



# Green finance sources in Iberian listed firms: A socially responsible investment approach

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## ABSTRACT

Climate change and implementation of the European Green Deal have raised the demand for ecologically friendly financial products and green finance, particularly fixed-income instruments such as green bonds. Given the scarcity of research on the simultaneous effects of market and accounting-based characteristics when combined with green business innovation ability, the purpose of this study is to determine whether market-based and firm accounting variables, as well as environmental technological innovation, play a role in the decision to issue green bonds. Four Limited Dependent Variable models are used, and the results show that market size and market liquidity are the most important predictors of green bond issuance, with proportionate positive and negative effects. Green bond issuance is also impacted by the size factor and environmental technological innovation. Because assets and capitalization are used as collateral when issuing green debt, the current empirical findings demonstrate that size is an essential component in market accounting features other than green bonds, which portray themselves as a hedge market to stock market liquidity. Environmental technological innovation drives green bond issuance because it acts as a market signalling mechanism for a socially responsible company strategy, providing critical information to decision-makers, managers, and investors.

## 1. Introduction

Corporate Finance has become the cornerstone of financial literature as seen by an increase in evidence on capital structure. Capital structure is based on theories that pertain to a given firm's optimal capital structure. For example, agency cost theory (Jensen and Meckling, 1976) is based on conflict between the manager, shareholders, or investors

associated with questions of ownership and control; signaling theory (Ross, 1977) proposes that if managers have special information, their decision-making informs the market about the firm's financial structure; trade-off theory (Kraus and Litzberger, 1973) proposes that a firm's optimal structure is based on a trade-off between the benefit of debt and the cost of bankruptcy; pecking order theory proposes that greater return or cash reserves increase the probability of firms investing without

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the need for external capital (Myers and Majluf, 1984)<sup>1</sup>; dynamic trade-off theory states that firms make profits and losses over time, allowing them to exceed their target debt level, but they only adjust this if the benefits are greater than the costs (Fischer et al., 1989), which implies studying market and fiscal policy behavioral dynamics; market timing theory states that firms have no preference for obtaining finance in bond or equity markets, but choose the market that presents higher valorizations (Baker and Wurgler, 2002).

All the above-mentioned theories have been applied to the wisdom of traditional debt through research concentrating on how managerial actions support such beliefs. However, proof of capital structure in relation to green debt has yet to be established. It should be emphasized that the issue of green finance has gained traction,<sup>2</sup> given the urgent need to finance projects and activities that intensify the transition from fossil fuel consumption to renewable sources, and adhere to corporate principles and public policy regarding sustainable management. Second, it is possible to deepen knowledge about green finance instruments, such as green bonds, which favor sustainable innovation, thereby boosting sustainable growth (Stern and Valero, 2021).

Green bonds provide fixed income, which allows issuers to ensure capital for climate and energy transition projects (World Bank, 2015). This type of financing instrument has characteristics similar to those of conventional bonds (Barua and Chiesa, 2019; Fatica et al., 2021), but with lower financing costs (Li et al., 2020; Zhang et al., 2021). The cost difference compared to traditional bonds stems from the negative premium determined by the market (*greenium*), which stimulates the green bond market toward global investment in environmental projects (Nanayakkara and Colombage, 2019; Zerbib, 2019; Löffler et al., 2021). From this perspective, firms' green bonds, which are active agents in environmental, social, and governance (ESG) implementation, attract more environmentally aware investors, thereby increasing the firm's investor base (Russo et al., 2021) and market valorization (Flammer, 2020).

In light of the research gap identified in the literature, the lack of studies examining the effects of market and accounting-based characteristics (i.e. size, performance, and liquidity), when combined with green business innovation ability (e.g. green innovation), this study aims to determine which mechanisms (based on similar market-based and firm accounting factors) are decisive for the likelihood of Iberian managers' decisions moving towards a financing structure based on green debt. In general, the current study seeks to identify the market and/or accounting factors that influence the issuance of green bonds. Specifically, the goal is to determine whether the effects associated with the factors studied have an aggregate or specific impact on the issuance of green bonds, as well as whether the latter has a greater influence, in terms of market and accounting-based factors, on the likelihood of issuing green bonds.

Applying the analysis to the Iberian context is justified: first, the Portuguese and Spanish economies are integrated through production,

<sup>1</sup> This theory assumes that firms with a strong growth opportunity do not have sufficient internal funds to support future investment costs; therefore, they must resort to external financing (Shyam-Sunder and Myers, 1999).

