**, as formally classified by the supervisory authority according to size, relevance, and systemic risk criteria. These entities became subject to enhanced prudential supervision, stricter governance requirements, and additional reporting obligations. The control group comprises **non-ESI pension funds with total assets above R$ 2 billion**, ensuring comparability in terms of scale and institutional characteristics while excluding entities directly affected by the intensified regulatory framework.

The final sample includes **17 EFPC-ESI** in the treatment group and **52 non-ESI funds** in the control group. All variables are constructed consistently across entities and years, following regulatory definitions. The main outcome variables analyzed are:

(i) population size (number of participants),

(ii) total assets,

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(iii) applied expenditure,
(iv) consolidated performance,
(v) sustainability index, and
(vi) absolute deviation measures associated with volatility and stability.

To mitigate scale effects and improve comparability across funds, variables expressed in monetary terms are analyzed in levels and growth-adjusted form, as reported in the original regulatory datasets.

Variable Definitions and Measurement. The key outcome variables analyzed in this study are defined as follows:

Population: Number of active participants in the pension fund.

Total Assets: Book value of total assets in Brazilian Reais (R$), reported at year-end.

Applied Expenditure: Total expenses applied to pension operations, in R$.

Absolute Deviation of Assets: A volatility measure calculated as the absolute deviation of annual asset growth from its trend, capturing short-term instability (Adrian and Shin, 2010).

Consolidated Performance: Annual financial performance measured as the net result of pension operations, in R$.

Sustainability Index: A composite indicator ranging from 0 to 2, where values above 1 indicate that the fund's technical provisions are fully covered by its assets (Impavido et al., 2010).

2.2 Identification strategy and regulatory shock

The empirical identification exploits an asymmetric regulatory shock associated with the consolidation of prudential regulatory intensification in 2019. While all pension funds operate under the same macroeconomic environment and general regulatory framework, only EFPC classified as systemically important were subject to enhanced supervision and governance requirements.

This setting creates a quasi-experimental environment analogous to a difference-in-differences (DiD) design embedded in a time-series framework, where EFPC-ESI constitute the treated group and comparable non-ESI funds serve as the control group. The year 2019 is defined as the intervention point, consistent with the effective enforcement and operational consolidation of the intensified supervisory regime documented in the regulatory records.

2.3 Structural break analysis

To assess whether the regulatory shock is associated with persistent changes in the underlying data-generating process, the analysis first applies structural break tests. Specifically, Chow tests are employed to evaluate parameter stability before and after 2019 for each outcome variable and group.

The Chow test compares the fit of a pooled regression model with that of two sub-period regressions (pre- and post-2019), testing the null hypothesis of parameter stability. Rejection of the null indicates a structural break consistent with a regime change. This approach allows distinguishing between temporary fluctuations and lasting structural shifts associated with regulatory intensification.

2.4 Interaction-based regression models

To estimate the differential impact of regulatory intensification on EFPC-ESI, the study employs regression models with **time trends and interaction terms**, consistent with the econometric structure presented in the results files.

The baseline specification is given by:

$$Y_{it} = \alpha + \beta_1 ESI_i + \beta_2 Post_t + \beta_3 (ESI_i \cdot Post_t) + \gamma_t + \varepsilon_{it} \quad (1)$$

where Y_{it} represents the outcome variable for fund i in year t, ESI_i is a binary indicator for systemically important funds, $Post_t$ denotes the post-2019 period, $ESI_i \times Post_t$ captures the differential regulatory effect, and t is a linear time trend, and g_t denotes a linear time trend. This specification follows the standard difference-in-differences design adapted to a panel setting.

The coefficient $-_3$ is the parameter of interest, representing the causal effect of intensified prudential supervision on treated funds relative to the control group. Robust standard errors are used to account for heteroskedasticity.

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2.5 Time-series intervention and robustness checks

In addition to the regression framework, the analysis incorporates time-series intervention techniques to evaluate dynamic responses to the regulatory shock. For selected variables, ARIMA models with intervention components are estimated separately for treatment and control groups. These models capture autoregressive dependence and allow assessing whether post-2019 deviations are statistically distinguishable from historical dynamics.

3. Results

This section presents the econometric evidence on the effects of prudential regulatory intensification applied to systemically important Brazilian closed pension funds (EFPC-ESI). The analysis focuses on identifying whether the regulatory shock consolidated in 2019 generated persistent structural changes and differential post-event dynamics relative to comparable non-ESI funds.

Table 1 presents descriptive statistics for the main variables, separately for ESI and non-ESI funds. On average, ESI funds are substantially larger, with mean total assets of R$ 34.3 billion compared to R$ 4.3 billion for non- ESI funds. ESI funds also have higher applied expenditure, greater asset volatility, and a slightly lower sustainability index. The two groups exhibit similar patterns in population growth and consolidated performance. The full set of descriptive statistics is available in the online appendix.

Table 2 reports the results of structural break tests around 2019. Statistically significant breaks are detected for most capital-related indicators in both groups, particularly total assets and consolidated performance. These results indicate a change in the underlying data-generating process coinciding with the period in which enhanced supervisory requirements became fully operational. In contrast, demographic and sustainability-related indicators display weaker or mixed evidence of structural change, suggesting that the regulatory shock did not uniformly affect all dimensions of pension fund activity.

Table 3 summarizes the results from interaction-based regressions designed to capture the causal effect of regulatory intensification on EFPC-ESI after 2019. The baseline treatment coefficient (ESI) is positive and statistically significant for most financial variables, reflecting structural differences between systemically important and non-ESI funds. However, the interaction term identifying the differential post-2019 regulatory effect (Regulation × ESI) is statistically significant only for total assets and volatility-related measures. This indicates that regulatory intensification primarily amplified existing capital accumulation trajectories and improved stability, rather than generating broad performance gains.

Table 4 reports the complete regression results for the difference-in-differences specification. Each column corresponds to a separate regression. The interaction coefficient captures the causal effect of the regulatory intensification on treated funds relative to the control group.

The results indicate that the regulatory shock had a statistically significant differential effect on total assets ((b_3= 10.1, billion, p = 0.034) and on asset volatility ((b_3 = -0.0116), p = 0.0003). For the other outcomes—population, applied expenditure, consolidated performance, and sustainability index—the interaction terms are not statistically distinguishable from zero at conventional levels. This pattern suggests that the intensified supervision primarily amplified existing trajectories in balance- sheet size and stability, without generating broad-based improvements in demographic or sustainability indicators.

Taken together, the results suggest that prudential regulatory intensification in Brazil produced selective and economically meaningful effects, concentrated in balance-sheet size and stability. Other outcomes, such as population dynamics and sustainability indicators, exhibit limited responsiveness, consistent with transitory adjustments rather than persistent structural transformation.

