

DEVELOPING A Z-ESG SCORE MODEL

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Abstract

Our study aims to develop a novel, unique ESG rating model that exploits the logic of the Z-score by Altman (1968) to discriminate between ESG compliant and non-ESG compliant firms using indicators of ESG performance in the domain of the three pillars – Environmental (E), Social (S), Governance (G). We name our model the Z-ESG rating model. Based on a sample of 325 European listed firms, we build a multiple discriminant analysis model to estimate the Z-ESG score for each firm and confirm these results by employing a logistic regression to determine respective probabilities of being ESG compliant. Z-ESG scores are then converted into agency-equivalent rating classes. Despite the growing interest in the ESG ratings, little is still known about the black-box of the rating agencies' ESG assessment systems, which generates uncertainty as to how to integrate the information provided by the ESG performance in the investment decision-making process. In this regard, our Z-ESG rating model is the first attempt to build an ESG assessment framework based on the well-established logic of credit ratings, but using appropriate ESG indicators in place of financial ratios. Implications are drawn for researchers and practitioners: asset managers may utilize our Z-ESG rating model to identify new investment opportunities and build their ESG-compliant portfolios; risk managers may exploit our Z-ESG metrics to assess the ESG position of a firm and monitor its evolving path; credit risk managers can link the Z-ESG score of a firm to its Z-score to measure the impact of its ESG compliance on its probability of default; chief sustainability officers of companies can self-assess the degree of their ESG compliance to design and pursue a sustainability strategy to target an upgrade of the Z-ESG rating; corporate boards can include the Z-ESG metrics into executive compensation plans so as to link the managers' annual pay to their capabilities to better position the company in the ESG space by achieving higher Z-ESG scores.

Keywords: ESG Compliance, Z-ESG Score, Z-Score, Credit Ratings.

1. Introduction

Some theorists predict that investor preferences for ESG affect asset prices (Pedersen, Fitzgibbons, and Pomorski, 2021; Pástor, Stambaugh, and Taylor, 2021). In practice, investment choices may be guided by ESG ratings, which can make ESG metrics an important foundation for the field of sustainable finance (Berg, Kolbel and Rigobon, 2022). Indeed, it has been estimated that a third of all professionally managed assets at the global level, amounting to about \$30 trillion, are now subject to ESG criteria (Howard-Grenville, 2021).

ESG is a highly heterogeneous space and providers of ESG ratings play an increasingly important role in the investment process through their assessments of companies using various ESG metrics (Li and Polychronopoulos, 2020). ESG rating agencies collect and evaluate ESG data by analyzing corporate disclosures (e.g., sustainability reports), administering surveys for companies to complete and reviewing information coming from other stakeholders (e.g., regulatory agencies, industry associations) to produce ESG ratings, with the common objective of measuring the ESG performance of a company (Christensen, Serafeim and Sikochi, 2022).¹ The concept of ESG performance is intended to provide an assessment of how well a company is managing environmental, social, and governance risks and opportunities, that is a summary measure (based on heterogeneous issues) of non-financial performance (Christensen, Serafeim and Sikochi, 2022). ESG rating agencies assess ESG performance using a wide array of metrics pertaining to a firm's efforts (e.g., policies or programs) or outcomes on ESG issues. The exact metrics that rating agencies are able to develop can differ, and how those metrics are used is a proprietary part of the rating process and is not observable to outside researchers. Indeed, while ESG rating agencies offer tools enabling investors to assess the ESG performance of a company similarly to how credit ratings make the evaluation of a firm's creditworthiness possible, these two concepts are fundamentally different. First, ESG performance is still an ambiguous notion, whereas creditworthiness is very clearly defined as the risk of default of a company. Second, ESG reporting is still in its infancy, while financial reporting standards have been developed and harmonized over the past decades (Del Vitto, Marazzina, and Stocco, 2023). Additionally, both research (Chatterji et al., 2016; Billio et al., 2021; Brandon, Krueger and Schmidt, 2021; Christensen, Serafeim and Sikochi, 2022; Berg, Kolbel and Rigobon, 2022) and practice (Li and Polychronopoulos, 2020; Pérez et al., 2022) have highlighted the divergence of ESG ratings.

The purpose of our paper is to propose an ESG rating metrics to measure the degree of ESG compliance (or performance) of non-financial firms.² To do so, we concentrate on firms

¹ ESG rating agencies are compensated by investors, and not by the company they rate, thus mitigating potential conflicts of interest (Christensen, Serafeim and Sikochi, 2022).

² The terms ESG compliance and ESG performance are used interchangeably in this article. Indeed, a firm that is ESG compliant will also perform well in respect to the 3 ESG dimensions (Environmental, Social, Governance).

headquartered in Europe and listed in European stock markets. The latter choice is motivated by the fact that the EU institutions have made special efforts to design and roll-out a set of regulations to promote an effective transition to a more sustainable economy. Indeed, we cannot observe an equivalent deployment of ESG efforts in the U.S. eco-financial system as common ESG standards are still lacking or in their infancy overseas. Instead, the European Commission has recently approved an ESG regulatory package – comprising the Corporate Sustainability Reporting Directive (CSRD) (2022/2464/EU), the Sustainable Finance Disclosure Regulation (SFDR), and the EU Taxonomy – which is key to the EU's sustainable finance strategy. These three ESG regulations are designed to ensure that companies assess and disclose environmental, social, and governance (ESG) factors that influence their impact on climate-related financial risks, sustainable business practices, and compliance with regulatory standards. Through these regulations, companies are held accountable for their ESG measures, ranging from CO2 emissions to social and governance factors reflected in their annual reports and audited financial statements, fostering a sustainable finance ecosystem. In essence, companies applying such three regulations will meet ESG compliance requirements by integrating the ESG reporting and disclosure into their sustainable business strategies so as to support the EU's goal of becoming climate-neutral by 2050. The components of this ESG regulatory package are briefly described next.

The CSRD is a revision and improvement of the existing Non-Financial Reporting Directive (NFRD) that seeks to standardize and simplify ESG reporting across various sectors, extending its scope to most entities (large companies and listed SMEs, except micro-enterprises) operating within the EU. The CSRD mandates comprehensive disclosures on ESG factors, such as carbon emissions data, waste management, diversity and inclusion, employee rights and corporate governance. By facilitating access to essential ESG data, the directive supports financial market participants and customers in making informed decisions. The SFDR is a mandatory EU regulation that requires financial market participants and financial advisers to disclose information about the ESG risks and opportunities of their investment products.³ The EU Taxonomy is a classification system created to provide a common language for European sustainable finance regulations. It aims to eliminate greenwashing by creating a holistic understanding of sustainable economic activities. CSRD and SFDR legislations are aligned with the scope and definitions outlined in the EU Taxonomy.

ESG compliance requires three strategic actions: (i) the measurement of ESG performance based on the definition of key performance indicators (KPIs) aligned with the international

³ Under the SFDR, for example, fund managers must submit quarterly, detailed, quantitative ESG data on behalf of their portfolio companies. Two levels of disclosure are required about (1) whether and how sustainability risks are considered in the investment decision-making process and their impacts on the returns of the financial products offered; (2) the principal adverse impacts of investments on sustainability factors.

sustainability standards (e.g., Global Reporting Initiative, GRI; International Sustainability Standards Board); (ii) reliance on accurate and timely ESG data; (iii) regular ESG audits to identify areas for improvements. A company's degree of ESG compliance is typically measured through the assignment of an ESG rating by a specialized rating agency. In this respect, in February 2024 the Council and European Parliament have proposed a regulation on ESG rating activities to strengthen the reliability and comparability of ESG ratings. Under the new rules, ESG rating providers will need to be authorized and supervised by the European Securities and Markets Authority (ESMA) and comply with transparency requirements, in particular with regard to their methodology and sources of information.

Relying on the research presented above and on the new EU regulatory landscape, our study aims to develop a novel, unique ESG rating model that exploits the logic of the Z-score by Altman (1968) and Altman, Hotchkiss and Wang (2019), whose objective was to estimate a company's probability of default using a set of explanatory financial variables. More specifically, our proposed model applies the statistical techniques underlying the calculation of the Z-score to discriminate between ESG compliant and non-ESG compliant firms using indicators of ESG performance in the domain of the three pillars – Environmental (E), Social (S), Governance (G) - that are typically recurrent across the leading ESG rating agencies. For this reason, we name our model the Z-ESG rating model and the related outcome, the Z-ESG score (or rating). While acknowledging that “measuring ESG performance is challenging” (Berg, Kolbel and Rigobon (2022)), we believe that the ESG metrics can be improved by combining a well-known and widely accepted technique, such as that of the Z-score, that analysts employ to assess a firm's creditworthiness, with the E, S, and G categories of indicators commonly used to assess ESG compliance in the context of sustainable finance. In doing so, we follow the suggestion by Chatterji et al. (2016) that “efforts to develop common measurement systems may lead to an improvement in convergence” of ESG ratings. More importantly, we respond to the call for more work on the development of proprietary ESG ratings by Berg, Kolbel and Rigobon (2022), who assert that “researchers should invest in developing their own category-specific metrics and ideally make them available to others”.

Albeit our proposed model is not intended to score the creditworthiness of a company, this article is in the spirit of those studies which investigate the effect of ESG scores on credit ratings (Weber, Scholz and Michalik, 2010; Attig et al., 2013; Kiesel and Lucke, 2019; Agosto, Giudici and Tanda, 2023). More importantly, our article extends the extant research that makes use of quantitative techniques to better predict, interpret, or reconstruct ESG scores (D'Amato, D'Ecclesia and Levantesi, 2021; D'Amato, D'Ecclesia and Levantesi, 2022; Dupuy and Garibal, 2022; Del Vitto, Marazzina and Stocco, 2023; Lewellyn and Muller-Kahle, 2023).

Despite the growing interest in the ESG ratings and related modeling techniques, little is still known about the black-box of the rating agencies' ESG assessment systems, which generates uncertainty as to how to integrate the information provided by the ESG performance in the investment decision-making process. In this regard, our Z-ESG rating model is, to the best of our knowledge, the first attempt to build a unique ESG assessment framework based on the well-known and well-established logic of credit ratings, but using appropriate ESG indicators in place of financial ratios.

Our study makes three contributions to the literature. First, we develop a novel and simple ESG rating by relying on the notion of the Z-score that measures the probability of a firm being ESG compliant. Z-ESG scores or ESG compliance probability values are highly correlated (at 80% level) with the ratings provided by LSEG Workspace (formerly Refinitiv). Second, we offer investors an easy-to-use and replicable ESG rating model that is fuelled by ESG data individually collected to determine and assign an ESG score to a given firm. Our Z-ESG scores can be used at the firm and portfolio level to identify new investment opportunities, monitor their current ESG positioning based on the Z-ESG rating matrix and design a future evolving path so as to target a Z-ESG rating upgrade. Third, our Z-ESG rating model can enable a corporate board to include the ESG metrics into executive compensation. Managers' annual pay can be linked to their capabilities to better position the company they work for in the ESG space by achieving higher Z-ESG scores.

The paper is organized as follows. Section 2 provides a review of the most relevant literature. Section 3 describes the data used to build our model. Section 4 proposes the methodology underlying our Z-ESG Rating model and presents the empirical findings. In Section 5, we construct a Z-ESG rating matrix which results from converting the Z-ESG scores into agency-equivalent, ordinal, alphabetical rating classes. Section 6 explains the robustness analysis. Section 7 concludes by highlighting the implications of our findings for researchers and practitioners.

2. Literature Review

Based on a framework developed by Li and Polychronopoulos (2020), there exist three types of ESG rating providers: (1) “fundamental” (e.g., Bloomberg), which collect and aggregate publicly available data without having a rating methodology; (2) “comprehensive” (e.g., Morningstar Sustainalytics, Vigeo Eiris), which rely on data produced by their own analysts to develop their own rating methodology; (3) “specialist” (e.g., TruCost, Equileap), which specialize in a specific ESG issue, such as environmental/carbon scores, or gender diversity. The ESG ratings offered by the rating agencies help investors integrate ESG factors into their decisions, screen portfolio for risks and opportunities, generate investment ideas, conduct due diligence, determine opportunities for engagement, and support implementation of the UN PRI principles (MSCI, 2018). Corporate boards

are also increasingly paying attention to ESG issues as they may decide to incorporate ESG metrics into executive compensation packages (Starks, 2023). Indeed, despite some doubts about this practice (Edmans, 2022; Bebchuk and Tallarita, 2022), there is evidence suggesting that firms using ESG metrics in their executive compensation contracts have better business performance as well as environmental and social performance (Flammer, Hong, and Minor, 2021).