<sup>2</sup> Throughout this study, understanding of the terms green finance and sustainable finance is based on a similar conceptualization, that is, a financial activity that promotes entrepreneurial activity with environmental benefits. Green finance is becoming part of sustainable finance. Green finance primarily includes green bonds, and to a lesser extent, green loans. In turn, sustainable finance is emerging as a financial activity including the following financial products: Green Bonds, Social Bonds, Sustainability Bonds, and Sustainability-linked bonds. Concerning the relationship between green finance and green bonds, it is worth noting that green finance encompasses all financial activities structured and oriented toward improving environmental issues and the transition to renewable energy. Green bonds are fixed-income financial products aimed at improving environmental issues. This type of financial product is integrated in the green finance framework, as is green credit.

consumption, and foreign direct investment. Second, Portugal has become a European market of reference in the transition to clean, green energy sources through technological innovation based on green patents. Third, Spain has become a larger producer and consumer and is clearly expanding, stimulated by the application of green technology to develop renewable energy sources (European Commission, 2018).

As a result, to gain insight into how the energy transition is being carried out in the Iberian market for renewable energies, which is in a period of growth and consolidation, an analysis including several financial and market indicators, as well as a company's ability to innovate, must be conducted.

What are the most important market, organizational, and innovation elements in the strategic choice to issue green bonds? Answers to this question are critical in order to develop guidelines to identify viable financing sources for future investments in green activities that will accelerate the energy transition at the entrepreneur level. It is also becoming clear that the rate at which the Iberian economies, pioneers in creating an Iberian energy market, are making that energy transition, has the potential to serve as a regulatory and competitive benchmark. This can motivate sustainable development and the growth of new green finance markets, which enable greater capacity and autonomy, in terms of both energy and individual economies.

In terms of contributions to the literature on sustainable finance, firstly, the effects of several determinants of green bonds issuance are demonstrated, with emphasis on two dimensions of business characteristics: firm-market based; and firm-accounting based, in conjunction with a green innovation factor. Secondly, the effects of size, performance, and liquidity on the cumulative probability of green bond issuance, are examined. Thirdly, within the framework of green bond analysis, the probability of green bond issuance is assessed in the context of Iberian companies, using a variety of economic techniques based on Limited Dependent Variable models.

## 2. Literature review and research hypotheses

Although business characteristic effects on leverage (i.e., capital structure) have been examined in the corporate finance literature, empirical evidence on business characteristics related to issuing debt is limited. Few studies have examined the relationship between business characteristics and green finance sources (e.g., green bonds or green credit) or the determinants of issuing green debt.

This literature review identified, firstly, the state-of-the-art of green bonds, and secondly, summarizes the essential aspects of traditional theories on corporate finance and the empirical literature on sustainable management. This led to developing the research hypotheses by focusing on the relationships between firms' characteristics and decisions regarding green bond issuance.

### 2.1. Green bonds: brief state-of-the-art

Green bonds are a financial innovation product that aims to fund environmentally friendly projects (Bhutta et al., 2022). The financing of institutions has emerged as an important mechanism in the energy transition (Jakubik and Uguz, 2021), as it has the potential to intensify the mitigation of greenhouse gas effects, particularly in institutions financed by green bonds (Fatica and Panzica, 2021).

The greater interest observed in green products is due to agents' increased sensitivity to the effects of climate change in three dimensions: economic, environmental, and social (Gianfrate and Peri, 2019), indicating institutions' greater commitment to this problem (Flammer, 2021), in response to regulatory changes introduced by the European Green Deal (Leitao et al., 2021). Green bonds may be used as a signaling mechanism for markets and society, allowing for more attention from investors and consumers (Maltais and Nykvist, 2021; Tang and Zhang, 2020; Flammer, 2021; Sangiorgi and Schopohl, 2021).

It is worth noting that green bonds allow for reduced information

asymmetry between the issuer and the investor, thereby increasing the transparency of the resources allocated (Hyun et al., 2020; Jankovic et al., 2022; Fatica and Panzica, 2021; Sangiorgi and Schopohl, 2021; Zhang et al., 2021). Information asymmetry can be reduced through an external consulting process provided by ESG analysts, who produce an independent review of the investment processes to ensure the necessary information about the green project's issuer (Fatica and Panzica, 2021; Jankovic et al., 2022). This approach is essential to avoid greenwashing (Flammer, 2021), as well as investors demanding lower returns due to lower information costs (Hyun et al., 2020; Sangiorgi and Schopohl, 2021) and shareholder benefits (Tang and Zhang, 2020).

It is also worth mentioning that despite the environmental component, investor yields on green bonds are not considerably higher than traditional bond rates (Zerbib, 2019).