Table 1: Descriptive Statistics by Group (2014-2023)

Variable	Group	N	Mean	SD	Median	Min	Max	Miss
Population	Non-ESI	468	2.37e4	2.59e4	1.67e4	2.03e3	2.12e5	0
Population	ESI	153	6.39e4	6.00e4	2.87e4	1.40e3	1.98e5	0
Total Assets	Non-ESI	468	4.29e9	2.11e9	3.63e9	8.71e8	1.22e10	0
Total Assets	ESI	153	3.43e10	5.11e10	1.62e10	2.89e7	2.69e11	0

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Expenditure	Non-ESI	468	1.72e7	1.14e7	1.50e7	1.91e6	8.53e7	0
Expenditure	ESI	153	8.43e7	8.31e7	5.33e7	138	3.54e8	0
Abs. Dev.	Non-ESI	468	0.004	0.002	0.004	7.56e-4	0.027	0
Abs. Dev.	ESI	153	0.012	0.035	0.003	9.75e-7	0.308	0
Performance	Non-ESI	468	1.67e3	2.79e3	1.10e3	45.1	2.20e4	0
Performance	ESI	153	2.43e3	4.07e3	1.35e3	0.017	2.12e4	0
Sust. Index	Non-ESI	468	1.02	0.117	1.00	0.323	1.68	0
Sust. Index	ESI	153	0.974	0.142	1.00	0.301	1.32	0

Table 2: Structural break tests around the 2019 prudential regulatory intensification

Variable	Group	Break year	F-statistic	p-value
Population	Non-ESI	2019	2.085	0.0007
Population	ESI	2019	2.749	<0.0001
Total assets	Non-ESI	2019	2.847	<0.0001
Total assets	ESI	2019	2.003	0.0013
Applied expenditure	Non-ESI	2019	2.682	<0.0001
Applied expenditure	ESI	2019	2.387	<0.0001
Consolidated performance	Non-ESI	2019	3.219	<0.0001
Consolidated performance	ESI	2019	2.641	<0.0001
Sustainability index	Non-ESI	2019	1.710	0.011
Sustainability index	ESI	2019	1.985	0.0015

Table 3. Summary of regulatory and treatment effects

Variable	ESI effect	2019 regulation	Regulation × ESI	Interpretation
Population	+	n.s.	n.s.	Structural size effect
Total assets	+	n.s.	+	Regulatory amplification
Applied expenditure	+	n.s.	n.s.	Persistent cost differences
Absolute deviation	+	n.s.	−	Reduced volatility
Consolidated performance	+	n.s.	n.s.	Performance gains unrelated to regulation
Sustainability index	−	n.s.	n.s.	Trade-off effect

The ESI coefficient captures baseline differences between treated and control funds, the regulation coefficient reflects common time effects, and the interaction term (Regulation × ESI) identifies the differential impact of regulatory intensification after 2019. Reported signs refer to statistically significant effects at conventional levels (<0.05).

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Table 4: Complete Regression Results

Dependent Variable	Estimate (-3)	Std. Error	Statistic	P-Value	Significant
Population	3,898.43	6,980.24	0.558	0.5767	No
Total Assets	1.01e+10	4.79e+09	2.119	0.0345	Yes
Absolute Deviation	-0.0116	0.0031	-3.664	0.0003	Yes
Sustainability Index	0.0163	0.0232	0.704	0.4815	No
Applied Expenditure	4,837,477	7,936,033	0.609	0.5423	No

4. Discussion

The results of this study indicate that prudential regulatory intensification targeted at systemically important Brazilian closed pension funds (EFPC-ESI) generated selective and asymmetric economic effects. Structural changes and differential post-2019 impacts are concentrated in capital-related indicators—particularly total assets and volatility measures—while demographic and sustainability outcomes exhibit limited or non-persistent responses. This pattern is consistent with a growing body of international evidence suggesting that intensified supervision primarily affects risk management, balance sheet size, and stability, rather than producing broad performance improvements.

The finding that regulatory intensification amplifies existing capital accumulation trajectories aligns with the literature on institutional investors and scale effects. Andonov, Bauer, and Cremers (2017) show that larger pension funds benefit from scale economies in investment management, governance, and access to sophisticated asset classes, which may be reinforced under stricter supervisory regimes. In this context, enhanced regulation may act less as a constraint and more as a coordinating mechanism that stabilizes and legitimizes growth paths already available to large funds.

At the same time, the absence of strong differential effects on population and sustainability indicators echoes prior evidence that regulatory tightening does not automatically translate into improved participant outcomes or broader welfare metrics. Rauh (2010) and Poterba, Rauh, Venti, and Wise (2007) document that pension fund regulatory and accounting reforms often affect funding behavior and asset allocation without materially altering participation dynamics or long-run benefit adequacy. The Brazilian evidence presented here is consistent with these findings, suggesting that intensified supervision primarily reshapes internal financial dynamics rather than external demographic engagement.

The reduction in volatility-related measures for EFPC-ESI after 2019 is particularly noteworthy. This result supports the interpretation that prudential supervision enhances risk discipline and reporting quality, consistent with international regulatory objectives. Similar effects are documented in studies analyzing the impact of tighter oversight on institutional investors and financial intermediaries (IMF, 2019; BIS, 2021). These studies emphasize that regulatory scrutiny can reduce excessive risk-taking and smooth balance sheet fluctuations, even when effects on average returns are modest.

From a regulatory economics perspective, the results also resonate with the theory of regulatory intensity and cost–benefit trade-offs. Baldwin, Cave, and Lodge (2012) argue that heightened regulation may improve governance outcomes while simultaneously imposing non-trivial compliance costs, potentially leading to diminishing marginal returns. Evidence from pension systems in OECD countries suggests that overly prescriptive supervision may crowd out managerial discretion without delivering proportional performance gains (OECD, 2016; OECD, 2023). The lack of strong post-2019 differential effects on performance and sustainability indicators in this study is consistent with this concern.

Importantly, the Brazilian case contributes to the literature by providing evidence from an emerging economy, where institutional capacity, enforcement credibility, and market depth differ from those of advanced economies. Studies focusing on Latin American pension systems highlight that regulatory reforms often interact with structural characteristics such as fund size concentration and governance heterogeneity, producing uneven outcomes across entities (Impavido, Lasagabaster, and García-Huitrón, 2010). The asymmetric effects observed between EFPC-ESI and non-ESI funds reinforce the relevance of proportionality in supervisory design.

To assess the practical relevance of the estimated effects, we compute the average percentage change in key variables from the pre- to post-period for each group. ESI funds grew by 39.2% in total assets after the regulatory intervention, compared to 37.3% for non-ESI funds. The similar growth rates underscore that the regulatory shock did not alter the relative growth trajectory of treated funds in a dramatic way, but rather reinforced pre-existing differences. The reduction in asset volatility for ESI funds corresponds to a decrease of about 0.012 in the absolute-deviation metric, which represents a meaningful improvement in stability given the sample mean.

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Our analysis relies on a panel of 74 unique pension funds (18 ESI, 56 non-ESI) observed over ten years (2014–2023), yielding 621 fund-year observations. While this sample is representative of the Brazilian closed pension fund sector and provides sufficient statistical power to detect moderate to large effects, it may be underpowered to identify very small effect sizes. We therefore interpret non-significant results as indicative of effects that are either absent or too modest to be reliably detected with the available data. Future research with longer time series or more granular data could help clarify whether the regulatory intensification had subtler impacts on dimensions such as sustainability or governance quality.

Overall, the findings suggest that prudential regulatory intensification should be interpreted primarily as a risk-stabilization and scale-amplification mechanism, rather than a universal tool for improving all dimensions of pension fund performance. While enhanced supervision appears effective in shaping capital accumulation and reducing volatility among systemically important funds, its ability to deliver broader socioeconomic or sustainability gains remains limited. This reinforces recent calls in the literature for complementary policy instruments that address participant engagement, long-term adequacy, and cost efficiency alongside prudential oversight.

5. Conclusion

This paper examined the economic effects of prudential regulatory intensification applied to systemically important Brazilian closed pension funds (EFPC-ESI). Exploiting the asymmetric regulatory shock consolidated in 2019, we compared treated and non-treated funds within the same institutional environment to assess whether enhanced supervision generated persistent structural changes or merely transitory adjustments.