Despite their best efforts, the ESG ratings that agency ratings produce tend to diverge greatly for a given firm, which has drawn attention and criticism from both practitioners (Li and Polychronopoulos, 2020; Pérez et al., 2022) and researchers (Chatterji et al., 2016; Billio et al., 2021; Brandon, Krueger and Schmidt, 2021; Christensen, Serafeim and Sikochi, 2022; Berg, Kolbel and Rigobon, 2022). Taking a practitioners' perspective, Li and Polychronopoulos (2020) find that two well-established ESG data vendors with robust methodologies end up assigning different ESG ratings to the same company. Such a discrepancy is illustrated for Wells Fargo and Facebook. Pérez et al. (2022) argue that while credit scores of S&P and Moody's are correlated at 99%, ESG scores from six of the most prominent ESG rating providers correlate on average by only 54% due to the use of different, proprietary analyses and weightings which lead to diverging ratings.

On the front of research, Chatterji et al. (2016) first document the divergence of ESG ratings finding that the ratings of six major social raters have low correlations with each other. Their analysis provides two reasons for the divergence, suggesting that SRI raters not only do not agree on one definition of corporate social responsibility (their "theorizations" of CSR differ), but also that raters may measure the same construct (for example, independent board) in different ways (the "commensurability" of CSR is low). However, their results are not sufficient to understand to what extent each of these components drives divergence. The heterogeneity in the ESG industry, leading the agencies to have opposite opinions on the evaluated companies, is confirmed by Billio et al. (2021). Brandon, Krueger and Schmidt (2021) examine the consequences arising from ESG rating disagreement finding that stock returns are positively related to such divergence, which, being perceived as a source of uncertainty, commands a firm-specific risk premium. ESG rating uncertainty, resulting from the lack of consistency of ESG information across rating agencies, reduces investor demand for stocks and leads to higher perceived risk and higher market premium (Avramov et al., 2022). Hence, investors are less likely to make ESG investments and actively engage in corporate ESG issues. A higher market premium also increases the cost of capital for green firms, thus limiting their capacity to make socially responsible investments and generate real social impact.

Most recently, researchers have attempted to quantify the drivers of ESG rating disagreement. Christensen, Serafeim and Sikochi (2022) focus on the role of disclosure as a determinant of ESG rating disagreement and find that greater ESG disclosure leads to greater ESG disagreement across

ESG rating agencies. More interestingly, using the ratings of six ESG rating providers and mapping the different methodologies into a common taxonomy of categories, Berg, Kolbel and Rigobon (2022) find three distinct sources of ESG rating divergence: scope, measurement, and weightings by decomposing it into their different, relative contributions. Scope divergence implies that ratings are based on different sets of attributes. Measurement divergence refers to a situation where rating agencies measure the same attribute using different indicators. Weight divergence results when rating agencies take different views on the relative importance of attributes. Their findings are that measurement contributes 56% of the divergence being the primary driver of rating divergence, scope 38% and weight only 6%. Further analyzing the reasons for measurement divergence, they detect a “rater effect” meaning that a firm receiving a high score in one category is more likely to receive high scores in all the other categories from the same rater. Hence, ESG rating divergence is primarily driven by measurement divergence, which has to do with how rating agencies define their rating systems and organize their work.

Some studies have focused on the relationship between ESG scores and credit ratings (Weber, Scholz and Michalik, 2010; Attig et al., 2013; Kiesel and Lucke, 2019; Agosto, Giudici and Tanda, 2023). Other studies have attempted to better explain the formation of ESG ratings (D’Amato, D’Ecclesia and Levantesi, 2021; D’Amato, D’Ecclesia and Levantesi, 2022; Dupuy and Garibal, 2022; Del Vitto, Marazzina and Stocco, 2023; Lewellyn and Muller-Kahle, 2023). More specifically, D’Amato, D’Ecclesia and Levantesi (2021) and D’Amato, D’Ecclesia and Levantesi (2022) investigate the role of a company’s financial statement information such as profitability, liquidity and solvency ratios in explaining and predicting the determinants of Bloomberg and LSEG Workspace (formerly Refinitiv) ESG scores on a sample of the constituents of the STOXX Europe 600 index by adopting both a standard and a novel machine learning approach. Dupuy and Garibal (2022) study the formation of ESG scores and identify a novel source of divergence among raters’ ESG scores, named as the cross-dispersion bias, thus proposing a correction of it. Del Vitto, Marazzina and Stocco (2023) exploit machine learning techniques to replicate the ESG ratings issuance process shedding light on the proprietary model employed by LSEG Workspace. Concerning corporate governance, Lewellyn and Muller-Kahle (2023) apply a configurational analytical approach to investigating those board characteristics and institutional factors that lead to high or low ESG performance, so as to understand why some firms are ESG leaders while others are ESG laggards.

3. Data

3.1 Model Construction

We build our ESG rating model in five steps. First, we construct a sample of 325 European listed firms starting from the retrieval of ESG data from LSEG Workspace on 1341 small, medium and large-sized companies listed in the European stock markets in 2022. The final sample is obtained by performing a step-wise regression that includes or excludes firms based on the availability in the LSEG database of the most recurring ESG indicators across the major ESG rating providers. Second, we discriminate between ESG and non-ESG compliant firms by administering a straightforward survey of 10 yes-or-no questions, chosen on the basis of the key principles of the CSRD, to the 325 companies included in our sample. The response outcomes of this survey populate (the column vector of) the dependent variable(s) of our model: companies responding “yes” to at least 6 out of 10 questions (above median) are classified as ESG compliant (group 1); companies responding “yes” to less than 6 out of 10 questions (equal to or below median) are classified as non-ESG compliant (group 0). The idea is that responding “yes” to a number of questions below the median would correspond to a relatively poor ESG compliance, thus denoted as non-ESG compliance. Third, based on ESG data from step 1 we have several, recurring indicators of ESG performance being used by rating agencies for which we collect relevant information from public sources for the 325 companies of our sample. However, we do not know which indicators are the most effective to measure a company’s ESG performance. Hence, we identify the explanatory variables of our model by conducting a further step-wise analysis of the most widely used indicators of ESG performance across ESG rating agencies, which yields 13 variables for each of the three pillars (Environmental, Social, Governance) showing the highest correlation with our y variable. This total set of 39 independent variables is intended to best explain and measure the degree of ESG compliance of a given firm. All independent variables are based on the information collected from documents or reports (e.g., sustainability report, corporate governance document, code of ethics) prepared by the companies in our sample. Fourth, consistently with the logic of the Z-score (Altman, 1968; Altman, Hotchkiss and Wang, 2019) we build a multiple discriminant analysis (MDA) model to estimate the Z-ESG score for each firm and confirm these results by employing a logistic regression (LR) (Z-metrics) model (Altman et al., 2010) to determine respective probabilities of being ESG compliant. Fifth, we develop a Z-ESG rating scale by converting the Z-ESG scores into agency-equivalent, ordinal, alphabetical rating classes (e.g., AAA, AA). The classes of our Z-ESG rating model are ten. Hence, each company is assigned a Z-ESG score or, alternatively, a Z-ESG rating class. To validate our findings, we perform supplemental robustness checks.

3.2 Sample

We retrieve ESG data for 1341 small, medium and large-sized companies listed in the European stock markets from LSEG Workspace (formerly Refinitiv) in 2022. We then perform a step-wise regression to include only those firms for which the most recurring ESG indicators used by the major ESG rating agencies are available in the LSEG database. This procedure yields a sample of 325 European listed (mostly large-sized) firms. Figure 1 shows the geographic distribution of companies across Europe; 49 firms are based in France, 44 in the U.K. and 39 in Italy. Figure 2 displays the breakdown of our sample of firms per economic activity based on the NACE code. It can be noted that 54% of the firms operate in the manufacturing sector, of which 12% in the chemical sector and 11.4% in the machinery sector; 7% of the firms operate in the mining sector and 6.77% in the energy (e.g., electricity) sector.

[INSERT FIGURES 1 AND 2 ABOUT HERE]

3.3 ESG Compliance Discrimination Survey

To discriminate between ESG and non-ESG compliant firms within our sample, we have designed a simple but comprehensive survey of 10 yes-or-no questions, elaborated on the basis of the key principles of the CSRD. We have then administered this survey to the 325 companies included in our sample in 2022. About half responded. The remaining 50% of answers were filled out on the basis of what actually published in official documents. The response outcomes of this survey from all firms create the dependent variable of our Z-ESG rating model. Companies that respond “yes” to at least 6 out of 10 questions (above median) are classified as ESG compliant and are assigned value 1 (group 1), while companies that respond “yes” to less than 6 out of 10 questions (equal to or below median) are classified as non-ESG compliant and are assigned value 0 (group 0). Hence, the y variable of our model is a dichotomous variable that takes the value of 1 if the firm is ESG compliant and the value of 0 if the firm is non-ESG compliant.

The use of a questionnaire enables us to obtain information about a phenomenon, such as the ESG performance of a firm, that is, by nature, not observable (differently from bankruptcy: defaults can be observed). The questionnaire of the ESG Compliance Discrimination Survey is based on the key principles of the CSRD. EU rules require large companies and listed companies to publish regular reports on the social and environmental risks they face, and on how their activities impact people and the environment. To address these issues, a new directive, which modernizes and strengthens the rules concerning the social and environmental information that companies have to report, has been designed. The CSRD entered into force in January 2023. Hence, a broader set of large companies, as

well as listed SMEs, will now be required to report on sustainability (approximately 50,000 companies in total).⁴ It should be noted that the 10 questions of the survey are designed to be generalist (by generally referring to the ESG-compliant behaviour of a firm), while the independent (explanatory) variables of our econometric models are pillar-specific. This distinction ensures the independence between the y and the x variables of our models, which is a key assumption of any Z-score modelling. The 10 questions of the survey are also equally weighted. This is a specific choice, which aims to simplify the construction of the questionnaire avoiding the attribution of arbitrary weights to the questions.

Furthermore, the answers to the 10 questions of our survey may be affected by greenwashing, which is a growing phenomenon across ESG-rated firms. In this respect, the advantage of our questionnaire is that most questions can be easily verified from public sources of information regarding each company. Only question 6 (ESG due diligence) and question 8 (measurement of the impact of the firm's business activity on its ESG profile) are exposed to the risk of greenwashing. To address this issue, we have considered the two sub-samples into which the original sample of our companies can be divided - 50% of firms that self-responded to the questions vs 50% of firms that did not self-respond and for which the information was collected from public sources – and we have counted the number of firms of group 1 vs that of firms of group 0 in each sub-sample. As there not exists any material difference between the number of firms of group 0 and group 1 in each of the two subsamples compared to what can be found in the total sample, we can conclude that the greenwashing bias is not significant. Table 1 reports the 10 questions of our survey.

[INSERT TABLE 1 ABOUT HERE]

3.4 Independent Variables

We identify the independent variables of our Z-ESG rating model by conducting a further step-wise analysis of the most widely used indicators of ESG performance across ESG rating agencies. Our step-wise regression analysis yields a total of 39 independent variables (showing the highest correlation with our y variable) aimed at best explaining and measuring the degree of ESG compliance for any given firm. The independent variables are grouped into three categories: Environmental, Social, Governance. Each category includes 13 variables. All explanatory variables are based on the information collected from documents or reports (e.g., sustainability report, corporate governance document, code of ethics) prepared by the companies in our sample. Five explanatory

⁴ The implementation of the directive has been planned as follows: i) from January 1 2024, the large companies of public interest (with more than 500 employees) will be subject to the CSRD; ii) from January 1 2025, the companies with more than 250 employees and/or revenues in excess of €40 million and/or total assets in excess of €20 million; iii) from January 1 2026, the listed SMEs (with an option to wait until 2028).

variables are quantitative (CO2 Emissions to Revenues, Waste Recycled to Total Waste, Women Employees x Diversity and Equal Opportunity Targets, Female Board Members, Independent Board Members). The rest of them are of qualitative nature only requiring a yes or no answer. The framework of our Z-ESG rating model, including both the dependent and independent variables, is shown in Figure 3. Table 2 reports the description of all independent variables.

[INSERT FIGURE 3 AND TABLE 2 ABOUT HERE]

4. The Z-ESG Rating Model

The construction of our Z-ESG rating model requires an empirical analysis that is based on the application of two statistical methodologies: (a) multiple discriminant analysis (MDA); (b) logistic regression (LR). The implementation of these two techniques is described below.