## 2.2. Market size effects

A firm's market size indicates its valorization (expected future value for investors), and valorization in the market diminishes a firm's participation in the bond or credit market, which may result in it being identified as leveraged because it failed to obtain capital funds owing to weak market assessment (Baker and Wurgler, 2002). In a bullish market context, managers direct their financing decisions to the share market rather than the debt market (Antoniou et al., 2008). Similar decision-making is expected in the context of corporate bond yields, because of higher finance costs (Kuvshinov and Zimmermann, 2022) relative to lower share market finance costs (Bancel and Mittoo, 2004). Although increased share prices increase the likelihood of firms financing themselves through share markets, they could still issue debt or be leveraged, because financing is correlated with market sentiment (Hovakimian et al., 2004). Firms sometimes issue debt to guard against hostile takeovers (Dell'Acqua et al., 2013). In certain market behavior contexts, co-movement between share markets and the green bond market varies over time (Reboredo, 2018).

From a corporate social responsibility and sustainability perspective, firms with greater market capitalization have more reason to invest in projects oriented toward energy transition (Ahmed and Jahanzeb, 2021; Raghutla et al., 2021; Zhang, 2022), aiming for sustainable development of production and exports (Ahmed and Jahanzeb, 2021). Notably, firms with strong market capitalization that adopt sustainable practices arouse greater investor and stakeholder interest, which contributes to developing socially responsible investment portfolios (Nelling and Webb, 2009; Garcia et al., 2017). Therefore, Hypothesis 1 was proposed:

**H1.** *Market size contributes to a significant increase in green bond issuance.*

Studies have shown that firm size is an important proxy for corporate finance, which has a critical effect on the level of debt issued (Dang et al., 2018). In financial markets, players follow the motto *too big to fail* to leverage investment through debt. The size effect is a dominant factor in leveraging, since large firms enjoy a greater reputation in markets (Huang and Shang, 2019), and therefore more easily access credit and debt markets (Friend and Lang, 1988) at a lower cost (Fama and French, 2002; Dell'Acqua et al., 2013). Through this connection, large firms, or those with more valuable assets, tend to issue debt (and obtain leverage) through bond markets rather than bank credit, because the bond market does not have the inflexible pressure relationship of, for example, presenting collateral (Flannery and Rangan, 2006). Large firms' high reputation arises from their lower likelihood of bankruptcy (Baker and Wurgler, 2002; Mao, 2003; Hovakimian et al., 2004; Udomsirikul et al., 2011; McMillan and Camara, 2012; Dell'Acqua et al., 2013). In other words, as a firm's assets increase, the probability of bankruptcy decreases (Rajan and Zingales, 1995; Antoniou et al., 2008; de Jong et al., 2008). Trade-off theory predicts a positive relationship between leverage and firm size (Hovakimian et al., 2001; Frank and Goyal, 2009; Udomsirikul et al., 2011; McMillan and Camara, 2012; Jarallah et al., 2019), because larger firms present less volatile flows (Udomsirikul

et al., 2011; McMillan and Camara, 2012), a more mature relationship with the market (Frank and Goyal, 2009; Udomsirikul et al., 2011), and greater diversity (Frank and Goyal, 2009; McMillan and Camara, 2012).

Pecking order theory asserts that financing costs increase with greater information asymmetry between market agents and managers. Additionally, financing through equity is preferable for external funding. Although information asymmetry is related to size, it facilitates external financing with a longer maturity (Zeitun and Goaid, 2021), especially in a bearish share market context (Hovakimian et al., 2001). Leverage and size may be negatively related, because larger firms have greater market maturity, and therefore, a greater capacity to retain profits and make investments without the need for external funds (Frank and Goyal, 2009). Moreover, firms with strong market valorization can identify growth opportunities (Hovakimian et al., 2001), which provides better access to the share market and attracts stakeholders interested in increasing capital gains (Chen, 2004).

In the domain of environmental sustainability and energy transition, the existing literature indicates that firm size contributes to increased funds originating from green bonds (Barua and Chiesa, 2019; Chiesa and Barua, 2019). Therefore, Hypothesis 2 was formulated:

**H2.** *Firm size contributes to a significant increase in the issue of green bonds.*

Although market size and firm size are usually strongly correlated, their effects on the dependent variable are not interchangeable (Dang et al., 2018), but can have opposite effects. Therefore, size effects are considered in the context of sustainable practices and the literature on green bonds to develop Hypothesis 3:

**H3.** *The size factor contributes to a significant increase in the issue of green bonds.*

## 2.3. Performance effects

Firms with strong market performance must show low rates of leverage or debt (Flannery and Rangan, 2006; Machokoto et al., 2020), or recourse to financing sources that provide less leverage (Hovakimian et al., 2004), to avoid jeopardizing future profitable investments and to prevent the transfer of investors/shareholders' wealth to creditors (including high-risk securities) (Fama and French, 2002; Huang and Song, 2006; de Jong et al., 2008). Consequently, firms with high growth opportunities or performance have the flexibility to reduce investment levels and lessen their debt exposure, which essentially transfers creditors' wealth to investors/shareholders, that is, issuing less debt (Chen, 2004). In addition, market performance and leverage have a negative relationship when firms are underinvested, given the high debt level (Zeitun and Goaid, 2021) and high returns demanded by creditors (Antoniou et al., 2008; Huang and Shang, 2019). In turn, high performance contributes to firms' valorization in the share market, which encourages managers to issue shares (Rajan and Zingales, 1995; Frank and Goyal, 2009), at lower financing costs, rather than issuing debt in bond markets (McMillan and Camara, 2012). Nevertheless, firms with a strong future investment perspective tend to issue debt to support future investment needs (Doukas et al., 2011), and buy back shares (devalued because of increased debt), ultimately to prevent new shareholder or investor entry (Jarallah et al., 2019).