The results indicate that intensified prudential regulation produced selective and economically meaningful effects. Structural breaks and differential post-2019 dynamics are concentrated in capital-related indicators, particularly total assets and measures of volatility, suggesting that enhanced supervision strengthened balance-sheet stability and reinforced existing accumulation trajectories. In contrast, demographic outcomes and sustainability indicators exhibit limited or non-persistent responses, indicating that regulatory intensification did not translate into broad-based improvements across all dimensions of pension fund activity.

These findings contribute to the applied econometric literature by providing evidence that differentiated prudential supervision functions primarily as a risk-stabilization and scale-amplification mechanism, rather than as a universal driver of performance enhancement. While heightened oversight appears effective in reducing instability and supporting large funds' operational scale, its marginal impact on participation and sustainability outcomes remains limited.

Since the implementation of the ESI framework in 2019, Previc has continued to refine its supervisory approach, introducing additional governance guidelines and risk-based monitoring tools. These subsequent changes, however, fall outside the observation window of the present study and do not affect the identification of the initial regulatory shock. Future work could examine whether the cumulative effect of successive regulatory adjustments leads to different long-run outcomes.

From a policy perspective, the results underscore the importance of regulatory proportionality. Prudential intensification targeted at systemically important institutions may improve financial stability, but it should be complemented by additional policy instruments if broader objectives—such as long-term sustainability, participant engagement, or cost efficiency—are to be achieved. Future research may extend this analysis by incorporating fund-level risk measures, investment allocation channels, and longer post-regulation horizons to further assess the long-term welfare implications of differentiated pension fund supervision.

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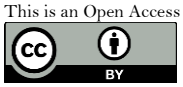

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ESG Ratings and Underpricing on Emerging Markets: Case of European IPOs between 2014 and 2023

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ABSTRACT

Purpose:
Given the increasing salience of Environmental, Social, and Governance (ESG) criteria in investment decisions, this study investigates the extent to which pre-Initial Public Offering (IPO) ESG ratings function as a mechanism to reduce information asymmetry and, consequently, influence the phenomenon of IPO underpricing. The analysis is focused on a sample of IPOs within developed and emerging European markets.

Design/methodology/approach:
An Ordinary Least Squares (OLS) regression analysis is employed to empirically examine the relationship between the RepRisk rating (as a proxy for corporate sustainability performance) and the Initial Return (IR) as the measure for underpricing. The sample comprises 1,927 European IPOs executed between 2014 and 2023. Model robustness is ensured through the inclusion of control variables covering firm, offer, and market characteristics.

Findings:
The results demonstrate a conditional influence of the ESG rating on underpricing. For the overall sample, no significant effect of the RepRisk rating on underpricing was identified. However, a sub-analysis of rated companies during the period prior to the COVID-19 pandemic (2014-2019) revealed a statistically significant negative relationship between the ESG rating and underpricing. This finding supports the hypothesis that higher ESG transparency mitigates information asymmetry. Conversely, for IPOs originating from European emerging markets, no significant influence of the ESG rating could be established.

Research limitations/implications:
The findings suggest that the role of ESG ratings in alleviating IPO underpricing is highly dependent on the observation period and the specific submarket. The assumption that ESG activities universally contribute to greater market certainty during times of crisis could not be confirmed. Future research should address the heterogeneity of European regulatory frameworks and incorporate ratings from multiple agencies to enhance the generalizability of these conclusions

Originality/value:
This study makes a novel contribution to the literature by explicitly linking pre-IPO Environmental, Social, and Governance (ESG) ratings to the underpricing of Initial Public Offerings (IPOs) in both developed and emerging European markets. While prior research has examined the role of ESG in post-IPO performance and firm valuation, few studies have investigated its function as a signal to mitigate information asymmetry during the IPO process. By employing RepRisk ratings as a proxy for corporate sustainability performance, this research provides a unique empirical examination of how ESG considerations can influence initial investor perceptions and pricing outcomes.
The study's value lies in its dual contribution to theory and practice. Theoretically, it extends the signaling and information asymmetry frameworks by incorporating ESG metrics as a credible pre-IPO signal to investors. Practically, the findings offer actionable insights for issuers, underwriters, and policymakers on how sustainability practices and ESG disclosure can shape investor behavior and potentially reduce the cost of capital associated with IPOs. Additionally, the inclusion of both developed and emerging European markets provides a comparative perspective, enhancing the generalizability of the results

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and highlighting market-specific dynamics in ESG signaling and IPO underpricing.

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1. Introduction

The contemporary socioeconomic landscape is profoundly shaped by major social and geopolitical challenges, including escalating social inequality, advancing climate change, and persistent political conflicts. This context has engendered a heightened sense of uncertainty, particularly among younger demographics, leading to a notable shift in consumer behavior and, consequently, a growing demand for sustainable products (Boluda-Verdú et al., 2022). This paradigm shift has also extended to financial markets, evidenced by a significant increase in the supply of sustainable investment products in recent years (Driessen, 2021). As a result, the strategic integration of sustainability into corporate business models has assumed a pivotal role for investors, directly influencing their capital allocation decisions (Sciarelli et al., 2021).

For investors, the acquisition of reliable information on ESG criteria during an IPO remains a challenge. The limited availability of credible data sources hinders a thorough due diligence process and comprehensive risk assessment prior to a company's public debut (Ilhan et al., 2023). In addition to voluntary disclosures of ESG data within IPO prospectuses, ESG ratings serve as a critical mechanism for evaluating a company's sustainability efforts. These ratings, issued by a variety of agencies, can be commissioned by companies themselves to voluntarily communicate ESG-related information. While ESG ratings aim to provide an objective assessment of corporate sustainability, achieving complete neutrality in scoring is not attainable (Jámbor & Zanócz, 2023). Discrepancies between ratings from different agencies are common, often stemming from variations in the weighting and importance assigned to specific sustainability factors (Escrig-Olmedo et al., 2019).

The increasing importance of ESG ratings and sustainability strategies has begun to fundamentally reshape investor decision-making, concurrently with a significant rise in academic and scientific interest in these subjects. This evolution has prompted a revaluation of established economic concepts, such as market efficiency and regulatory mechanisms (Friede et al., 2015). Investors now systematically incorporate ESG criteria into their investment strategies, either to divest from companies that do not align with their sustainability values or to actively seek out firms with superior ESG performance that are congruent with their financial objectives (Nakajima et al., 2021). In the specific context of IPO pricing, at least three distinct mechanisms through which ESG ratings may influence underpricing can be identified. First, ESG ratings may function as a signal of lower ex ante uncertainty: a strong sustainability profile reduces the informational gap between issuer and investor, thereby narrowing the underpricing discount required to compensate uninformed investors (Rock, 1986). Second, ESG performance may serve as a marker of overall firm quality, with high-rated firms being perceived as better governed and more resilient, attracting a broader and more confident investor base. Third, ESG ratings may operate as a reputational or regulatory signal whose relevance varies systematically across market types: in developed markets with mature ESG infrastructure, ratings are more credible and widely understood, whereas in emerging markets with less developed regulatory frameworks and lower investor familiarity with ESG metrics, the same signal may carry less weight. These three mechanisms generate distinct empirical predictions and help explain why the ESG effect on underpricing is found to be conditional on market context and observation period.