4.1 Multiple Discriminant Analysis

Following the logic of the Z-score (Altman, 1968), we first build a multiple discriminant analysis (MDA) model to estimate the Z-ESG score for each firm. The objective of the MDA is to identify a set of explanatory variables, and their weightings, that can best discriminate the 325 firms of our sample between two predefined groups, which are known *a priori* (Fisher, 1936). A dependent variable defines the groups and one or more quantitative and/or qualitative variables are used to discriminate between the groups. In the context of this study, the dependent variable is the degree of ESG compliance defined on the basis of the responses to the ESG Compliance Discrimination Survey from the 325 companies of our sample. Hence, the two predefined groups are ESG compliant and non-ESG compliant firms. The MDA constructs our Z-ESG score as a linear combination of the independent variables that is able to minimize the probability of misclassification. The discriminant function takes the following form:

$$Z = v_1X_1 + v_2X_2 + \dots + v_nX_n \quad (1)$$

where:

v_1, v_2, \dots, v_n = discriminant coefficients;

$X_1, X_2 \dots X_n$ = independent variables.

The value of the discriminant coefficients is determined by applying the following equation:

$$v = (X_1 - X_2) * S^{-1} \quad (2)$$

where:

- X_1 is the vector of mean values of the independent variables of group 1;
- X_2 is the vector of the mean values of the independent variables of group 2;
- S^{-1} is the matrix of variances-covariances between the independent variables.

The MDA obeys two criteria: (1) maximize the distance between the average scores of the 2 groups considered; (2) minimize the variance of the scores within the 2 groups. Once the Z-ESG score is calculated for all firms in the sample, it is necessary to identify a “threshold value” (cut-off)⁵ in order to classify the companies into one or the other group: if the Z-ESG score is lower or equal than the cut-off, the company is classified as 0 (“non-ESG compliant”); if the Z-ESG score is greater than the cut-off, the company is classified as 1 (“ESG compliant”). To measure the discriminating power of our MDA model, we use the Wilks’ Lambda, which ranges from 0 to 1 (where 0 means total discrimination, and 1 means no discrimination). We perform three distinct MDA models for each of the three pillars. The empirical results obtained using the multiple discriminant analysis (MDA) for the environmental, social and governance pillars are reported in Tables 3, 4 and 5 respectively.

In the MDA model for the environmental pillar, the coefficients have a sign in line with what was expected and are mostly statistically significant at 1% level. The only exception is the coefficient associated with the occurrence of a firm’s investments to proactively reduce risks or increase future opportunities concerning the environment (Environment Investments), which is significant at 5% level. More specifically, the coefficient of the CO2 Emissions to Revenues is negative, which implies that a greater (lower) amount of CO2 emissions is associated with a lower (higher) firm’s ESG compliance. The reverse applies to the second regressor: Waste Recycled to Total Waste. Its coefficient is positive implying that the higher amount of waste recycled by a company, the higher the latter’s ESG compliance. The coefficients associated with the firm’s offer of lines of products (or services) designed to have a positive impact on the environment (Environmental Products) and the firm’s use of renewable electricity (Renewable Energy Use) have the greatest magnitude (1.443 and 0.915 respectively) and are, as expected, both positive. The coefficient with the lowest magnitude (0.087) is that of the Waste Recycled to Total Waste. The average Z-ESG score of group 0 is 2.619,

⁵ If the sizes of the groups are equal, the cut-off is the average of the average scores of the 2 groups. If the sizes of the 2 groups are different, the cut-off is the weighted average of the average scores of the 2 groups (with weights equal to the relative frequencies of the 2 groups). As the sizes of the two groups of ESG and non-ESG compliant firms are different, the latter calculation of the cut-off applies here.

the average Z-ESG score of group 1 is 5.186, and the cut-off level is 3.150. The Wilks' Lambda of our Z-ESG score model for the environmental pillar is 0.587.

In the MDA model for the social pillar, the coefficients have a sign in line with what was expected and are statistically significant at 1% level, with the exception of that associated with a firm's provision (to employees) of Day Care Services, which is significant at 10% level. The quantitative variable of the model – Women Employees x Diversity and Equal Opportunity Targets – is an interaction variable between the percentage of female employees (out of the total number of employees in a given firm) and a dummy variable that takes the value of 1 if the company has set goals to insure diversity and equal opportunities for all employees and 0 otherwise. The coefficient associated with the availability within the firm of a policy to prevent bribery and corruption (Bribery and Anti-Corruption Policy) shows the greatest magnitude (3.185) and, as expected, has a positive sign. The coefficient with the lowest magnitude (0.006) is that of the interaction term Women Employees x Diversity and Equal Opportunity Targets. The average Z-ESG score of group 0 is 6.029, the average Z-ESG score of group 1 is 9.443, and the cut-off level is 6.880. The Wilks' Lambda of our Z-ESG score model for the social pillar is 0.587.

The coefficients of the variables included in the MDA model for the governance pillar are positive as expected and strongly significant (at 1% level). The only exception is the coefficient associated with the Shareholder Rights Policy (a dummy variable that takes the value of 1 if the firm offers a policy for ensuring equal treatment of minority shareholders, facilitating shareholder engagement or limiting the use of anti-takeover defences), which is significant at 5% level. The coefficient with the highest magnitude (1.140) is that associated with the public availability of the firm's statutes (Corporate Statutes Public Availability). The coefficient with the lowest magnitude (0.013) is that of the ratio (in percentage) of the Independent Board Members to the total number of directors. The average Z-ESG score of group 0 is 4.926, the average Z-ESG score of group 1 is 6.757, and the cut-off level is 5.423. The Wilks' Lambda of our Z-ESG score model for the governance pillar is 0.577.

[INSERT TABLES 3, 4 AND 5 ABOUT HERE]

The above MDA models are very powerful in correctly classifying the firms of our sample between ESG compliant and non-ESG compliant entities. The MDA model for the environmental pillar achieves a 91.4% of correct classifications; the MDA model for the social pillar obtains a 95.4% of correct classifications and the MDA model for the governance pillar correctly classifies 84% of firms. The classification matrix (also called confusion matrix) associated with the MDA model for

the environmental pillar is reported in Table 6, Panel A. It shows that the number of cases classified incorrectly by our MDA model is 28: 16 companies belonging to group 0 (i.e. non-ESG compliant at environmental level) that are instead classified as members of group 1 (Type I errors) and 12 companies belonging to group 1 (ESG compliant at environmental level) that are instead classified as members of group 0 (Type II errors). Type I errors are 41.0% and Type II errors are 4.2% for the environmental pillar. The other classification matrices associated with the MDA models for the social and governance pillars are reported in Table 6, Panels B and C. The number of firms classified incorrectly by our MDA model for the social pillar is 15 for the social pillar and 52 for the governance pillar. Type I errors are 42.9% and 35.6% and Type II errors are 2.0% and 6.8% for the social and governance pillars respectively.

[INSERT TABLE 6 ABOUT HERE]

4.2 Logistic Regression

We also perform a logistic regression (LR) in line with the Z-Metrics model developed by Altman et al. (2010), which enables us to estimate the probability of ESG compliance for each firm (Berkson, 1944). Once the Z-ESG score is obtained based on the following regression:

$$Z - ESG_{i,t} = \alpha + \sum \beta X_{i,t} + \varepsilon_{i,t} \quad (3)$$

where:

$Z - ESG_{i,t}$ = Z-ESG score for a firm i at time t ;

β = coefficients;

$X_{i,t}$ = independent variables;

$\varepsilon_{i,t}$ = error term.

the $Z - ESG_{i,t}$ is transformed into a probability of ESG compliance (ranging from 0 to 1) through the following function, whose coefficients are estimated by the maximum likelihood method:

$$P(Y = 1) = \frac{e^{(\alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k)}}{1 + e^{(\alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k)}} \quad (4)$$

The goodness of fit of a logistic regression model is measured by the pseudo R^2 or McFadden's R^2 . We perform three distinct logistic regression models for the three pillars with each including the same explanatory variables employed in the MDA. The logistic regression models confirm the results of the multiple discriminant analysis discussed above. The empirical findings obtained using the logistic regression (LR) analysis for the environmental, social and governance pillars are reported in Tables 7, 8 and 9 respectively.

In the LR model for the environmental pillar, the majority of the variables have statistically significant coefficients (only Waste Recycled to Total Waste, Environment Management Team, Environmental Supply Chain Management, and Biodiversity Risk are not significant) and all coefficients present the expected signs. For example, the only coefficient with a negative sign is that of the ratio of CO₂ Emissions to Revenues, which implies that lower (higher) CO₂ emissions lead to higher (lower) ESG performance. The coefficient with the greatest magnitude (3.167) is that associated with the design and the offer of lines of products (or services) having a positive impact on the environment (Environmental Products). The coefficient with the lowest magnitude (0.344) is that associated with the presence of an Environment Management Team within the firm. The pseudo R^2 or McFadden's R^2 of the LR model for the environmental pillar is 0.547 and the number of correct classifications of firms to ESG and non-ESG compliant entities is equal to 92.9%.

In the LR model for the social pillar, most variables have statistically significant coefficients (only Employee Health & Safety Policy, Data Privacy Policy, and Day Care Services are not significant) and all coefficients present the expected signs. The coefficient with the greatest magnitude (3.469) is that associated with the firm's use of human rights' criteria in the selection of suppliers or sourcing partners (Human Rights-Compliant Contracting). The coefficient with the lowest magnitude (0.067) is that associated with the interaction variable Women Employees x Diversity and Equal Opportunity Targets. The pseudo R^2 or McFadden's R^2 of the LR model for the social pillar is 0.643 and the number of correct classifications of firms to ESG and non-ESG compliant entities is equal to 96.6%.

In the LR model for the governance pillar, all variables (with the exception of Stock Options and Audit Committee Independence) have statistically significant coefficients and all coefficients display the expected signs. The coefficient with the greatest magnitude (2.053) is that associated with the Corporate Statutes Public Availability within the firm. The coefficient with the lowest magnitude (0.022) is that associated with the presence of Independent Board Members. The pseudo R^2 or McFadden's R^2 of the LR model for the governance pillar is 0.398 and the amount of correct classifications of firms to ESG and non-ESG compliant entities is equal to 84.3%.

[INSERT TABLES 7,8 AND 9 ABOUT HERE]

To assess the accuracy of both MDA and LR models for each of the three pillars, we construct the Receiver Operating Characteristic (ROC) curves (Huguet, Castineiras, and Fuentes-Arderiu, 1993). The area under the ROC curve is a measure of the model's accuracy. In case of perfect discrimination between the two groups considered, the area under the ROC curve (AUC) is equal to 1, and is equal to 0.5 when the two groups considered are weakly discriminated. Hence, the greater the area under the ROC curve (with the curve being closer to the upper left corner of the diagram), the higher the discriminating power of the model and thus its accuracy. The ROC curves for both the MDA and LR models for the environmental, social and governance pillars are shown in Figure 4 Panels A, B and C. All MDA and LR models present a high degree of accuracy and discriminating power for all three pillars.

[INSERT FIGURE 4 ABOUT HERE]

5. The Conversion of the Z-ESG Score into Ratings: The Z-ESG Rating Matrix

To make our Z-ESG Score Model more easily applicable and recognizable vis-a-vis established credit ratings, we develop a Z-ESG rating “scale” by converting the Z-ESG scores into agency-equivalent, ordinal, alphabetical rating classes (e.g., AAA, AA, etc.). To do so, we exploit the ESG data provided by LSEG Workspace on our sample of 325 companies. The construction of a Z-ESG rating scale is based on three steps. First, we calculate the average Z-ESG scores and probabilities of ESG compliance associated with the environmental pillar for those firms that are assigned one of the twelve rating classes by LSEG. Each group of firms with a given LSEG rating class is assigned the corresponding average Z-ESG score. Second, we build our Z-ESG rating scale by using the average Z-ESG scores as upper thresholds of ten classes. The ten rating classes range from AAA (highest ESG compliance) to D (low or nil ESG compliance). The upper threshold of the CC rating class (medium-low ESG compliance) corresponds to the cut-off level of 3.150. The cut-off level allows to distinguish those Z-ESG rating classes that are associated with a high or medium ESG compliance from those corresponding to low ESG compliance. Hence, our Z-ESG rating scale is slightly simplified compared to that of LSEG as it is formed by ten (rather than twelve) classes. Table 10 displays the Z-ESG rating scale with 10 classes.