The nature of the relationship between market performance and corporate policies on sustainability and the environment (including social responsibility) is similar to that of market and firm performance. That is, a firm showing robust, sustained performance is associated with sustainable, environmentally friendly corporate policies, and has a positive effect on investor interest (Yu et al., 2018), meaning greater profits and financial stability (Gao and Zhang, 2015). Adopting socio-environmental policies provides a greater investment opportunity for firms with great maturity and reputation (Elsayed and Paton, 2009), although inverted U-shaped relationships can be found (Lahouel et al.,

2020). Based on the above, Hypothesis 4 was formulated:

**H4.** Market performance contributes to a significant increase in the issue of green bonds.

A highly profitable firm tends to finance itself through equity (internal finance), with retained profits over time contributing to its need to obtain funds from financial markets, which is consistent with pecking order theory forecasts (Friend and Lang, 1988; Rajan and Zingales, 1995; Baker and Wurgler, 2002; Frank and Goyal, 2003; Chen, 2004; Huang and Song, 2006; Flannery and Rangan, 2006; Antoniou et al., 2008; de Jong et al., 2008; Udomsirikul et al., 2011; McMillan and Camara, 2012; Fernández-Cuesta et al., 2019; Huang and Shang, 2019; Machokoto et al., 2020; Tascón et al., 2021; Zeitun and Goaid, 2021). Market timing theory (Baker and Wurgler, 2002) suggests a negative relationship between firm performance and leverage, because the public presentation of profits increases both the firm's share value and its issue costs, leading managers to choose share markets (McMillan and Camara, 2012), despite retained profits being the least expensive and quickest form of financing compared to issuing shares, since financing involves transaction costs and obstacles (Chen, 2004).

The negative relationship between firm performance and leverage can also be interpreted as a firm's response to information asymmetry among managers, debtholders, and stakeholders (Jarallah et al., 2019). Capital accumulation becomes a resource by substituting hypothetical financing with risk securities (Udomsirikul et al., 2011). Firms can use foreign ownership as an alternative form of financing because foreign investors apply their capital in projects where profits come from internal finance (The nonlinear effect of foreign ownership on capital structure in Japan: A panel threshold analysis). Unprofitable firms issue shares to reduce their capital structure leverage (Hovakimian et al., 2004) and profitable firms passively finance themselves by accumulating profits over time (Frank and Goyal, 2009). However, in trade-off theory situations, profitable firms with a tendency toward leverage have greater gains, implying greater tax benefits and lower bankruptcy costs (Xu, 2012; Colla et al., 2012).

The environmental and responsible viewpoint asserts that larger, profitable firms are likely to communicate and highlight their corporate policy and ESG strategy (Yu et al., 2018) above all, because of their reputation and visibility in the market (Elsayed and Paton, 2009). Obtaining sustainable returns over time facilitates issuing (green) debt in higher monetary amounts, and greater persistence in acquiring this type of debt security with a fixed income (Barua and Chiesa, 2019; Chiesa and Barua, 2019). This implies lower financing costs (Fernández-Cuesta et al., 2019; Tascón et al., 2021) and better environmental performance (Lee et al., 2016). Nevertheless, firms with good financial performance that are integrated into markets where transparency practices and policies are limited or non-existent do not necessarily ensure improved environmental performance (García et al., 2017). Therefore, Hypotheses 5 and 6 were formulated:

**H5.** Firm performance contributes to a significant increase in the issue of green bonds.

**H6.** The performance factor contributes to a significant increase in the issue of green bonds.

#### 2.4. Liquidity effects

The negative relationship between market liquidity and leverage is explained by firms with liquidity preferring finance through share markets, leading to a greater incentive to increase capital rather than take on more debt (Lipson and Mortal, 2009; Udomsirikul et al., 2011; Ahangar, 2021), which contributes to greater financial flexibility (Shang, 2020). Share liquidity allows shareholders to monitor management more closely and mitigates conflicts of interest between agents (Marks and Shang, 2021).