In the context of emerging markets, ESG exerts a particularly profound influence. Here, enhanced ESG performance is not merely perceived as a risk mitigation strategy but as a catalyst for economic and social development. Investments that adhere to ESG principles can contribute to elevating local standards in environmental protection, labor rights, and corporate governance. For firms from these markets, robust ESG disclosure can build trust among international investors, potentially lowering their cost of capital and improving access to global markets. A positive ESG track record can therefore serve as a signal of corporate quality, attracting investors who might otherwise be deterred by perceived higher risks (Huang, 2021).

In the specific context of IPOs, ESG factors and ratings play a vital role in shaping corporate communication strategies throughout the offering process, thereby ensuring that investors receive relevant data for informed decision-making (Zumente & Lāce, 2021). Transparent and effective communication is paramount for both the success of an IPO and the long-term strength of the company's capital structure. The phenomenon of IPO underpricing—defined as the setting of an initial share price below the intrinsic market value—is often indicative of information inefficiencies and asymmetries within financial markets (Rock, 1986). While short-term fluctuations are common, the persistent valuation gap between offering prices and subsequent market values is a widely documented trend across global stock exchanges (Rehkugler & Schenek, 2001). This observation suggests a potential correlation between the level of ESG information disclosed and the magnitude of IPO underpricing.

This study aims to empirically analyze the influence of pre-IPO ESG ratings and to investigate the relationship between the publication of this information and the underpricing effect. Furthermore, the analysis will **examine differences between developed and emerging markets in Europe.**

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2. Research Hypothesis

To evaluate the hypothesized effects on the dependent variable, the study employs an Ordinary Least Squares (OLS) regression, a method well-suited for the analysis of IPO-related data. The linear regression framework is utilized to investigate the relationship between the dependent and independent variables. A dedicated section of the analysis further concentrates on the subsample of firms with an ESG rating and the relationship between the ESG score and underpricing:

$$\textbf{H1}: IR_{ad} = \alpha + ESG_{rating} + \ln(\text{Assets}) + \ln(\text{revenues}) + \ln(\text{offer price}) + \ln(age) + VC_{dummy} + UW_{ranking}$$

For this model, the analysis places particular emphasis on rated firms as well as European companies operating in emerging markets.

3. Methodology and Data

This study examines the influence of ESG ratings on IPO underpricing drawing on a sample of IPOs from the European capital market. The sample includes IPOs between 2014 and 2023. The Refinitiv Eikon database from the London Stock Exchange Group (LSEG) was used to obtain the primary data. This database contains essential information on IPO offer prices and closing prices, issue date, economic sectors, issuing bank, use of venture capital and financial metrics.

Firms that did not successfully complete their IPOs or failed to disclose financial ratios were removed from the dataset, as these ratios are essential for constructing and analyzing the control variables. In order to ensure comparability between the various IPOs in different countries, the respective national currencies were converted into euros on the reporting dates.

To ensure that the ESG rating employed in this study remains objective and free from potential bias associated with company self-reporting, ratings from the RepRisk ESG database were utilized. RepRisk focuses primarily on ESG-related risks, drawing exclusively on external and publicly available information. The database employs machine learning tools to systematically collect data on a daily basis, which is then transformed into a quantifiable score—the RepRisk Index (RRI). This score determines the RepRisk Rating (RRR), ranging from AAA to D, thereby enabling comparability and benchmarking across firms.

Daily ESG ratings for the period 2014 to 2023 were obtained for all ISINs contained in the Refinitiv Eikon dataset through the Wharton Research Data Services (WRDS) platform.

3.1 Variables

3.1.1 Dependent Variable

The dependent variable of this study is IPO underpricing, measured by the initial return (IR). The principal independent variable is the pre-IPO ESG rating, operationalised via the RepRisk rating. ESG disclosure is not treated as a separate dependent variable in this model; rather, the RepRisk rating serves as an objective, externally sourced proxy for a firm's sustainability transparency, thereby capturing the information-reducing function of ESG disclosure within a single composite measure.

Alongside voluntary ESG information disclosure, underpricing is examined as a dependent variable, serving as a proxy for the degree of uncertainty. The assessment of underpricing, as well as the associated opportunity costs for issuers, necessitates a quantitative framework in which the initial return (IR) functions as the primary measure. The initial return is calculated as follows:

$$IR = \frac{(P_{o,t} - E_i)}{E_i}$$

3.1.2 Independent Variables

The assigned values are not arbitrary but reflect two established principles from the credit rating and ESG literature. First, the upper range of the scale (AAA = 0.9 to BBB = 0.6) is spaced at equal intervals of 0.1, consistent with the assumption that incremental improvements in high ESG performance carry roughly symmetric informational value for investors. Second, the lower end of the scale is deliberately compressed (B = 0.3, CCC = 0.2, CC = 0.1, C = 0.001), reflecting the well-documented asymmetry in reputational and financial risk: a deterioration into sub-investment-grade ESG territory is associated with disproportionately severe consequences for firm reputation, investor confidence, and access to capital (Cantor & Packer, 1996). This non-linear treatment of the lower tail is analogous to approaches used in the sovereign and corporate credit rating literature, where the distance between low-grade categories is understood to carry greater risk weight than equivalent steps at the top of the scale. The value of 0.001 assigned to the lowest rating category (C) — rather than 0.0 — preserves the distinction between a rated firm at the bottom of the scale and an unrated firm, for which a score of 0.0 is reserved. It is acknowledged that this transformation imposes quasi-cardinal assumptions on an inherently ordinal variable; the chosen scaling is therefore

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presented as a theoretically motivated approximation rather than a precise measurement, and its implications for the interpretation of regression coefficients should be borne in mind when reading the results.

Table 1: ESG Ratings – Value

Rating Score	Value
AAA	0.9
AA	0.8
A	0.7
BBB	0.6
BB	0.5
B	0.3
CCC	0.2
CC	0.1
C	0.001
Not rated	0.0

3.1.3 Control variables

The control variables are classified into three categories: firm characteristics, offer characteristics, and market characteristics.

Firm characteristics include proxies for company size, such as revenues, which are expected to influence investor decision-making. Larger firms are generally perceived as less risky, implying that companies with higher revenues should exhibit lower levels of underpricing (Leone et al., 2007). Total assets are included as an additional size-related proxy, as they, too, can mitigate informational asymmetries and thereby reduce uncertainty. Firm age—measured as the difference between the founding year and the IPO year—is also incorporated. Older firms typically provide more extensive financial histories and greater publicly available information, which diminishes ex-ante uncertainty and, consequently, IPO underpricing (Engelen & van Essen, 2010).

Market characteristics are captured by factors such as venture capital (VC) involvement. IPOs backed by VC investors often exhibit higher underpricing relative to those without such backing, potentially reflecting the elevated perceived risk associated with VC-financed firms (Lowry & Schwert, 2004). Similarly, listings on the NASDAQ are frequently associated with greater underpricing, as the exchange is characterized by smaller, younger, and more technology-oriented firms (Corwin, 2003).

Offer characteristics include the reputation of the bookrunner responsible for managing the IPO process. Issuers engaging highly reputable underwriters generally experience lower underpricing, as the credibility of a prestigious bookrunner conveys reliability and trustworthiness to investors. In this study, underwriter reputation is operationalized using Ritter's underwriter ranking, scaled from 0 to 9.1, with particular emphasis placed on the lead underwriter identified in the dataset.