[INSERT TABLE 10 ABOUT HERE]

The process described above is repeated with the average Z-ESG scores and probabilities of ESG compliance associated with the social and the governance pillars, which yields a full Z-ESG rating matrix for the all three pillars based on the findings obtained by both the MDA and the LR models (Table 11). The Z-ESG rating matrix is structured as follows. The first, the third and the fifth column report the Z-ESG scores serving as upper thresholds of each rating class for each of the three pillars respectively. The second, the fourth and the sixth column report the probabilities of ESG compliance serving as upper thresholds of each rating class for each of the three pillars respectively. The last two columns display the Z-ESG scores and the probabilities of ESG compliance serving as upper thresholds of each rating class at the overall ESG level. These Z-ESG scores and probabilities of ESG compliance are obtained as average of the preceding three Z-ESG scores and probabilities of ESG compliance corresponding to each pillar respectively and can be used to assess the overall ESG performance of a company based on one of the 10 rating classes.

The availability of a full Z-ESG rating matrix allows us to assign a Z-ESG rating to any company that is contingent on the degree of its compliance with the principal ESG issues. For example, the level of ESG performance of a firm can be assessed as follows: (1) the firm answers all 13 questions underlying the independent variables of the MDA model for each of the three pillars, with some answers resulting in quantitative outcomes and most of them being of dichotomous nature (1 = yes or 0 = no); (2) the firm's answer-related outcomes are multiplied by the coefficients of the MDA equations shown in Tables 3, 4 and 5, thus leading to the firm obtaining a Z-ESG score; (3) the firm's Z-ESG score is compared to the thresholds of the Z-ESG rating matrix and the firm is assigned a Z-ESG rating class ranging from AAA to D. For example, a firm obtaining a Z-ESG score of 4.501 at the environmental level will be assigned a B rating, which corresponds to a 84.1% of ESG compliance in the environmental domain. The assignment to a given Z-ESG rating class allows us to determine the level of the firm's ESG compliance for the environmental, social and governance pillar. The higher the Z-ESG score of a company (and hence its Z-ESG rating class), the higher its ESG performance. Depending on the level of ESG compliance achieved by the firm, the firm itself can be advised on how to improve its ESG performance and reach a higher position in the Z-ESG rating matrix.

[INSERT TABLE 11 ABOUT HERE]

The use of the Z-ESG rating matrix, based on the conversion of the Z-ESG scores obtained by the MDA models into alphabetical rating classes for our sample of 325 firms, allows us to map each firm in terms of overall ESG compliance. The distribution of these firms across the rating classes

of our Z-ESG rating matrix is reported in Table 12, Panel A. It can be noted that 26 firms (8.0% of our sample) are AAA-rated, 34 firms (10.5% of our sample) receive a AA rating, and only 2 companies are classified in the lowest rating category D. The firms with a BBB rating are 61 (18.8% of our sample) and represent the most concentrated class across the Z-ESG rating matrix. 303 companies (93.2% of our sample) are positioned in the upper part of the Z-ESG rating matrix, being thus characterized by a maximum, medium-high or average ESG compliance, while the remaining 22 companies (6.8% of our sample) are positioned in the bottom part of the Z-ESG rating matrix, weakly complying with the ESG criteria (medium-low, low or no ESG compliance). Panels B, C and D of Table 12 display the distribution of the 325 firms of our sample across the rating classes of our Z-ESG rating matrix at pillar level (Environmental, Social, Governance). At the environmental level, 80 firms (24.6% of our sample and the most frequent class) are AAA-rated, with only 35 firms (10.8% of the sample) being positioned in the bottom part of the Z-ESG rating matrix; at the social level, 69 firms (21.2% of our sample and the most frequent class) are AA-rated, with only 14 firms (4.3% of the sample) being positioned in the bottom part of the Z-ESG rating matrix; at the governance level, 64 firms (19.7% of our sample and the most frequent class) are AAA-rated, with 77 (23.7% of the sample) being classified in the bottom part of the Z-ESG rating matrix. The latter finding, combined with that concerning the environmental dimension, suggests that the companies of our sample are better compliant with the environmental criteria and are comparatively weaker as to how they have organized their corporate governance structures.

[INSERT TABLE 12 ABOUT HERE]

6. Robustness Analysis

We perform several further analyses to check the robustness of our findings. First, we calculate the correlation between the Z-ESG scores and the LSEG Workspace ratings for all firms of our sample and we find that the two ratings are highly correlated. As shown in Figure 5 and Table 13, it can be noted that our ratings obtained by the MDA models have a correlation coefficient of about 72% with the LSEG ratings for each of the three pillars, with the total Z-ESG rating having a correlation of 83.6%. Our ratings yielded by the LR models have correlations with the LSEG ratings ranging between 61.9% (Social pillar) and 71.2% (Governance pillar), with the total Z-ESG rating having a correlation of 78.9%. These results are interesting as the LSEG rating is based on 162 explanatory variables per pillar with a total of 486 variables, while our Z-ESG rating model is only based on 13 variables per pillar, a total of 39 variables. Hence, we achieve highly correlated results by employing a much simpler but still effective rating model.

[INSERT FIGURE 5 AND TABLE 13 ABOUT HERE]

Furthermore, our findings are validated by randomly selecting subsamples of our dataset of firms and employing them to perform both the MDA and LR models for each of the three pillars. We do so by randomly selecting five different subsamples equal to 50% of our original sample of 325 firms (random sample-cutting). Each subsample is created by randomly removing 162 companies based on five separate times, so as to build five subsamples of 163 firms. We then use each of these five subsamples to perform the multiple discriminant analyses and the logistic regressions that have been described in Section 3 and applied to our full sample. We repeat that for each of the three pillars and find that our baseline results are robust. Indeed, our findings do not change by analyzing only half of our sample repeatedly. For the sake of illustration, Panels A and B of Table 14 show the results obtained for the environmental and social pillars based on the fifth subsample and Panel C shows the results associated with the governance pillar based on the second subsample.⁶

[INSERT TABLE 14 ABOUT HERE]

To further confirm that our results are robust, we perform an interesting procedure developed by Lachenbruch (1975) and also used by Altman et al. (1977), in the context of discriminant analysis. This consists of building 325 distinct samples by starting from the original sample of 325 firms and removing one company at a time and using that one as “holdout” sample, thus creating 325 different samples where each consists of 324 firms. We then employ each of these 325 samples to perform the MDA models, with all variables discussed in Section 3, for each of the three pillars. The robustness test consists of calculating the average of the Wilks’ Lambdas and rates of correct classifications obtained by running the MDA model for each of the 325 samples and then comparing the results with those of the baseline analysis. We find that such a robustness test corroborates the results obtained with our previous baseline analyses as the two types of results are not significantly different from each other.⁷

⁶ At the environmental level, the MDA robustness analysis reports a Wilks’ Lambda of 51.8% and a 93.3% rate of correct classifications; the LR robustness analysis reports a pseudo R² or McFadden’s R² of 41.3% and a 94.5% rate of correct classifications. At social level, the MDA robustness analysis has a Wilks’ Lambda of 41.3% and a 95.7% rate of correct classifications; the LR robustness analysis reports a pseudo R² or McFadden’s R² of 37.1% and a 98.2% rate of correct classifications. At the governance level, the MDA robustness analysis is characterized by a Wilks’ Lambda of 54.8% and a 86.5% rate of correct classifications; the LR robustness analysis obtains a pseudo R² or McFadden’s R² of 43.6% and a 84% rate of correct classifications.

⁷ For the environmental pillar, the average Wilks’ Lambda from the multiple discriminant analysis performed for all 325 samples is equal to 58.7% and the rate of correct classifications is 91.4%. For the social pillar, the average Wilks’ Lambda associated with the MDA performed for all 325 samples is equal to 58.6% and the rate of correct classifications is 95.4%.

Finally, we conduct a robustness analysis of our dependent variable, which is aimed at capturing a not observable phenomenon: the ESG performance of a firm. As said, to discriminate among ESG and non-ESG performing firms within our sample, we have administered a questionnaire based on the key principles of the CSRD. It is important to confirm the robustness of our discrimination between group 1 firms (ESG compliant) and group 0 firms (non-ESG compliant) by using another, equally reliable source of information that can enable us to allocate our firms to these two groups. This source of information is the RepRisk Index (RRI), a proprietary algorithm developed by RepRisk that dynamically captures and quantifies a company's reputational risk exposure to ESG issues based on the ESG incidents occurred at company level over a certain period of time. The RRI ranges from 0 to 100, whereby the higher its value, the higher the company's reputational risk exposure to ESG issues. More specifically, a RRI of 0-24 denotes low risk exposure; a RRI of 25-49 represents medium risk exposure; a RRI of 50-59 implies high risk exposure; a RRI of 60-74 identifies very high risk exposure; a RRI of 75-100 detects extremely high risk exposure. In particular, we use the Peak RRI, which measures the highest level of the RRI of a firm over the last two years and is considered a proxy for its overall reputational exposure to ESG misconduct.

We have retrieved the RRI data for our sample of firms in the 2022-2023 period and calculated the average RRI for each company. However, the RRI data are not available for all 325 firms of our sample. Due to this constraint, the sample to perform this robustness test is reduced to 238 firms (73% of the original sample). We have assigned firms to group 0 (non-ESG compliant) when their RRI ranges from 50 to 100 and to group 1 (ESG compliant) when their RRI ranges from 0 to 49. Based on this new y variable, we have then re-estimated the MDA models for the environmental, social and governance pillars using the same independent variables associated with each of these three pillars. The findings are very close to those obtained in the baseline analysis. The only difference is represented by the loss of significance of some coefficients. Table 15 shows, as an example, the MDA model for the environmental pillar.

[INSERT TABLE 15 ABOUT HERE]

Once obtained the Z-ESG scores, we have adopted the same procedure described in Section 5 to elaborate a new Z-ESG rating matrix based on the findings of the MDA models estimated with the restricted sample of 238 firms and the new y variable related to the RRI. Table 16 reports the Z-ESG rating matrix associated with our robustness test. This new Z-ESG rating matrix enables us to map

For the governance pillar, the average Wilks' Lambda from the multiple discriminant analysis performed for all 325 samples is equal to 57.7% and the rate of correct classifications is 84.2%.

the 238 firms of our restricted sample in terms of their overall ESG and pillar-level performance based on 10 rating classes. Table 17, Panel A displays the distribution of our 238 firms across the rating classes of the new Z-ESG rating matrix at the overall ESG level. 195 companies (82% of our sample) are positioned in the upper part of the Z-ESG rating matrix, having a maximum, medium-high or average ESG compliance. 43 companies (18% of our sample) are instead assigned a lower Z-ESG rating (CC, C or D) in the bottom part of the matrix, which implies that they are characterized by a medium-low, low or no ESG compliance. Panels B, C and D of Table 17 report the distribution of the 238 firms of our restricted sample across the rating classes of the new Z-ESG rating matrix at pillar level (Environmental, Social, Governance). At the environmental level, 77 firms (32% of our sample) are A-rated (the most frequent class), with BB being the least frequent rating class (only 1 firm). At the social level, 56 firms (24% of our sample) are AAA-rated (the most frequent class), with D being the least frequent rating class (only 1 firm). At the governance level, 63 firms (26% of our sample) are AAA-rated (the most frequent class), with AA being the least frequent rating class (only 1 firm). The concentration of companies in the bottom part of the Z-ESG rating matrix reveals their relative E, S or G compliance. At governance level, 76 companies (32% of our sample) are positioned in the bottom part of the Z-ESG rating matrix; at environmental level, 67 companies (28% of our sample) are positioned in the bottom part of the Z-ESG rating matrix; at social level, 29 (12% of our sample) are positioned in the bottom part of the Z-ESG rating matrix. Hence, the companies of our restricted sample are weaker in the governance domain and are more strongly compliant at social level. This result is confirmed by the fact that at social level more than two-thirds of our firms (79%) have received a Z-ESG rating ranging from AAA to BB. The same does not apply to the environmental and governance pillar. At the E pillar level, 71% of firms and, at the G pillar level, 61% of firms are assigned a Z-ESG rating ranging from AAA to BB.

[INSERT TABLES 16 AND 17 ABOUT HERE]

7. Conclusions and Applications

In this article, we have challenged the measurement of ESG performance by developing a novel, unique ESG rating model that relies on the logic of the Z-score model by Altman (1968). Our model exploits the statistical techniques employed to calculate the Z-score so as to discriminate between ESG compliant and non-ESG compliant firms making use of indicators of ESG performance in the domain of the three pillars – Environmental (E), Social (S), Governance (G) - that are typically found across the leading ESG rating agencies.