From a corporate sustainability perspective, this study emphasizes

two lines of empirical evidence. First, firms with greater liquidity demonstrate more limited socially responsible behavior (Chang et al., 2019). Second, firms presenting greater socially responsible performance and ESG show greater liquidity because of their reputation and visibility, which attracts more investors (Egginton and McBrayer, 2019; Luo, 2022; Roy et al., 2022). However, firms with greater visibility related to carbon emissions show greater repercussions through disinvestment (Mama and Mandaroux, 2022). Lower share liquidity equates to higher green bond yield spreads (Chang et al., 2021). This led to formulating Hypothesis 7:

**H7.** Market liquidity contributes to a significant increase in the issue of green bonds.

Financial liquidity allows firms with greater gains to use internal cash flow to reduce debt or leverage (Frank and Goyal, 2003; de Jong et al., 2008; Dell'Acqua et al., 2013; Zeitun and Goaid, 2021; Nnadi et al., 2022). Corporate level adoption of this financial policy is based on: (i) diminishing debt, implying reduced liquid financial position in relation to liabilities (Dell'Acqua et al., 2013) and the risk of future liquidity (Nnadi et al., 2022); and (ii) attracting foreign capital to invest in profitable projects, thereby increasing firm value (Zeitun and Goaid, 2021). Nevertheless, internal cash flow reserves can serve as a restriction; firms that cannot access financial markets are forced to retain cash flow for their investments (Acharya et al., 2007; Denis and Sibilkov, 2010) or amortize short-term debt, because this segment incurs higher costs (Harford et al., 2014). This context may include changed situations for listed firms (with easier market access), and unlisted firms (with restricted market access) (Mortal et al., 2020). From another perspective, firms with a strong growth tendency have a strong future need for capital, which leads to increased external financing and reduced internal cash flow or savings (Lins et al., 2010; Campello et al., 2011; Chang and Hung, 2021). Considering the relationship between cash holdings and adopting corporate sustainability policies, previous research suggests that firms with internal cash reserves or internal savings have less need for external finance sources for their investments (Barua and Chiesa, 2019; Chiesa and Barua, 2019; Zhang et al., 2020). This does not invalidate the possibility of enjoying feedback between financial and socially responsible performance (Arouri and Pijourlet, 2017).

Atif et al. (2022) showed that ESG firms present low cash flow owing to moral capital,<sup>3</sup> and the ESG indicator becomes an instrument of market safety. Therefore, Hypothesis 8 was proposed:

**H8.** Firm liquidity contributes to a significant reduction in the issue of green bonds.

Previous corporate sustainability research has reported contradictory results. This study assumes that firms with greater liquidity tend to issue less debt, attract more capital, and obtain more internal flows for their investments, which are either directed toward green projects or core business projects. Therefore, Hypothesis 9 was formulated:

**H9.** The liquidity factor contributes to a significant reduction in the issue of green bonds.

#### 2.5. Environmental technological innovation effects

R&D activities that target environmental technology innovation are a determinant factor of financing through shares, because increased capital attracts new investors motivated to invest in clean energy projects (Raghu et al., 2021), and guards against hostile takeovers and external-investor-controlled management (Aghion et al., 2004). However, highly innovative firms are averse to financing through debt to

<sup>3</sup> Capital that promotes rational management of physical and monetary capital, in order to stimulate rational awareness in society with the aim of providing mutual benefits (Wang, 2018).

avoid future under-investment (Bhagat and Welch, 1995; Doukas et al., 2011), preferring to retain profits or cash reserves for future growth (Hall, 2002; Hsu et al., 2015).

Technological innovation promotes increased greenium (Agliardi and Agliardi, 2019), which means reducing production’s environmental costs, implying more robust competitiveness and economic performance (Wang et al., 2021). Thus, green bonds’ performance is related to environmental technological innovation development (Russo et al., 2021), which conveys to the market that scientific and technological innovation are connected to green growth (Zhou et al., 2022). However, investing in green projects, including intangible assets, increases the likelihood of firms applying their own funds because these latent assets cannot be used as collateral (Xiang et al., 2022). From this, Hypothesis 10 was formulated:

**H10.** Environmental technological innovation contributes to a significant increase in the issue of green bonds.

Given the literature on capital structure determinants, there are three fundamental elements to consider for strategic debt issuance decisions. First, size, which can be assumed as an image of reputation or collateral for indebtedness and leverage. Second, performance, which demonstrates the level of wealth creation for investors and shareholders, and as a result, allows us to determine if shareholders intend to participate in the debt and credit markets. However, considering the “green” component next to the dividend, decision-makers may decide to issue green bonds in order to increase corporate and environmental responsibility. Third, liquidity, as an indicator of cash flow (or cash reserves) and how the market perceives an organization’s management (purchase and sale of assets), demonstrates how an organization can honor its commitments in the future.

Taking into account the behavioral interdependence between the company, the stock market, and the bonds market, it is now necessary to analyze whether the indicators based on the company or the indicators based on the market (or both) influence (and in what way) the issuance of green bonds.