Source: (Author's construct, 2019)

3.2 Descriptive statistics

For the period from 2014 to 2023, 1,927 observations of IPOs were made for which data on the aforementioned variables were available. Of the total number of observations, 198 companies can be classified as emerging markets. Based on the classification of the International Monetary Fund (IMF), the following countries were classified as emerging markets: Bulgaria, Czech Republic, Greece, Hungary, Poland, Romania, Russia, Turkey, and Ukraine. The Czech Republic and Greece were included in this grouping even though they are now considered emerged markets. The distribution of IPOs is roughly the same across the observation period, with 2021 being an outlier. Figure 1 shows the stagnant to slightly negative trend in the number of IPOs per year.

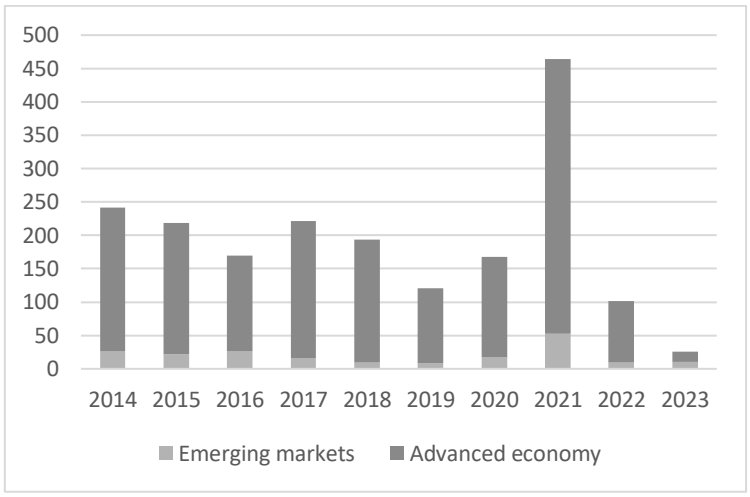

Figure 1: European IPOs between 2014 and 2023

The proportion of IPOs from emerging markets plays a minor role in the overall picture (10.28%). The distribution remains relatively constant over time. Between 2017 and 2019, the rate fell from 15.88% to 7.24%, 4.64%, and 6.61%. The distribution peaked in 2023, although only 26 IPOs were observed in total.

If only observations with a RepRisk rating are taken into account, the number of observations drops to 427. This corresponds to 22.16% of the total sample. The relative share of IPOs from emerging markets remains roughly the same on average (9.37%). The overall trend, including the 2021 outlier, mirrors the pattern observed in Figure 1. The relative share of rated IPOs falls from an initial 30.58% in 2014 to a low of 9.80% in 2022. A stable level of approximately 19% can be seen in the years 2017–2019. Subsequently, the relative share of IPOs with a RepRisk rating falls annually (Figure 2).

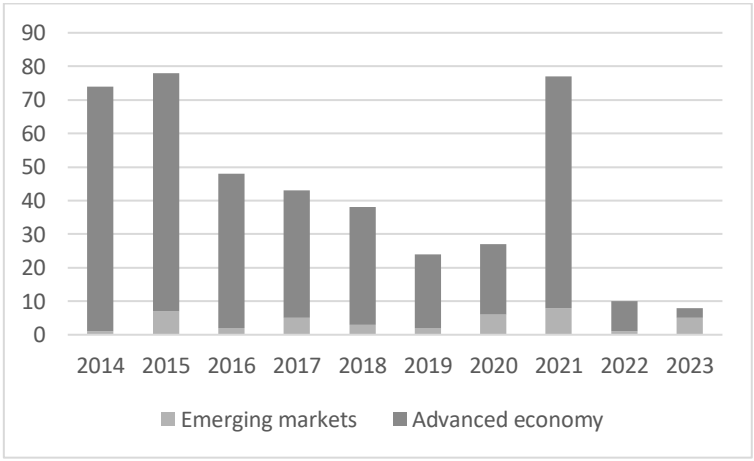

Figure 2: European IPOs with RepRisk Rating between 2014 and 2023

Table 2 shows a summary of the descriptive statistics for the total sample, grouped into the following subcategories: ESG rating, transaction characteristics, and firm and market characteristics. The average underpricing of the total sample is 23.4%, with average assets per IPO amounting to €1,498,969 million and revenues amounting to €364,842 million. Furthermore, the average bookrunner ranking is 2.764, which indicates that a large proportion of the sample has no rating, as the rating scale ranges from 0 to 9.1. This may be due to the high proportion of European bookrunners who have no rating in Ritter's underwriting ranking. The proportion of companies supported by venture capital is low at 3.27% compared to other capital markets (e.g., the US 28.3%) (Zasepa, 2025). The average age of the companies is 20 years at the time of their respective IPOs. Approximately 21.07% of the companies have a RepRisk rating at the time of their IPO, with an average rating of 17.25%.

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Table 2: Summary statistics: European IPOs between 2014 and 2023

	n	Mean	sd	IQR	Min	p25	Median	p75	Max
ESG rating characteristics									
Rating before IPO	1927	0.1725	0.3331	0.0000	0.0000	0.0000	0.0000	0.0000	0.9000
Rating before IPO (dummy)	1927	0.2107	0.4079	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Transaction characteristics									
Total Assets	1927	1,498.969	13,129.207	203.913	-	7.478	37.118	211.391	412,863.073
Total Revenues	1927	364.842	1,743.789	122.165	-407.456	0.718	17.734	122.884	41,810.467
Underpricing	1927	0.234	5.090	0.193	- 1.000	- 0.027	0.032	0.166	167.323
Offer Price	1927	7.526	12.128	7.852	0.010	1.508	3.802	9.360	240.000
Bookrunner.ranking	1927	2.764	3.076	3.000	1.001	1.001	1.001	4.001	9.001
Firm and market characteristics									
Company age	1927	20	28	17	1	6	12	23	441
Venture Capital Dummy	1927	0.0327	0.1779	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

If only companies that received a RepRisk rating during the observation period at the time of their IPO are considered, the number of observations drops to 427. The average rating of these companies is 0.77, which is between the scores A and AA. Compared to the overall sample, the average assets and revenues are significantly higher at EUR 5,121.547 million and EUR 985.737 million, respectively, indicating more established companies. This is supported by the higher average age of 28 years compared to 20 years. Underpricing is slightly higher at 25.1%, but at a similar level to the overall sample. The bookrunner ranking is slightly higher at 4.25, which also indicates more established companies, as they work with well-known bookrunners. As in the overall sample, venture capital also plays a rather minor role at 5.15%. A summary of this data can be found in Table 3.

Table 3: Summary statistics: European IPOs RepRisk rated between 2014 and 2023

	n	Mean	sd	IQR	Min	p25	Median	p75	Max
ESG rating characteristics									
Rating before IPO	427	0.7785	0.1694	0.2000	0.1000	0.7000	0.9000	0.9000	0.9000
Rating before IPO (dummy)	427	0.9508	0.2165	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000
Transaction characteristics									
Total Assets	427	5,121.547	26,808.509	1,731.812	-	77.206	439.856	1,809.017	412,863.073
Total Revenues	427	985.737	2,435.231	819.014	-	35.450	215.900	854.464	18,446.285
Underpricing	427	0.251	5.045	0.157	- 1.000	- 0.025	0.023	0.132	103.944
Offer Price	427	11.313	17.700	11.059	0.013	2.791	5.800	13.850	240.000
Bookrunner.ranking	427	4.253	3.696	7.375	1.001	1.001	1.001	8.376	9.001
Firm and market characteristics									
Company age	427	28	34	30	1	8	16	38	250
Venture Capital Dummy	427	0.0515	0.2213	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

Table 4 below shows the distribution of ratings. In addition to the distribution of the total sample, the distribution for IPOs in emerging markets is also shown. In principle, a similar proportion of companies are rated in both segments (approx. 20%), but the distribution differs between segments. The total number shows a high concentration in the AAA range (11.11%), while among companies from emerging markets, the highest concentration is in the B rating level (5.05%), which was to be expected.