From the empirical findings leading to the development of our Z-ESG rating model, we can draw implications for researchers and practitioners. From a research perspective, we complement recent studies on the ESG metrics by developing a novel and simple ESG rating model that exploits the logic of the Z-score by Altman (1968) using appropriate ESG indicators in place of financial ratios.

From a practical standpoint, asset managers may utilize our Z-ESG rating model to identify new investment opportunities or examine existing portfolio investments, and build their ESG-compliant portfolios. Risk managers may exploit our Z-ESG metrics to build their own models to assess the ESG position of a firm and monitor its evolving path. Credit risk managers can link the Z-ESG score of a firm to its Z-score to measure the impact of its ESG compliance on its probability of default. Chief sustainability officers of companies can self-assess the degree of ESG compliance of the company they work for, or their competitors, and pursue a sustainability strategy to target an upgrade or maintenance of a satisfactory Z-ESG rating. Boards of companies can decide to include the Z-ESG metrics into their executive compensation plans by linking the Z-ESG rating to top managers' annual compensation.

Our Z-ESG rating model has several advantages but also some limits. First, our model is more transparent compared to the ESG rating systems developed by the leading market providers such as LSEG and RepRisk. Second, it can be replicated and used effectively as it occurred for the widespread applications of the Z-score (Altman, 1968) to predict the level of financial distress and probability of default of a firm. The Z-ESG score is based on a much fewer number of explanatory variables than the current ESG rating systems available in the market, but it relies on a higher number of independent variables compared to the five financial ratios employed by the Z-score. So, in the latter respect, the calculations required by the Z-ESG score are less trivial and more time-consuming compared to those of the Z-score.

One promising avenue for future research is the design of pillar-specific surveys to estimate the degree of ESG compliance for a firm in each of the three domains (Environmental, Social, Governance). Indeed, our work can be extended by building a pillar-specific questionnaire (rather than one of generalist type) to discriminate between compliant and non-compliant companies at E, S, or G pillar level (rather than at the overall ESG level). Another avenue for further research could involve modelling the interaction between the Z-ESG score and the Z-score to investigate the impact of a company's ESG performance on its probability of default.

Our hope is to have contributed to opening the black box of the ESG metrics by shedding new light on the logic of ESG ratings.

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Figure 1. Geographic Distribution of Firms per Country across Europe

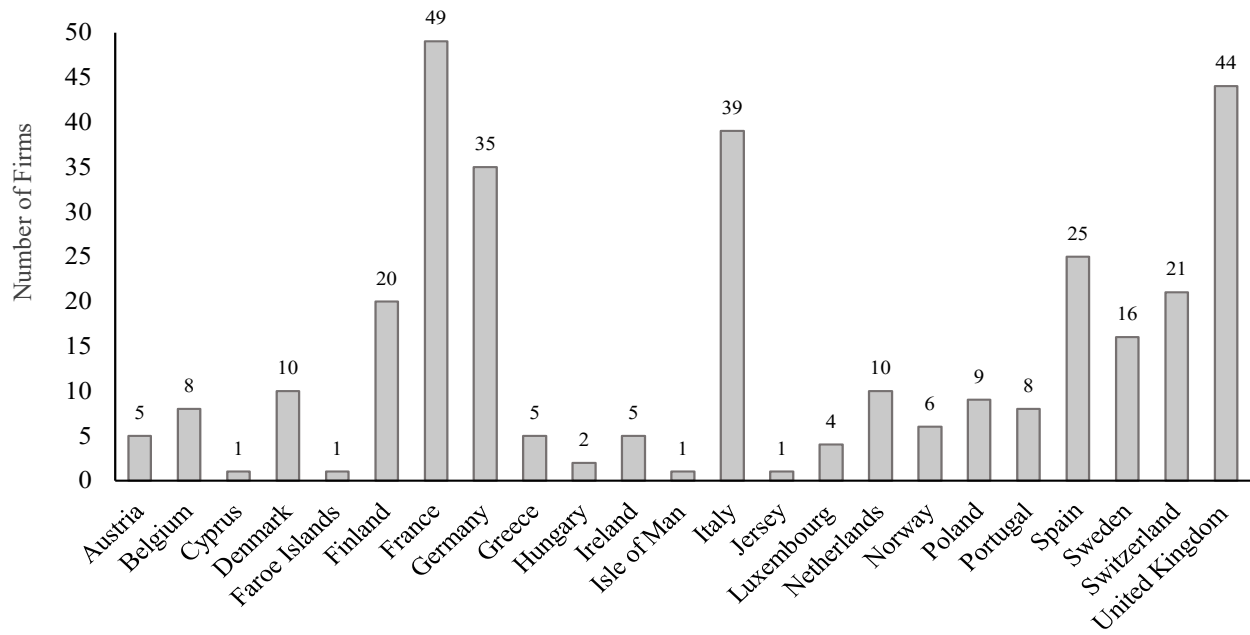
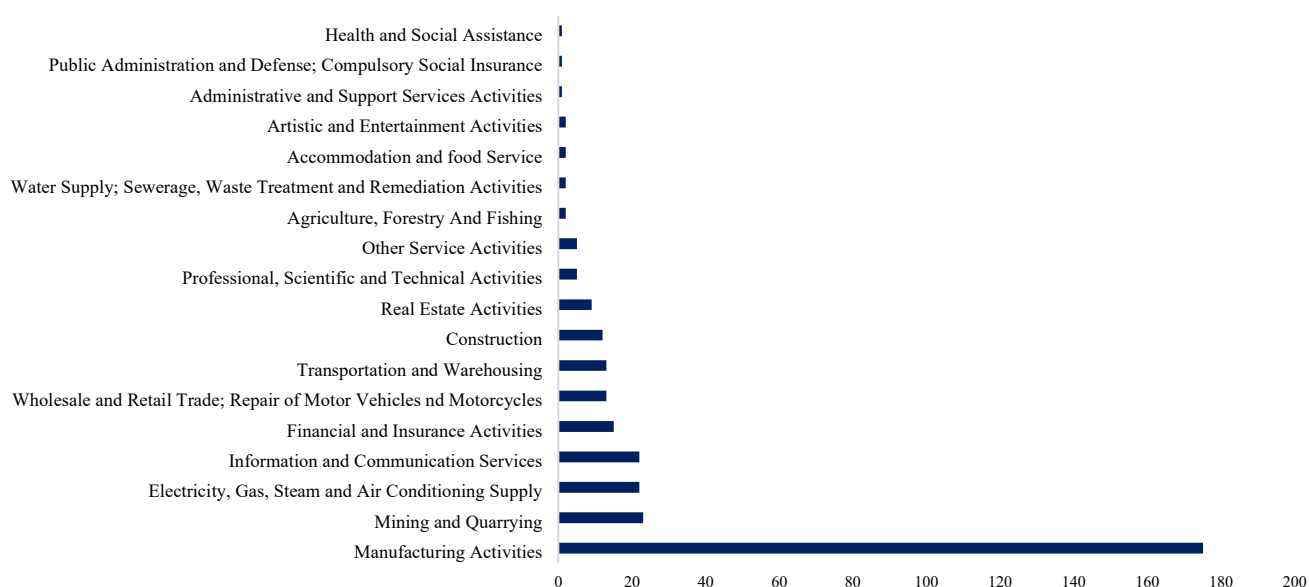


Figure 2. Breakdown of the Sample of Firms per Economic Activity (NACE code)



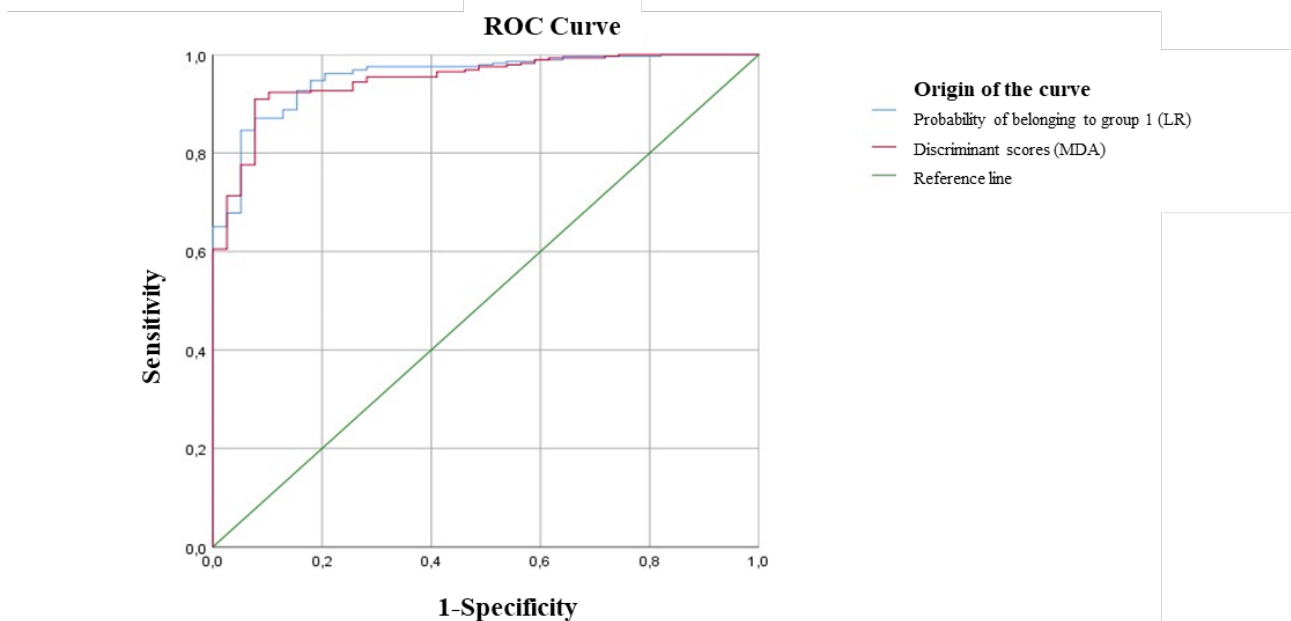
Economic Activity	Number of Companies	% of Companies
Manufacturing Activities	175	53.85%
Mining and Quarrying	23	7.08%
Electricity, Gas, Steam and Air Conditioning Supply	22	6.77%
Information and Communication Services	22	6.77%
Financial and Insurance Activities	15	4.62%
Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	13	4.00%
Transportation and Warehousing	13	4.00%
Construction	12	3.69%
Real Estate Activities	9	2.77%
Professional, Scientific and Technical Activities	5	1.54%
Other Service Activities	5	1.54%
Agriculture, Forestry And Fishing	2	0.62%
Water Supply; Sewerage, Waste Treatment and Remediation Activities	2	0.62%
Accommodation and food Service	2	0.62%
Artistic and Entertainment Activities	2	0.62%
Administrative and Support Services Activities	1	0.31%
Public Administration and Defense; Compulsory Social Insurance	1	0.31%
Health and Social Assistance	1	0.31%
Total	325	100.00%