The focus in the market for green bonds should be on the current energy transition period, in the context of the European Green Deal, as well as the fact that there is an increased demand for these activities, with the Iberian economies serving as a laboratory, the result of a benchmark of regulation and competition, leading to liberalization of the electricity market, and the subsequent establishment of an Iberian electricity market. It is worth noting that the increased demand for green bonds might be positively associated with corporate social responsibility or lower issuance costs.

The incorporation of green innovation into the model is justified by being a driving force of green and sustainable growth, capable of positively influencing corporate sustainability and reinforcing signalling to investor and consumer markets.

### 3. Methodology and data

#### 3.1. Econometric methodological approach

This study adopted market- and accounting-based factors and environmental technological innovation approaches to examine effects associated with the probability of issuing green bonds. A panel probit model is used, because the linear probability model (i.e., least squares) operates probabilities below zero and above one (Wooldridge, 2020), making it unsuitable for this study because it does not have the properties of a limited dependent variable model (LDV). To compensate for this disadvantage, other LDV models were used as alternatives to confirm better estimate consistency.

##### 3.1.1. Main econometric model

A panel probit model identifies the likelihood of a given event occurring (in this case, green bond issuance) and has the implicit

property of a normal distribution (Wooldridge, 2020).<sup>4</sup> Therefore, based on Greene (2004a), a panel probit model is:

$$Y_{it}^* = X'_{it}\beta^0 + \varepsilon_{it} \quad t = 1, \dots, N \text{ and } i = 1, \dots, T$$

$$Y_{it} = 1(Y_{it}^* > 0) \tag{1}$$

where  $Y_{it}^*$  is an unobserved latent variable, and  $1[\cdot]$  is an indicator function with a value of one when the event occurs and zero otherwise. Additionally,  $Y$  has a value of one when  $Y^* \geq 0$  and the value of zero when  $Y^* < 0$  (Wooldridge, 2020). It should be noted that the set of independent variables  $X'_{it}$  is strictly exogenous and independent of  $\varepsilon_{it}$ , that is,  $Cov[X_{it}, \varepsilon_{jt}] = 0 \forall i \neq j, t \neq s$ .

The random disturbance has a normal distribution with an average of zero and variance  $\sigma_{\varepsilon}$ , which indicates that  $1 - G(-z) = G(z), \forall$  the real numbers  $z$ , where  $G$  is a standard normal cumulative distribution function (cdf)<sup>5</sup> with values  $0 < G(z) < 1$  (Wooldridge, 2020). From Eq. (1):

$$P(Y = 1|X) = P(Y^* > 0|X) = P[e > -(\beta_0 + X\beta)|X] = 1 - G[-(\beta_0 + X\beta)] = G(\beta_0 + X\beta) \tag{2}$$

##### 3.1.2. Other dichotomous dependent variable models

The panel logit model is distinguished from the panel probit model by the cumulative distribution function, which is expressed as a logistic function (Wooldridge, 2020):

$$G(z) = \frac{\exp(z)}{1 + \exp(z)} = \Lambda(z) \tag{3}$$

In other words, by considering Eq. (2),  $G(\beta_0 + X\beta)$  has a logistic function similar to that presented in Eq. (3). Therefore,  $\varepsilon_{it}$  is an independent and identically distributed stochastic process of a logistic distribution with an average of nil and variance  $\frac{\pi^2}{3} \approx 3.29$  (Cramer, 2007).

The panel cloglog (complementary log-log) model is asymmetric (the panel probit and panel logit models are symmetric) because it models extreme events with skewed distribution properties (Agostino et al., 2022). Therefore, by considering Eq. (2), the log-log function is:

$$G(z) = G(\beta_0 + X\beta + \varepsilon_{it}) = 1 - \exp\{-\exp(z)\} \tag{4}$$

where  $\varepsilon_{it}$  is an independent and identically distributed stochastic process of an extreme value or Gumbel distribution with an average equal to the Euler constant ( $\approx 0.577$ ) and variance  $\frac{\pi^2}{6} \approx 1.645$  (Ntzoufras, 2009; Agresti, 2013).

##### 3.1.3. Count variable models

Count variable models contribute to greater robustness, consistency, and requirements (of a penalizing nature) to ensure more accurate re-

<sup>4</sup> The literature recommends that the probit and logit models should present identical estimates, but the probit model estimates the probability of an event occurring and the logit model estimates results corresponding to the odds of confirming an event. In this connection and given that the model is more efficient and consistent with random effects (as is shown in the main results section), we used the panel probit model because it does not assume fixed effects, unlike the panel logit model. Also, including fixed-effects with the maximum likelihood estimator causes inconsistency in the model, since the number of parameters  $\alpha_i$  (nuisance parameters) increases as  $n \rightarrow \infty$  (for more details, see Neyman and Scott, 1948; Lancaster, 2000; Greene, 2004b). The panel cloglog model also incorporates a set of dichotomous dependent variable models, but does not incorporate fixed-effects, and is used as a complementary and robustness model (just as the panel logit model) for the principal panel probit model.