Table 4: Distribution RepRisk Rating

	Europe		Emerging Markets Europe	
Rating Score	**n**	**in %**	**n**	**in %**
AAA	214	11.11%	1	0.51%
AA	78	4.05%	7	3.54%
A	59	3.06%	3	1.52%
BBB	33	1.71%	3	1.52%
BB	22	1.14%	8	4.04%
B	13	0.67%	10	5.05%
CCC	6	0.31%	6	3.03%
CC	2	0.10%	2	1.01%
C	0	0.00%	0	0.00%
not rated	1500	77.84%	158	79.80%

If the focus is placed solely on the subsample of IPOs from emerging markets, a significantly higher underpricing of 45.3% on average can be observed (Table 5). Furthermore, due to other market conditions, assets and revenues are on average lower than IPOs from other European markets. VC participation is similar to the overall sample (4.04%), while companies from emerging markets are slightly younger on average at 18 years.

Table 5: Summary statistics: European IPOs RepRisk Rating between 2014 and 2023 - Emerging Markets

	n	Mean	sd	IQR	Min	p25	Median	p75	Max
ESG rating characteristics									
Rating before IPO	198	0.0949	0.2163	0.0000	0.0000	0.0000	0.0000	0.0000	0.9000
Rating before IPO (dummy)	198	0.1111	0.3151	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
Transaction characteristics									
Total Assets	198	626.274	2,637.475	173.458	-	14.600	48.622	188.058	22,764.118
Total Revenues	198	432.692	2,197.064	100.811	-407.456	6.232	27.961	107.043	27,064.290
Underpricing	198	0.453	7.406	0.205	- 1.000	- 0.035	0.024	0.170	103.944
Offer Price	198	5.034	6.980	6.223	0.013	0.898	2.088	7.121	51.139
Bookrunner.ranking	198	2.010	2.586	-	1.001	1.001	1.001	1.001	9.001
Firm and market characteristics									
Company age	198	18	14	15	1	9	16	24	71
Venture Capital Dummy	198	0.0404	0.1974	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000

If the observations are broken down by economic sector as shown in Table 6, different conclusions can be drawn regarding underpricing. This is particularly pronounced in the real estate and utilities sectors. At the same time, these sectors account for a large proportion of IPOs in emerging markets. Another notable feature is that companies in the consumer cyclicals, energy, basic materials, and consumer non-cyclicals sectors have a higher ESG rating (> 25.0%) than other sectors. Since the available liquidity on capital markets in emerging markets can be limited, a modification of underpricing was made (Donadelli & Prosperi, 2012). In order to make a statement about the short-term effect of underpricing in these specific capital markets, underpricing was determined using the average closing price of the 30 days following the IPO. The table below shows that this can lead to different statements about underpricing. For example, underpricing in the utilities sector falls from 2.23 to 1.41. In order to make a complete statement about the underpricing effect in emerging markets, both underpricing and modified underpricing are taken into account in the regression analysis.

Table 6: Summary statistics: European IPOs by economic Sector between 2014 and 2023

Economic Sector	n	Rating before IPO	Rating before IPO (dummy)	Total Assets	Total Revenues	Underpricing
Academic & Educational Services	8	0.1125	0.1250	47.971	38.541	-0.0522
Basic Materials	101	0.2396	0.2871	933.819	644.554	0.1404
Consumer Cyclicals	296	0.2601	0.3209	774.830	465.587	0.0323
Consumer Non-Cyclicals	90	0.2267	0.2667	515.851	372.240	0.0993
Energy	62	0.2903	0.3226	1,451.484	1,179.313	0.0630
Financials	265	0.1940	0.2491	6,100.844	633.593	-0.0074
Government Activity	5	0.0000	0.0000	3.083	4.104	0.0384
Healthcare	271	0.0923	0.1107	214.078	134.937	0.6594
Industrials	336	0.1780	0.2232	1,577.376	332.872	-0.0170
Institutions, Associations & Organizations	1	0.0000	0.0000	0.089	-	0.1095
Real Estate	64	0.1453	0.1719	725.134	154.885	1.5594
Technology	381	0.1066	0.1260	337.628	122.155	0.0993
Utilities	47	0.1234	0.1489	1,026.539	434.465	2.2324

Economic Sector	Underpricing (modified)	Offer Price	Bookrunner.ranking	Company age	Venture Capital Dummy	Emerging Market
Academic & Educational Services	-0.0522	4.8075	1.0010	18.25	0.0000	0 (0%)
Basic Materials	0.0698	5.3333	2.7270	30.47	0.0000	21 (20.79%)
Consumer Cyclicals	0.0226	7.9505	3.0623	26.83	0.0709	25 (8.45%)
Consumer Non-Cyclicals	0.0504	6.3639	2.1410	38.80	0.0333	16 (17.78%)
Energy	-0.0235	7.1782	2.8432	9.85	0.0161	8 (12.9%)
Financials	0.0619	7.8988	3.7354	16.12	0.0151	22 (8.3%)
Government Activity	0.0384	2.2940	1.6010	15.60	0.0000	0 (0%)
Healthcare	0.6546	8.8835	3.1001	12.63	0.0517	16 (5.9%)
Industrials	0.0113	8.4583	2.4202	26.20	0.0208	36 (10.71%)
Institutions, Associations & Organizations	0.1095	0.0546	1.0010	3.00	0.0000	0 (0%)
Real Estate	1.5144	6.8961	2.6485	17.22	0.0156	12 (18.75%)
Technology	0.0892	6.3297	2.2225	14.84	0.0289	29 (7.61%)
Utilities	1.4198	7.3920	2.0937	14.64	0.0213	13 (27.66%)

4. Results

The tables below present the results of the OLS regression analyses for the full European IPO sample (Table 7) and the subsample of rated firms (Table 8). Each table reports coefficient estimates, standard errors, and significance levels for all explanatory variables. The bivariate correlations are provided as supplementary context only and should not be interpreted as the primary evidence. Across both specifications, a strong negative and statistically significant relationship (at the 99% confidence level) is observed between the offer price and underpricing. This finding is

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contrary to signaling theory, in which a higher offer price would be expected to convey positive information and reduce underpricing; instead, the negative coefficient suggests that higher-priced offerings are associated with lower initial returns, possibly reflecting selection effects among larger, more established issuers.