Figure 3. Framework of the Z-ESG Rating Model

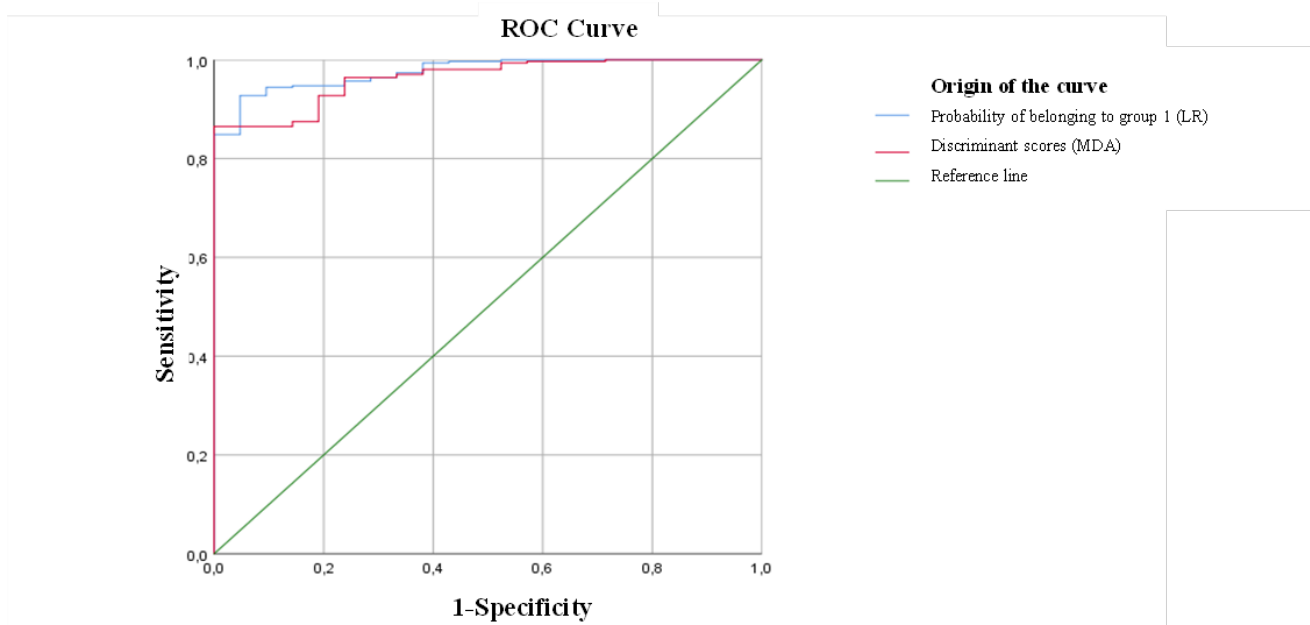
<i>Binary dependent variable</i>			
<i>Membership Group</i> = $\begin{cases} 1 & \text{if the company is ESG compliant} \\ 0 & \text{if the company is non – ESG compliant} \end{cases}$			
<i>Independent variables (13)</i>	<i>Environmental</i>	<i>Social</i>	<i>Governance</i>
	<ul style="list-style-type: none"> CO2 Emissions to Revenues 	<ul style="list-style-type: none"> Women Employees*Diversity and Equal Opportunity Targets 	<ul style="list-style-type: none"> Female Board Members
	<ul style="list-style-type: none"> Waste Recycled to Total Waste 	<ul style="list-style-type: none"> Human Rights 	<ul style="list-style-type: none"> Independent Board Members
	<ul style="list-style-type: none"> Environment Management Team 	<ul style="list-style-type: none"> Human Rights-Compliant Contracting 	<ul style="list-style-type: none"> Corporate Statutes Public Availability
	<ul style="list-style-type: none"> Environmental Supply Chain Management 	<ul style="list-style-type: none"> Business Ethics Improvement Tools 	<ul style="list-style-type: none"> Remuneration Committee Independence
	<ul style="list-style-type: none"> Environmental Investments 	<ul style="list-style-type: none"> Community Involvement Policy 	<ul style="list-style-type: none"> Sustainability-Linked Executive Pay
	<ul style="list-style-type: none"> Green Buildings 	<ul style="list-style-type: none"> Bribery and Anti-Corruption Policy 	<ul style="list-style-type: none"> Executive Pay Improvement Tools
	<ul style="list-style-type: none"> Environmental Products 	<ul style="list-style-type: none"> Smart Working 	<ul style="list-style-type: none"> UN Global Compact
	<ul style="list-style-type: none"> Biodiversity Risk 	<ul style="list-style-type: none"> Freedom of Association Policy 	<ul style="list-style-type: none"> Board Attendance
	<ul style="list-style-type: none"> Renewable Energy Use 	<ul style="list-style-type: none"> Crisis Management Planning 	<ul style="list-style-type: none"> Board Nomination Committee
	<ul style="list-style-type: none"> Emissions Reduction Targets 	<ul style="list-style-type: none"> Employee Health & Safety Policy 	<ul style="list-style-type: none"> TSR-Linked CEO Pay
	<ul style="list-style-type: none"> Climate Change Business Risks & Opportunities 	<ul style="list-style-type: none"> Data Privacy Policy 	<ul style="list-style-type: none"> Stock Options
	<ul style="list-style-type: none"> Environment Management Training 	<ul style="list-style-type: none"> Day Care Services 	<ul style="list-style-type: none"> Shareholder Rights Policy
	<ul style="list-style-type: none"> Environmental Partnerships 	<ul style="list-style-type: none"> Career Development Policy 	<ul style="list-style-type: none"> Audit Committee Independence

Figure 4. ROC Curves for the Environmental, Social and Governance Pillars

Panel A. Environmental Pillar



Panel B. Social Pillar



Panel C. Governance Pillar

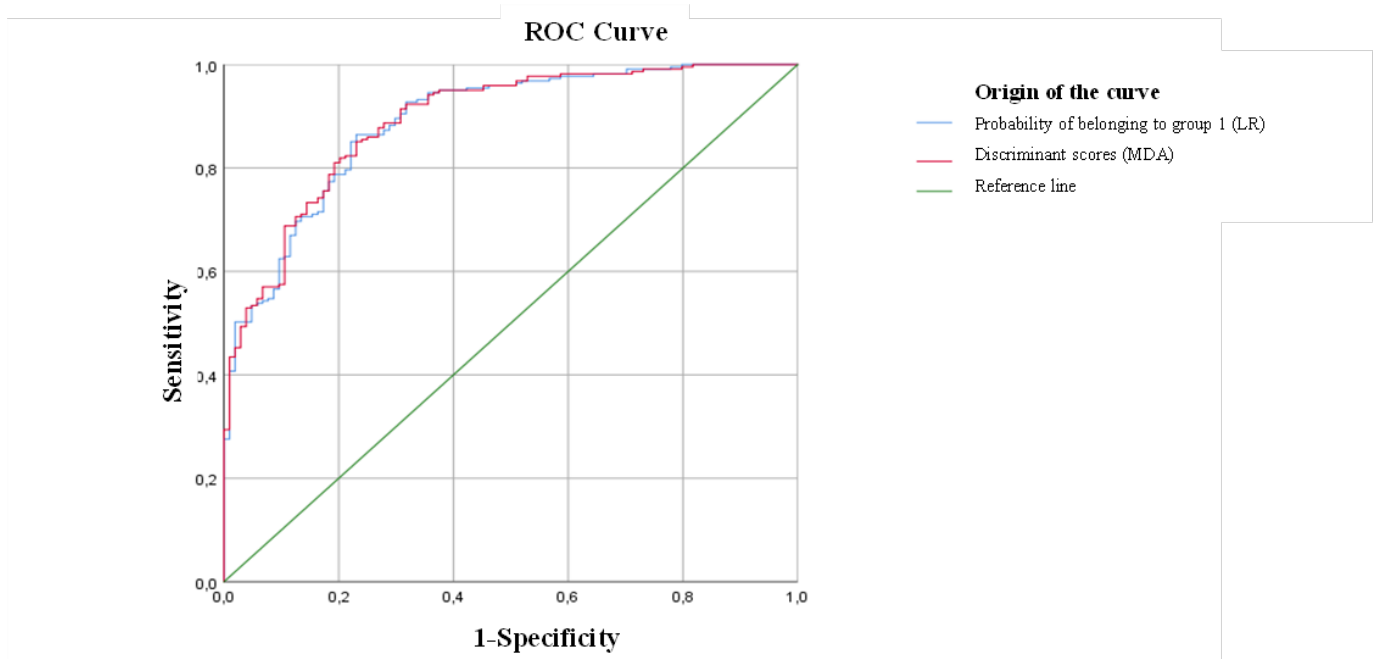
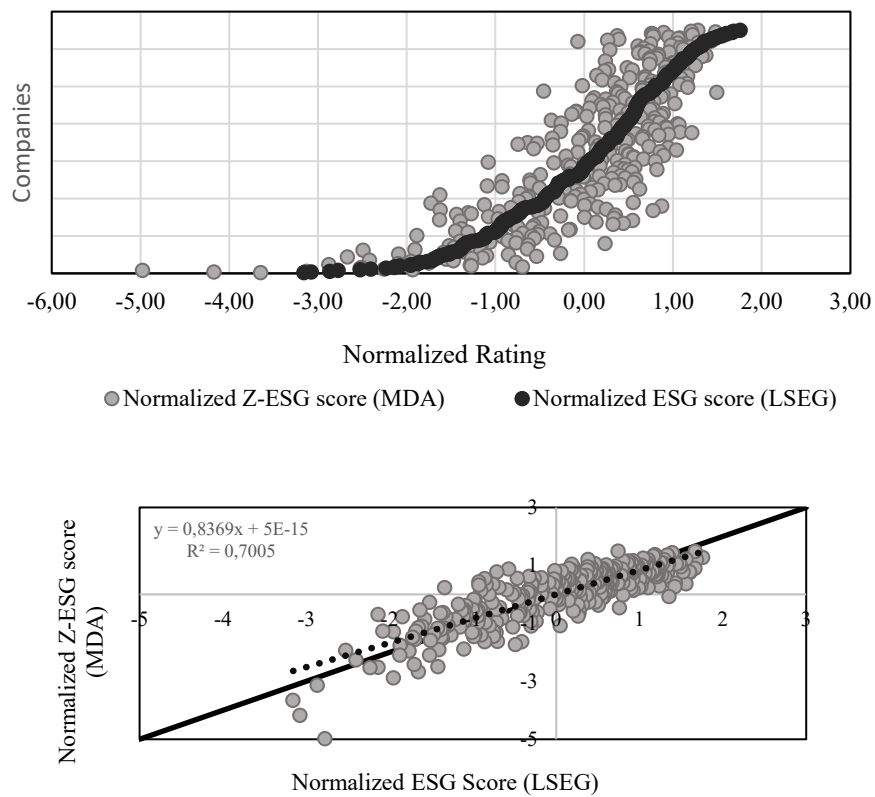


Figure 5. Correlation between Z-ESG and LSEG Ratings

Panel A. Multiple Discriminant Analysis Model



Panel B. Logistic Regression Model

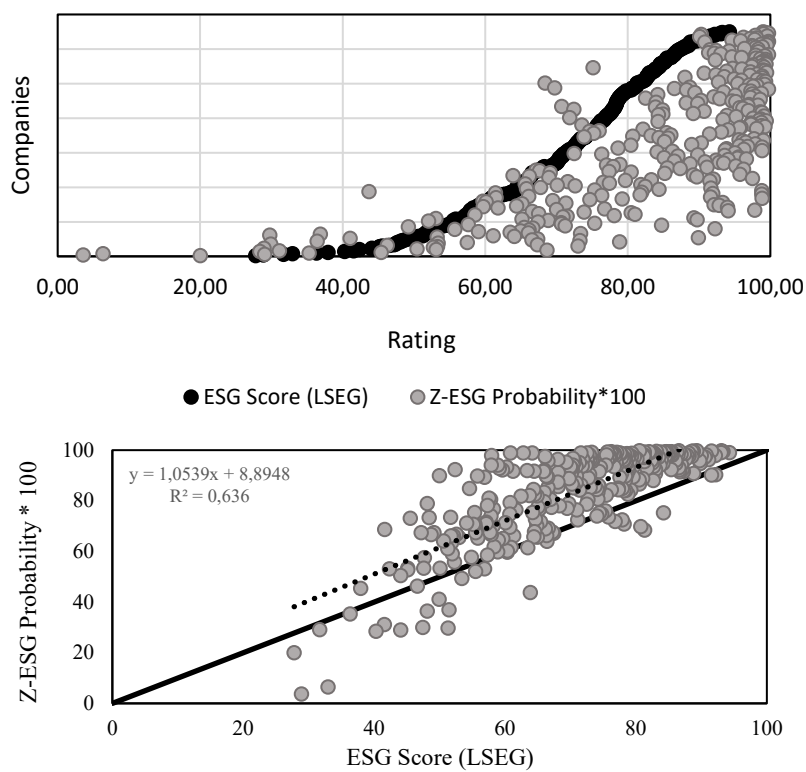


Table 1. Questions of the ESG Compliance Discrimination Survey

#	Question	Answer
1	Does the company prepare a Sustainability Report based on the GRI standards?	Yes/No
2	Is the company assigned a ESG score (or rating) from any provider?	Yes/No
3	Does the company follow the SDGs to define a strategy for improving the sustainability features of its business activity, converting its business model into a sustainable one and set sustainability targets to be achieved over the future years?	Yes/No
4	Does the company have a Sustainability Manager?	Yes/No
5	Does the company have a ESG Committee within its Board of Directors?	Yes/No
6	Does the company conduct a ESG due diligence?	Yes/No
7	Does the company identify its ESG risks and define methods to manage such risks?	Yes/No
8	Does the company measure the impact of its business activity on its ESG profile?	Yes/No
9	Does the company report about its intangible assets?	Yes/No
10	Does the company calculate Key Performance Indicators (KPI) concerning sustainability issues?	Yes/No