<sup>5</sup>  $G(z) = \Phi(z) = \int_{-\infty}^z \varphi(v)dv$ .

sults. The panel Poisson model<sup>6</sup> describes scenarios in which the response variable shows non-negative values. Moreover, the Poisson model specifies small values, because zero is a typical value to characterize the nature of scenarios and phenomena (Papke, 1991). The panel Poisson model with random effects is as follows (Hausman et al., 1984):

$$P(Y_{it} = y_{it} | X_{it}, \varepsilon_i) = \frac{e^{-\lambda_{it} e^{\varepsilon_i}} (\lambda_{it} e^{\varepsilon_i})^{y_{it}}}{y_{it}!} \quad (5)$$

where,  $\lambda_{it} = \exp(X_{it}\beta)$ ;  $y_{it} \equiv$  number of events, and  $\lambda \equiv$  event rate. Therefore, via Maximum Likelihood Estimator, the joint density function specification can be rewritten as follows (Hausman et al., 1984; Cameron and Tiveldi, 2015):

$$P(Y_{it}, \mu_i | X_{it}) = P(Y_{it} | X_{it}, \mu_i) g(\mu_i) = \prod_t \frac{\lambda_{it}^{y_{it}}}{y_{it}!} e^{-\lambda_{it}} e^{\mu_i \sum_t y_{it}} g(\mu_i) \quad (6)$$

where  $g(\cdot)$  is a density function with parameters, in which  $\mu_i$  is a specific effect that follows a Gamma distribution of parameters  $(\delta, \delta)$ , with an average of 1 and variance given by  $\frac{1}{\delta}$ . Expression of eq. (6) derived from the assumption that the conditional distribution of  $u_i$  given values of  $X_i$  is equal to the unconditional distribution of  $u_i$ . In this context, the panel Poisson with random effects exhibits as follows:

$$E(Y_{it} | X_{it}, \mu_i) = \mu_i \cdot \exp(X_{it}\beta) \quad (7)$$

Where,  $(Y_{it}) = \lambda_{it} \text{var}(Y_{it}) = E(Y_{it}) \cdot \frac{y_{it}}{\varphi}$ ,  $\varphi \equiv$  overdispersion parameter.

### 3.2. Data description and model specification

---


$$\text{Probit} : \Pr \left( \begin{matrix} GB_{it} = 1 | X_{it} = \text{Market\_SIZE}_{it}, \text{Market\_PERFORMANCE}_{it}, \text{Market\_LIQUIDITY}_{it}, \\ \text{Firm\_SIZE}_{it}, \text{Firm\_PERFORMANCE}_{it}, \text{Firm\_LIQUIDITY}_{it}, \text{Green\_TECH}_{it} \end{matrix} \right) = G(X_{it}\beta + \nu_i + \varepsilon_i) \quad (8)$$


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To analyze the effects of market- and accounting-based factors and environmental technological innovation on green bond issuance decisions in an Iberian context, four LDV models were used, unbalanced with annual longitudinal data and an analysis period from 2010 to 2020.

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$$\text{Logit} : \Pr \left( \begin{matrix} GB_{it} = 1 | X_{it} = \text{Market\_SIZE}_{it}, \text{Market\_PERFORMANCE}_{it}, \text{Market\_LIQUIDITY}_{it}, \\ \text{Firm\_SIZE}_{it}, \text{Firm\_PERFORMANCE}_{it}, \text{Firm\_LIQUIDITY}_{it}, \text{Green\_TECH}_{it} \end{matrix} \right) = G(X_{it}\beta + \nu_i + \varepsilon_i) = 1 + \exp \left\{ - (X_{it}\beta + \nu_i + \varepsilon_i) \right\}^{-1} \quad (9)$$


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<sup>6</sup> The literature suggests that a negative binomial model is an alternative to the Poisson model in that the latter allows overdispersion (when the conditional variance of the dependent variable is greater than the conditional average). However, the dependent variable in this study is dichotomous. Therefore, the coefficients and statistical significance will be similar in both models, because in the negative binomial model the parameter  $\alpha$  is equal to zero, then the negative binomial model is transformed into the Poisson model (for better understanding see Hausman et al., 1984; Cameron and Trivedi, 2013). So, the model is equi-dispersion. However, to advance this hypothesis, we used the regression-based test by Cameron and Trivedi (2013), indicating non-rejection of the null hypothesis of mean-variance equality or Poisson distribution. The results are available upon request from the author.