Table 7: OLS Regressions Results: European IPOs between 2014 and 2023

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	0.45106	0.28793	1.567	0.1174	
Bookrunner.ranking	0.01703	0.04454	0.382	0.7022	
ln_age	0.08394	0.24869	0.338	0.7358	
ln_assets	0.30352	0.1715	1.77	0.0769	.
ln_offer.price	-1.27339	0.21484	-5.927	3.65E-09	***
ln_revenues	-0.12908	0.16245	-0.795	0.427	
Rating_value	-0.04336	0.38279	-0.113	0.9098	
VC.Dummy	0.06025	0.65126	0.093	0.9263	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 8: OLS Regressions Results: European IPOs (rated) between 2014 and 2023

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	2.63105	1.40436	1.873	0.0617	.
Bookrunner.ranking	0.02038	0.0752	0.271	0.7865	
ln_age	-0.16144	0.46579	-0.347	0.7291	
ln_assets	0.46281	0.32782	1.412	0.1588	
ln_offer.price	-2.54715	0.48498	-5.252	0.00000024	***
ln_revenues	0.27642	0.28053	0.985	0.325	
Rating_value	-2.71968	1.45251	-1.872	0.0618	.
VC.Dummy	-0.08601	1.07088	-0.08	0.936	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

No further significance can be identified in either sample with regard to the control variables. The situation is similar with the ESG rating. Neither in the rated sample nor in the overall sample does the RepRisk rating have an impact on underpricing. This is contrary to expectations, which would suggest that a positive ESG rating would have a negative impact on underpricing by reducing information asymmetries (Horn, 2023).

Since part of the period under review coincides with the COVID-19 pandemic and the conflict between Russia and Ukraine, a modified review horizon for the years 2014–2019 will be used in the following. Crises and other global events can have a significant impact on investor behavior and shift the parameters according to which trades are executed. Looking at the rated companies for the period 2014–2019 (Table 9), a strong significance can be observed between the offer price and underpricing, as in the previous regression analysis. There is a significant change with regard to the ESG rating: the influence of RepRisk ratings in a rated sample is statistically significant and negative at a confidence level of 99%. This is consistent with the assumption that the rating reduces information asymmetry and consequently reduces underpricing.

Table 9: OLS Regressions Results: European IPOs (rated) between 2014 and 2019

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	8.73002	2.36456	3.692	0.000265	***
Bookrunner.ranking	0.03712	0.09824	0.378	0.705768	
ln_age	-0.27578	0.62335	-0.442	0.658507	
ln_assets	0.34533	0.43945	0.786	0.432599	
ln_offer.price	-4.13865	0.68714	-6.023	5.05E-09	***
ln_revenues	0.48659	0.38019	1.28	0.201593	
Rating_value	-8.69642	2.3774	-3.658	0.000301	***
VC.Dummy	-0.09394	1.23109	-0.076	0.939225	

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

When the sample of emerging market IPOs is examined in isolation, the offer price remains, as in the full European sample, a significant variable (Table 10). The RepRisk rating has no significant influence on underpricing. No other significant variables can be identified.

Table 10: OLS Regressions Results: European IPOs (rated) from Emerging Markets between 2014 and 2023

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.6063	12.3128	0.212	0.8337
Bookrunner.ranking	-0.1823	0.7467	-0.244	0.80872
ln_age	-5.0636	7.241	-0.699	0.48942
ln_assets	-0.8392	4.5532	-0.184	0.85493
ln_offer.price	-12.5098	3.9346	-3.179	0.00327 **
ln_revenues	4.1268	3.7566	1.099	0.28017
Rating_value	8.888	12.2208	0.727	0.47234
VC.Dummy	2.6923	9.7043	0.277	0.78323

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

If we consider the modified underpricing, which was calculated using the average price of the first 30 trading days, Table 11 shows that the offer price is not significant when taking into account a medium-term effect. However, it should be noted that the 40 rated IPOs from emerging markets represent a small sample. For this reason, a shorter period is not considered, as the number of rated IPOs in this subset would fall to 20 for the period 2014–2019. The non-significant result for ESG ratings in the emerging-market subsample should therefore be interpreted with considerable caution. Given the limited number of rated observations, the analysis may lack sufficient statistical power to detect a true effect even if one exists. The absence of significance is thus consistent with two distinct interpretations: either ESG ratings genuinely do not reduce information asymmetry in emerging European capital markets, or the available data are insufficient to identify such an effect. These findings are best treated as suggestive rather than definitive, and future research with larger rated samples from emerging markets is needed before stronger conclusions can be drawn.

Table 11: OLS Regressions Results modified: European IPOs (rated) from Emerging Markets between 2014 and 2023

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.2682	14.8989	-0.018	0.9857
Bookrunner.ranking	-0.2234	0.9035	-0.247	0.8063
ln_age	-5.1526	8.7619	-0.588	0.5606
ln_assets	-1.4899	5.5096	-0.27	0.7886
ln_offer.price	8.5749	4.7609	1.801	0.0811 .
ln_revenues	4.9251	4.5456	1.083	0.2867
Rating_value	8.4222	14.7875	0.57	0.573
VC.Dummy	-15.8387	11.7425	-1.349	0.1869

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

4.1 Robustness check

To ensure the econometric validity of the estimated model, the core assumptions of regression analysis were rigorously examined. The diagnostic process focused on assessing autocorrelation, correct functional form, and multicollinearity.

First, the presence of autocorrelation in the residuals was assessed using the Durbin-Watson (DW) test. The resulting DW values are close to the ideal value of 2.0, which strongly suggests the absence of significant serial correlation and thereby confirms the independence of the error terms.

Second, the structural integrity of the model's functional form was evaluated via the Ramsey RESET test. The calculated significance levels for this test are sufficiently high to retain the null hypothesis of correct model specification, effectively mitigating concerns regarding potential specification error.

Finally, multicollinearity among the explanatory variables was investigated using the Variance Inflation Factor (VIF). Given that all VIF values remain well below the commonly accepted critical threshold of 5 or 10, (Cleff, 2012) the existence of harmful multicollinearity within the current model can be definitively dismissed.

Collectively, these diagnostic results confirm the statistical robustness and validity of the estimated model.

5. Conclusion and Recommendations

This study investigated the influence of pre-IPO Environmental, Social, and Governance (ESG) ratings on the underpricing effect in initial public offerings (IPOs), specifically leveraging the RepRisk rating as an indicator. The central aim was to ascertain whether ESG ratings function as a mechanism to mitigate information asymmetry, thereby contributing an additional explanatory factor to the underpricing phenomenon. The empirical analysis focused on the both developed and emerging European IPO markets, selected due to their advanced stage of implementing and emphasizing ESG measures globally.

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The empirical results exhibit substantial consistency with established academic literature, although certain control variables yielded outcomes contrary to initial expectations. Notably, the research offers partial support for the premise that enhanced transparency, facilitated by ESG ratings, leads to a reduction in information asymmetry. However, this study demonstrates this for the period prior to the COVID-19 pandemic for rated companies only. This is inconsistent with the argument that ESG activities make a positive contribution to market stability in times of crisis and close information gaps (Yoo et al., 2021). Furthermore, no significant influence of ESG ratings on IPOs in emerging markets could be identified. This is consistent with prior evidence reporting a similarly absent ESG effect in emerging market equity returns (Plastun et al., 2022).

The central contribution of this study is not a universal claim that ESG ratings reduce IPO underpricing, but rather the finding that their influence is conditional: it depends on the observation period, the specific submarket, and whether firms carry an externally assigned ESG rating. Concretely, a significant negative effect of the RepRisk rating on underpricing was identified for rated companies in the pre-COVID period (2014–2019), consistent with the hypothesis that ESG transparency reduces information asymmetry. This effect disappears for the full sample period and is not detectable for emerging-market IPOs, though the latter result is limited by a small rated subsample. This conditionality is the paper's primary empirical finding and should be foregrounded accordingly. For issuers and underwriters, the results suggest that investing in credible ESG ratings may contribute to more efficient IPO pricing in stable, developed market conditions, but that this benefit cannot be assumed to hold universally across market regimes or crisis periods. For policymakers, the findings highlight the importance of building ESG rating infrastructure and investor literacy in emerging markets as a precondition for ESG signals to become effective pricing inputs.