Table 2. Independent Variables (Environmental, Social and Governance Pillars)

Independent Variable	Description	Expected Sign	Source
Environmental Pillar			
CO2 Emissions to Revenues	CO2 (and CO2 equivalent) emissions (in tons) divided by revenues (in U.S. billions).	-	Annual Report 2020/ Sustainability Report 2020/ Financial Statements
Waste Recycled to Total Waste	Total recycled and reused waste (in tons) divided by total waste produced (in tons).	+	Sustainability Report 2020/ Annual Report 2020
Environment Management Team	Dummy equal to 1 if the company has a stewardship team that performs functions dedicated to environmental issues, and 0 otherwise.	+	Governance documents (Sustainability Committee)
Environmental Supply Chain Management	Dummy equal to 1 if the company uses environmental criteria (e.g., ISO 14000) in the selection process of its suppliers, and 0 otherwise.	+	Sustainability Report 2020
Environmental Investments	Dummy equal to 1 if the company reports about making proactive investments in order to reduce future risks or increase future opportunities related to the environment (e.g., installation of cleaner technologies), and 0 otherwise.	+	Sustainability Report 2020
Green Buildings	Dummy equal to 1 if the company has green manufacturing sites or offices (with LEED/BREEAM certifications of the buildings), where the company conducts some operations (buildings must be operational at least at the end of the fiscal year), and 0 otherwise.	+	Sustainability Report 2020
Environmental Products	Dummy equal to 1 if the company has at least one line of products or services designed to have positive environmental effects or marketed in an environmental manner, and 0 otherwise.	+	Sustainability Report 2020
Biodiversity Risk	Dummy equal to 1 if the company reports about activities aimed at reducing or mitigating adverse impacts on ecosystems and native species, as well as biodiversity in protected and sensitive areas, and 0 otherwise.	+	Sustainability Report 2020
Renewable Energy Use	Dummy equal to 1 if the company makes use of renewable energy (produced or purchased only for own consumption), and 0 otherwise.	+	Annual Report 2020/Sustainability Report 2020
Emissions Reduction Targets	Dummy equal to 1 if the company has set short- or long-term targets to be achieved on emission reduction at the level of soil, air or water from company operations, and 0 otherwise.	+	Annual Report 2020/ Corporate Website / Sustainability Report 2020

Climate Change Business Risks & Opportunities	Dummy equal to 1 if the company is aware that climate change may pose business risks (threatening the company's existing business model) and/or opportunities for the development of new products (or services) to reduce or overcome climate change impacts, and 0 otherwise.	+	LSEG Workspace
Environment Management Training	Dummy equal to 1 if the company trains its employees on environmental issues (e.g., emissions reduction), and 0 otherwise. Training can be provided by the company or external trainers.	+	LSEG Workspace
Environmental Partnerships	Dummy equal to 1 if the company reports about partnerships or initiatives with specialized NGOs, industry organizations, governmental or supra-governmental organizations that focus on improving environmental issues, and 0 otherwise.	+	Sustainability Report 2020
Social Pillar			
Women Employees* Diversity and Equal Opportunity Targets	Quantitative variable of interaction between the percentage of female employees out of the total number of employees within the company multiplied by a dummy equal to 1 if the company has set goals to achieve on diversity and equal opportunity issues, and 0 otherwise.	+	Sustainability Report 2020;
Human Rights	Dummy equal to 1 if the company conforms to the convention on fundamental human rights of the ILO (International Labor Organization) or supports the Universal Declaration of Human Rights of the United Nations, and 0 otherwise	+	Sustainability Report 2020
Human Rights-Compliant Contracting	Dummy equal to 1 if the company uses human rights criteria in the process of selecting or monitoring its suppliers or procurement partners, and 0 otherwise.	+	Sustainability Report 2020
Business Ethics Improvement Tools	Dummy equal to 1 if the company has adequate communication tools (whistle-blowing, ombudsman, suggestion box, hotline, newsletter, website, etc.) to improve general business ethics, and 0 otherwise.	+	Code of Ethics
Community Involvement Policy	Dummy equal to 1 if the company has a policy to improve its corporate citizenship (e.g., community involvement through donations, volunteering, philanthropic activities; involvement in corporate social responsibility programs in educations, health and the environment), and 0 otherwise.	+	Sustainability Report 2020
Bribery and Anti-Corruption Policy	Dummy equal to 1 if the company states in the code of conduct its commitment to avoid corruption in all its operations (e.g., bribes, inappropriate payments), and 0 otherwise.	+	Code of Ethics; Anti-Bribery and Anti-corruption (ABAC) Global Standard
Smart Working	Dummy equal to 1 if the company claims to provide flexible work schedules or work schedules that promote work-life balance, and 0 otherwise.	+	Sustainability Report 2020
Freedom of Association Policy	Dummy equal to 1 if the company has processes in place to ensure its employees' freedom of association, and 0 otherwise.	+	Sustainability Report 2020

Crisis Management Planning	Dummy equal to 1 if the company puts in place crisis management systems or disaster recovery plans (e.g., to reduce or minimize, for example the effects of reputational disasters), and 0 otherwise.	+	Annual Report 2020
Employee Health & Safety Policy	Dummy equal to 1 if the company has a policy to improve the health and safety of its employees (e.g., processes to reduce workplace accidents and injuries or commuting accidents occurring on the way to and from workplace), and 0 otherwise.	+	Sustainability Report 2020
Data Privacy Policy	Dummy equal to 1 if the company has a policy to protect the privacy and integrity of customers and the general public, and 0 otherwise	+	Sustainability Report 2020
Day Care Services	Dummy equal to 1 if the company claims to provide day care services to its employees (e.g. vouchers for day care centers for adults, disabled or elderly people; child care leave is not included), and 0 otherwise.	+	LSEG Workspace
Career Development Policy	Dummy equal to 1 if the company has a policy to improve the career development paths of its employees (e.g., programs for career progression, development of leadership skills), and 0 otherwise.	+	Sustainability Report 2020
Governance Pillar			
Female Board Members	Percentage of women in the board of directors.	+	Sustainability Report 2020
Independent Board Members	Percentage of independent board members.	+	Annual Report 2020
Corporate Statutes Public Availability	Dummy equal to 1 if the company makes its statutes publicly available, and 0 otherwise.	+	Corporate Website
Remuneration Committee Independence	Dummy equal to 1 if the company reports that all remuneration committee members are non-executive, 0 otherwise.	+	Governance documents (Remuneration Committee)
Sustainability-Linked Executive Pay	Dummy equal to 1 if the compensation of the company's senior executives is tied to CSR/Sustainability goals, and 0 otherwise.	+	Annual Report 2020
Executive Pay Improvement Tools	Dummy equal to 1 if the company has the necessary internal improvement and information tools (e.g., outside legal advisor hired to determine executive compensation, reports or surveys on compensation, compensation committees to assist in performing the task of setting executive compensation) for board members to develop appropriate executive pay schemes so as to attract and retain senior executives, and 0 otherwise.	+	Annual Report 2020/Governance documents (Remuneration Committee)
UN Global Compact	Dummy equal to 1 if the company has signed the UN Global Compact, and 0 otherwise. This is a non-binding United Nations pact to encourage companies around the world to adopt sustainable and socially responsible policies and report on their implementation.	+	Sustainability Report 2020

Board Attendance	Dummy equal to 1 if the company publishes information about individual board members' attendance at board meetings, and 0 otherwise.	+	Annual Report 2020
Board Nomination Committee	Dummy equal to 1 if the company has a board nomination committee, and 0 otherwise. This committee examines the skills and characteristics required for board candidates.	+	Annual Report 2020/Governance documents (Nomination and Governance Committee)
TSR-Linked CEO Pay	Dummy equal to 1 if the CEO pay is tied to Total Shareholder Return (TSR), and 0 otherwise.	+	Governance documents (Remuneration Policy)
Stock Options	Dummy equal to 1 if the company requires that shareholders' approval be obtained prior to the adoption of share-based compensation plans (e.g., stock options' plans), and 0 otherwise.	+	LSEG Workspace
Shareholder Rights Policy	Dummy equal to 1 if the company has a policy to ensure equal treatment of minority shareholders, facilitate shareholder engagement or limit the use of anti-takeover devices, and 0 otherwise.	+	LSEG Workspace
Audit Committee Independence	Dummy equal to 1 if the company reports that all audit committee members are non-executive, and 0 otherwise.	+	Governance documents (Audit Committee)

Table 3. Multiple Discriminant Analysis Model (Environmental Pillar)

Dependent Variable: Environmental Compliance	N° of obs.: 325	
	MDA	
	Coefficient	P-value
CO2 Emissions to Revenues	-0.370***	0.000
Waste Recycled to Total Waste	0.087***	0.001
Environment Management Team	0.165***	0.003
Environmental Supply Chain Management	0.627***	0.000
Environmental Investments	0.302**	0.015
Green Buildings	0.110***	0.007
Environmental Products	1.443***	0.000
Biodiversity Risk	0.147***	0.003
Renewable Energy Use	0.915***	0.000
Emission Reduction Targets	0.664***	0.000
Climate Change Business Risks & Opportunities	0.880***	0.000
Environment Management Training	0.352***	0.007
Environmental Partnerships	0.671***	0.000
Wilks' Lambda	0.587	

Table 4. Multiple Discriminant Analysis Model (Social Pillar)

Dependent Variable: Social Compliance	N° of obs.: 325	
	MDA	
	Coefficient	P-value
Women Employees*Diversity and Equal Opportunity Targets	0.006***	0.001
Human Rights	0.709***	0.000
Human Rights- Compliant Contracting	1.655***	0.000
Business Ethics Improvement Tools	0.555***	0.000
Community Involvement Policy	1.516***	0.000
Bribery and Anti- Corruption Policy	3.185***	0.000
Smart Working	0.242***	0.008
Freedom of Association Policy	0.455***	0.000
Crisis Management Planning	0.148***	0.000
Employee Health & Safety Policy	0.945***	0.000
Data Privacy Policy	0.337***	0.000
Day Care Services	0.044*	0.054
Career Development Policy	0.181***	0.002
Wilks' Lambda	0.587	

Table 5. Multiple Discriminant Analysis Model (Governance Pillar)

Dependent Variable: Governance Compliance	N° of obs.: 325	
	MDA	
	Coefficient	P-value
Female Board Members	0.021***	0.001
Independent Board Members	0.013***	0.000
Corporate Statutes Public Availability	1.140***	0.001
Remuneration Committee Independence	0.690***	0.001
Sustainability-Linked Executive Pay	0.255***	0.000
Executive Pay Improvement Tools	1.058***	0.000
UN Global Compact	0.390***	0.003
Board Attendance	0.585***	0.000
Board Nomination Committee	0.941***	0.000
TSR-Linked CEO Pay	0.413***	0.000
Stock Options	0.237***	0.000
Shareholder Rights Policy	0.645**	0.039
Audit Committee Independence	0.110***	0.001
Wilks' Lambda	0.577	

Table 6. Classification Matrices for the MDA Models

Panel A. Environmental Pillar

		Environmental Pillar	Predicted Group Membership		Total
		Binary Score	0	1	
Actual Group Membership		0	23	16	39
		1	12	274	286
%		0	59.0	41.0	100.0
		1	4.2	95.8	100.0

Panel B. Social Pillar

		Social Pillar Binary	Predicted Group Membership		Total
		Score	0	1	
Actual Group Membership		0	12	9	21
		1	6	298	304
%		0	57.1	42.9	100.0
		1	2.0	98.0	100.0

Panel C. Governance Pillar

		Governance Pillar	Predicted Group Membership		Total
		Binary Score	0	1	
Actual Group Membership		0	67	37	104
		1	15	206	221
%		0	64.4	35.6	100.0
		1	6.8	93.2	100.0

Table 7. Logistic Regression (Environmental Pillar)

Dependent Variable: Environmental Compliance	N° of obs.: 325	
	Environmental	
	Coefficient	P-value
CO2 Emissions to Revenues	-0.603***	0.008
Waste Recycled to Total Waste	0.642	0.495
Environment Management Team	0.344	0.580
Environmental Supply Chain Management	0.070	0.936
Environmental Investments	1.180*	0.053
Green Buildings	1.494*	0.065
Environmental Products	3.167***	0.000
Biodiversity Risk	0.609	0.320
Renewable Energy Use	1.117*	0.073
Emissions Reduction Targets	1.319**	0.020
Climate Change Business Risks & Opportunities	1.007*	0.089
Environment Management Training	1.218**	0.046
Environmental Partnerships	1.810***	0.004
<i>Constant</i>	-5.506***	0.000
Pseudo-R2	0.547	
Cox & Snell R2	0.331	
Nagelkerke R2	0.636	
Loglikelihood	107.973	