Several limitations constrain the conclusions that can be drawn from this study. First, the reliance on a single ESG rating agency (RepRisk) limits the generalizability of the findings; the ESG literature has documented substantial divergence across rating providers, and the conditional effect identified here may not replicate with alternative rating sources. Future research should incorporate ratings from multiple agencies and test whether the pre-COVID effect holds across different ESG measurement frameworks. Second, the exclusion of IPOs with incomplete financial data introduces a potential selection bias, as systematically less transparent firms are removed from the sample. Third, the very small number of rated IPOs in the emerging-market subsample (40 observations total) means that the non-significant result for this group should be treated as inconclusive rather than as evidence of no effect. Future studies should expand the emerging-market sample and, where possible, disaggregate the European market by country to account for the substantial regulatory heterogeneity that a pan-European treatment obscures. These country-level legal and institutional factors likely mediate the relationship between ESG ratings and underpricing in ways the present model cannot fully capture.

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Appendix

European IPOs between 2014 and 2023

Variance Inflation Factor (VIF)

	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
	1.0880	1.0735	1.0357	1.2752	1.2751	1.0212	1.0696

	(Intercept)	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
(Intercept)	1	-0.615	-0.132	-0.219	-0.108	0.051	-0.778	0.028
Bookrunner.ranking	-0.615	1	0.179	0.015	0.022	-0.071	0.043	-0.208
Dummy.Nasdaq	-0.132	0.179	1	-0.103	0.084	0.06	-0.038	-0.087
ln_age	-0.219	0.015	-0.103	1	-0.027	0.015	0.107	-0.107
ln_assets	-0.108	0.022	0.084	-0.027	1	-0.441	0.039	-0.066
ln_revenues	0.051	-0.071	0.06	0.015	-0.441	1	0.031	-0.013
Pct...Rating.before.IPO	-0.778	0.043	-0.038	0.107	0.039	0.031	1	-0.047
VC.Dummy	0.028	-0.208	-0.087	-0.107	-0.066	-0.013	-0.047	1

Durbin-Watson test

DW	p-value
2.0191	0.5675

RESET test

RESET	df1	df2	p-value
0.57517	14	343	0.8842

European rated IPOs between 2014 and 2023

Variance Inflation Factor (VIF)

	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
	1.3378	1.1439	2.0088	1.2434	1.6957	1.0857	1.0075

	(Intercept)	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
(Intercept)	1	0.013	-0.28	-0.365	-0.04	0.03	-0.893	0.011
Bookrunner.ranking	0.013	1	0.229	-0.256	-0.277	-0.06	-0.079	0.001
Dummy.Nasdaq	-0.28	0.229	1	-0.124	-0.169	-0.1	0.079	-0.01
ln_age	-0.365	-0.256	-0.124	1	-0.15	-0.555	0.236	0.034
ln_assets	-0.04	-0.277	-0.169	-0.15	1	-0.006	-0.013	-0.007
ln_revenues	0.03	-0.06	-0.1	-0.555	-0.006	1	-0.086	-0.067
Pct...Rating.before.IPO	-0.893	-0.079	0.079	0.236	-0.013	-0.086	1	-0.045
VC.Dummy	0.011	0.001	-0.01	0.034	-0.007	-0.067	-0.045	1

Durbin-Watson test

DW	p-value
2.0827	0.7543

RESET test

RESET	df1	df2	p-value
0.90717	7	412	0.5007

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European rated IPOs between 2014 and 2019

Variance Inflation Factor (VIF)

	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
	1.3892	1.1749	2.2793	1.3533	1.8510	1.0886	1.0102

	(Intercept)	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
(Intercept)	1	0.015	-0.309	-0.348	0.11	0.032	-0.862	0.032
Bookrunner.ranking	0.015	1	0.237	-0.263	-0.255	-0.062	-0.108	-0.005
Dummy.Nasdaq	-0.309	0.237	1	-0.165	-0.165	-0.087	0.058	-0.006
ln_age	-0.348	-0.263	-0.165	1	-0.227	-0.575	0.226	0.013
ln_assets	0.11	-0.255	-0.165	-0.227	1	0.009	-0.145	-0.005
ln_revenues	0.032	-0.062	-0.087	-0.575	0.009	1	-0.081	-0.064
Pct...Rating.before.IPO	-0.862	-0.108	0.058	0.226	-0.145	-0.081	1	-0.058
VC.Dummy	0.032	-0.005	-0.006	0.013	-0.005	-0.064	-0.058	1

Durbin-Watson test

DW	p-value
2.0128	0.5368

RESET test

RESET	df1	df2	p-value
1.358	7	290	2.23E-01

European IPOs (rated) from Emerging Markets between 2014 and 2023

Variance Inflation Factor (VIF)

	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
	1.1439	1.0953	2.3687	1.4287	2.4061	1.4412	1.1653

	(Intercept)	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
(Intercept)	1	0.04	-0.676	-0.552	0.02	0.232	-0.351	0.124
Bookrunner.ranking	0.04	1	-0.006	-0.079	-0.141	-0.071	-0.186	0.085
Dummy.Nasdaq	-0.676	-0.006	1	0.169	-0.078	-0.245	0.019	-0.069
ln_age	-0.552	-0.079	0.169	1	0.201	-0.737	-0.037	0.044
ln_assets	0.02	-0.141	-0.078	0.201	1	-0.07	-0.402	-0.118
ln_revenues	0.232	-0.071	-0.245	-0.737	-0.07	1	-0.001	-0.105
Pct...Rating.before.IPO	-0.351	-0.186	0.019	-0.037	-0.402	-0.001	1	-0.238
VC.Dummy	0.124	0.085	-0.069	0.044	-0.118	-0.105	-0.238	1

Durbin-Watson test

DW	p-value
1.8327	0.2586

RESET test

RESET	df1	df2	p-value
6.5399	7	25	1.92E-04

European IPOs (rated) from Emerging Markets between 2014 and 2023 – modified Underpricing

Variance Inflation Factor (VIF)

	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
	1.1439	1.0953	2.3687	1.4287	2.4061	1.4412	1.1653

	(Intercept)	Bookrunne	Dummy.N	ln_age	ln_assets	ln_revenue	Pct...Ratin	VC.Dumm
(Intercept)	1	0.04	-0.676	-0.552	0.02	0.232	-0.351	0.124
Bookrunner.ranking	0.04	1	-0.006	-0.079	-0.141	-0.071	-0.186	0.085
Dummy.Nasdaq	-0.676	-0.006	1	0.169	-0.078	-0.245	0.019	-0.069
ln_age	-0.552	-0.079	0.169	1	0.201	-0.737	-0.037	0.044
ln_assets	0.02	-0.141	-0.078	0.201	1	-0.07	-0.402	-0.118
ln_revenues	0.232	-0.071	-0.245	-0.737	-0.07	1	-0.001	-0.105
Pct...Rating.before.IPO	-0.351	-0.186	0.019	-0.037	-0.402	-0.001	1	-0.238
VC.Dummy	0.124	0.085	-0.069	0.044	-0.118	-0.105	-0.238	1

Durbin-Watson test

DW	p-value
1.8933	0.3268

RESET test

RESET	df1	df2	p-value
0.62701	7	25	7.29E-01

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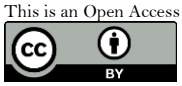

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