Table 8. Logistic Regression (Social Pillar)

Dependent Variable: Social Compliance	N° of obs.: 325	
	LR	
	Coefficient	P-value
Women Employees * Diversity and Equal Opportunity Targets	0.067*	0.054
Human Rights	3.036***	0.002
Human Rights- Compliant Contracting	3.469***	0.001
Business Ethics Improvement Tools	1.753*	0.086
Community Involvement Policy	2.621**	0.045
Bribery and Anti- Corruption Policy	3.524**	0.011
Smart Working	1.415*	0.097
Freedom of Association Policy	2.002**	0.017
Crisis Management Planning	1.494*	0.062
Employee Health & Safety Policy	0.371	0.841
Data Privacy Policy	0.426	0.768
Day Care Services	1.010	0.365
Career Development Policy	-2.767	0.144
<i>Constant</i>	-9.287***	0.002
Pseudo-R2	0.643	
Cox & Snell R2	0.265	
Nagelkerke R2	0.697	
Loglikelihood	55.495	

Table 9. Logistic Regression (Governance Pillar)

Dependent Variable: Governance Compliance	N° of obs.: 325	
	LR	
	Coefficient	P-value
Female Board Members	0.038***	0.010
Independent Board Members	0.022***	0.002
Corporate Statutes Public Availability	2.053**	0.013
Remuneration Committee Independence	1.078***	0.010
Sustainability-Linked Executive Pay	0.669*	0.092
Executive Pay Improvement Tools	1.473***	0.000
UN Global Compact	0.831**	0.019
Board Attendance	0.918***	0.007
Board Nomination Committee	1.449***	0.001
TSR-Linked CEO Pay	0.701*	0.052
Stock Options	0.444	0.194
Shareholder Rights Policy	1.157*	0.077
Audit Committee Independence	0.179	0.677
<i>Constant</i>	-9.280***	0.000
Pseudo-R2	0.398	
Cox & Snell R2	0.393	
Nagelkerke R2	0.550	
Loglikelihood	245.389	

Table 10. The Z-ESG Rating Scale

Rating Scale	Description
AAA	Maximum ESG compliance. Company with excellent ESG performance in every pillar
AA A BBB	Medium-high ESG compliance. Company with good ESG performance in the three pillars
BB B CCC	Average ESG compliance. Company with mixed ESG performance across all three pillars
CC C	Medium-low ESG compliance. Company lagging compared to competitors, low ESG performance in each pillar
D	Low or no ESG compliance. Company with inadequate and insufficient ESG performance

Table 11. The Z-ESG Rating Matrix

	Environmental		Social		Governance		ESG		
<i>Rating Scale</i>	<i>MDA</i>	<i>LR</i>	<i>MDA</i>	<i>LR</i>	<i>MDA</i>	<i>LR</i>	<i>MDA</i>	<i>LR</i>	<i>Description</i>
AAA	>5.920	>0.993	>10.064	>0.997	>7.489	>0.961	>7.823	>0.975	Maximum ESG compliance
AA	5.920	0.993	10.064	0.997	7.489	0.961	7.823	0.975	Medium-high ESG compliance
A	5.536	0.979	9.782	0.955	7.384	0.916	7.601	0.965	
BBB	5.414	0.932	9.588	0.909	6.967	0.875	7.312	0.924	
BB	4.982	0.890	9.123	0.883	6.784	0.844	6.939	0.879	Average ESG compliance
B	4.660	0.841	8.535	0.728	6.376	0.750	6.390	0.781	
CCC	4.099	0.656	8.374	0.573	6.186	0.710	5.879	0.682	
CC	3.150	0.500	6.880	0.500	5.423	0.500	5.151	0.500	Medium-low ESG compliance
C	2.390	0.388	6.153	0.446	4.587	0.283	4.769	0.418	
D	<1.270	< 0.058	< 3.237	<0.023	<2.207	<0.160	<2.768	<0.148	Low or no ESG compliance

Table 12. Distribution of Firms Across the Z-ESG Rating Classes

Panel A. Overall ESG Score	
Z-ESG Rating Scale (Overall Score)	Number of Firms
AAA	26
AA	34
A	52
BBB	61
BB	57
B	38
CCC	35
CC	9
C	11
D	2
Total	325

Panel B. Environmental Pillar	
Z-ESG Rating Scale (Environmental)	Number of Firms
AAA	80
AA	51
A	9
BBB	46
BB	27
B	37
CCC	40
CC	14
C	15
D	6
Total	325

Panel C. Social Pillar

Z-ESG Rating Scale (Social)	Number of Firms
AAA	66
AA	69
A	44
BBB	60
BB	24
B	8
CCC	36
CC	4
C	12
D	2
Total	325

Panel D. Governance Pillar

Z-ESG Rating Scale (Governance)	Number of Firms
AAA	64
AA	44
A	14
BBB	12
BB	43
B	13
CCC	38
CC	29
C	19
D	29
Total	325

Table 13. Correlations Between Z-ESG and LSEG Ratings

Correlation Coefficients Between Z-ESG and LSEG Ratings			
	<i>Z-ESG Rating (MDA)</i>	<i>Z-ESG Rating (LR)</i>	<i>Average</i>
<i>E</i>	0.725	0.661	0.693
<i>S</i>	0.723	0.619	0.671
<i>G</i>	0.723	0.712	0.717
<i>ESG</i>	0.836	0.789	0.812

Table 14. Robustness Analysis Based on Random Sample-Cutting (to 50%)

Panel A. Environmental Pillar

Dependent Variable: Environmental Compliance	N° of obs.: 325		Dependent Variable: Environmental Compliance	N° of obs.: 325
	MDA		LR	
	Coefficient	P-value	Coefficient	P-value
CO2 Emissions to Revenues	-0.365***	0.001	-1.365**	0.026
Waste Recycled to Total Waste	0.332***	0.008	2.095	0.178
Environment Management Team	0.156***	0.003	0.943	0.418
Environmental Supply Chain Management	0.196***	0.001	-2.550	0.259
Environmental Investments	0.386	0.154	2.977**	0.013
Green Buildings	0.291	0.191	2.542*	0.072
Environmental Products	1.097***	0.000	3.564***	0.002
Biodiversity Risk	0.146*	0.072	1.063	0.228
Renewable Energy Use	1.440***	0.000	2.535**	0.023
Emissions Reduction Targets	0.757***	0.000	3.092***	0.008
Climate Change Business Risks & Opportunities	0.894***	0.000	1.014	0.275
Environment Management Training	0.438**	0.038	2.363*	0.056
Environmental Partnerships	0.851***	0.000	3.291***	0.007
<i>Constant</i>			9.481***	0.000
Wilks' Lambda	0.518		Pseudo-R2	0.413
			Nagelkerke R2	0.742
			Loglikelihood	45.800

Panel B. Social Pillar

Dependent Variable: Social Compliance	N° of obs.: 325		Dependent Variable: Social Compliance	N° of obs.: 325
	MDA		LR	
	Coefficient	P-value	Coefficient	P-value
Women Employees * Diversity and Equal Opportunity Targets	0.000***	0.009	0.023	0.543
Human Rights	0.764***	0.000	3.711**	0.023
Human Rights- Compliant Contracting	2.187***	0.000	4.128**	0.011
Business Ethics Improvement Tools	0.182***	0.000	1.194	0.442
Community Involvement Policy	3.678***	0.000	6.152**	0.014
Bribery and Anti- Corruption Policy	3.098***	0.000	4.962**	0.027
Smart Working	0.652***	0.000	3.425*	0.055
Freedom of Association Policy	0.127***	0.002	0.602	0.659
Crisis Management Planning	0.322***	0.003	2.391	0.136
Employee Health & Safety Policy	2.136***	0.000	17.804	0.999
Data Privacy Policy	0.648***	0.000	0.973	0.686
Day Care Services	-0.117**	0.020	0.023	0.990
Career Development Policy	0.596***	0.000	-1.577	0.843
<i>Constant</i>			-33.701	0.999
Wilks' Lambda	0.413		Pseudo-R2	0.371
			Nagelkerke R2	0.809
			Loglikelihood	24.459

Panel C. Governance Pillar

Dependent Variable: Governance Compliance	N° of obs.: 325		Dependent Variable: Governance Compliance	N° of obs.: 325
	MDA		LR	
	Coefficient	P-value	Coefficient	P-value
Female Board Members	0.039***	0.000	0.084***	0.000
Independent Board Members	0.013***	0.000	0.027**	0.019
Corporate Statutes Public Availability	1.223	0.122	1.987*	0.089
Remuneration Committee Independence	0.256*	0.079	0.369	0.548
Sustainability-Linked Executive Pay	0.307***	0.000	1.101*	0.079
Executive Pay Improvement Tools	0.829***	0.000	1.350**	0.017
UN Global Compact	0.433	0.008	1.129**	0.044
Board Attendance	0.581***	0.000	0.959*	0.080
Board Nomination Committee	0.662***	0.000	1.511**	0.028
TSR-Linked CEO Pay	0.539***	0.000	1.184**	0.038
Stock Options	0.182***	0.004	0.489	0.374
Shareholder Rights Policy	0.509	0.478	0.571	0.607
Audit Committee Independence	0.388***	0.001	0.785	0.217
<i>Constant</i>			-10.535***	0.000
Wilks' Lambda	0.548		Pseudo-R2	0.436
			Nagelkerke R2	0.616
			Loglikelihood	107.535

Table 15. Robustness Analysis Based on the RepRisk Index (RRI) (Environmental Pillar)

Dependent Variable: Environmental Compliance	N° of obs.: 238	
	MDA	
	Coefficient	P-value
CO2 Emissions to Revenues	-0.545***	0.002
Waste Recycled to Total Waste	0.491	0.461
Environment Management Team	0.165	0.284
Environmental Supply Chain Management	0.361	0.217
Environmental Investments	0.548***	0.009
Green Buildings	1.216***	0.002
Environmental Products	0.890**	0.018
Biodiversity Risk	0.355**	0.014
Renewable Energy Use	0.763	0.862
Emission Reduction Targets	0.168	0.147
Climate Change Business Risks & Opportunities	0.244	0.211
Environment Management Training	0.268**	0.046
Environmental Partnerships	0.773***	0.007
Wilks' Lambda	0.828	

Table 16. Robustness Analysis Based on the RepRisk Index (RRI): The Z-ESG Rating Matrix

	Environmental	Social	Governance	ESG	
<i>Rating Scale</i>	MDA				<i>Description</i>
AAA	>2.680	>4.365	>3.995	>3.639	Maximum ESG compliance
AA	2.680	4.365	3.995	3.639	Medium-high ESG compliance
A	2.624	4.024	3.963	3.544	
BBB	2.329	3.812	3.685	3.303	
BB	1.963	3.538	3.430	3.063	Average ESG compliance
B	1.884	3.426	3.400	2.869	
CCC	1.794	3.047	2.995	2.406	
CC	1.559	2.542	2.834	2.429	Medium-low ESG compliance
C	0.979	2.003	2.501	2.341	
D	< 0.404	< 0.084	< 1.996	< 1.529	Low or no ESG compliance

Table 17. Robustness Analysis Based on the RepRisk Index (RRI): Distribution of Firms Across the Z-ESG Rating Classes

Panel A. Overall ESG Score	
Z-ESG Rating Scale (Overall Score)	Number of Firms
AAA	63
AA	10
A	24
BBB	26
BB	72
B	-
CCC	-
CC	4
C	37
D	2
Total	238

Panel B. Environmental Pillar	
Z-ESG Rating Scale (Environmental)	Number of Firms
AAA	69
AA	22
A	77
BBB	-
BB	1
B	-
CCC	2
CC	39
C	20
D	8
Total	238

Panel C. Social Pillar

Z-ESG Rating Scale (Social)	Number of Firms
AAA	56
AA	43
A	28
BBB	33
BB	27
B	-
CCC	22
CC	11
C	17
D	1
Total	238

Panel D. Governance Pillar

Z-ESG Rating Scale (Governance)	Number of Firms
AAA	63
AA	1
A	18
BBB	18
BB	46
B	-
CCC	16
CC	25
C	23
D	28
Total	238