The study included 129 listed firms, 98 corresponding to the Spanish financial market and 31 corresponding to the Portuguese financial market.<sup>7</sup> The sample period was chosen because it covered events with a European impact, such as the sovereign debt crisis, approval of sustainable and ecological packages (e.g., European Green Deal), and the launch of the global green bond index (e.g., S&P Green Bonds).

In the main model (and consequently in the robustness models), green bonds were the dependent variable, indicating whether firms issued green bonds in the international market (value = 1, and 0 otherwise). The independent variables representing market- and accounting-based variables were continuous.

Market value (Market\_SIZE), as a logarithm, was used as a proxy for market size (Beck et al., 2000; Dang et al., 2018; Kuvshinov and Zimmermann, 2022); Tobins' q (Market\_PERFORMANCE) was a proxy for market performance (Bharadwaj et al., 1999; Nason and Patel, 2016; Jia, 2018); and share turnover (Market\_LIQUIDITY) was a proxy for market liquidity (Chordia et al., 2001; Baker and Stein, 2004; Lipson and Mortal, 2009; Ahangar, 2021).

Total assets as a logarithm (Firm\_SIZE) were a proxy for firm size (Chen, 2004; Flannery and Rangan, 2006; Dang et al., 2018); profitability (Firm\_PERFORMANCE) was a proxy for firm performance (Frank and Goyal, 2009; Colla et al., 2012); and cash holdings (Firm\_LIQUIDITY) were a proxy for firm liquidity (Opler et al., 1999; Ferreira and Vilela, 2004; Campello et al., 2011; Morais et al., 2021). The environmental technological innovation variable (Green\_TECH) (Ding et al., 2022) was used as a proxy. Table 1 describes the variable characteristics.

The selected specification models are:

In which  $i = 1, \dots, 129$  firms,  $t = 2010, \dots, 2020$ ,  $\nu_i$  represents the random effects, and  $\varepsilon_i$  the error term.

In which  $i = 1, \dots, 129$  firms,  $t = 2010, \dots, 2020$ ,  $\nu_i$  represents the random effects, and  $\varepsilon_i$  the error term.

<sup>7</sup> Data were not collected for listed firms in the financial services sector or listed firms for which information was not available.

**Table 1**  
Model variable characteristics.

Variables	Description	Source	Unit
<i>Dependent variable</i>			
Green Bonds (GB)	Green Bonds Issuance (1 = True; 0 = False)	Climate Bonds Initiative; Euronext ESG Bonds; Frankfurt börse Green bonds; Luxembourg Boerse Green Bonds Exchange; Press release	Binary
<i>Market-based variables</i>			
Market Capitalization (Market_Size)	Stock Price * Shares Outstanding	Amadeus Bureau Van Dijk	Euro
Tobin's Q (Market_performance)	Market value + Total assets – Book value of common equity/(Total Assets)		
Share Turnover (Market_liquidity)	Trading Volume/Shares Outstanding		
<i>Firm accounting-based variables</i>			
Log Total Assets (Firm_size)	Log (Total Assets)	Amadeus Bureau Van Dijk	Euro
Profitability (Firm_performance)	EBITDA/Total Assets		
Cash Holdings (Firm_liquidity)	Cash and Cash Equivalent/Total Assets		
<i>Environmental technology innovation</i>			
Green Patents (Green_tech)	Number of Green Patents	WIPO Green Database	Counting

$$Cloglog : \Pr \left( \begin{matrix} GB_{it} = 1 \\ Firm\_SIZE_{it}, Firm\_PERFORMANCE_{it}, Firm\_LIQUIDITY_{it}, Green\_TECH_{it} \end{matrix} \middle| X_{it} = Market\_SIZE_{it}, Market\_PERFORMANCE_{it}, Market\_LIQUIDITY_{it} \right) = G(X_{it}\beta + \nu_i + \varepsilon_i) = 1 - \exp \left\{ - \exp(X_{it}\beta + \nu_i + \varepsilon_i) \right\} \quad (10)$$

In which  $i = 1, \dots, 129$  firms,  $t = 2010, \dots, 2020$ ,  $\nu_i$  represents the random effects, and  $\varepsilon_i$  the error term.

In which  $i = 1, \dots, 129$  firms,  $t = 2010, \dots, 2020$ ,  $\nu_i$  represents the

$$Poisson : \Pr \left( \begin{matrix} GB_{it} = 0 \\ Firm\_SIZE_{it}, Firm\_PERFORMANCE_{it}, Firm\_LIQUIDITY_{it}, Green\_TECH_{it} \end{matrix} \middle| X_{it} = Market\_SIZE_{it}, Market\_PERFORMANCE_{it}, Market\_LIQUIDITY_{it} \right) = E(Y_{it}|X_{it}, \mu_i) = \mu_i \cdot \exp(-X_{it}\beta + \varepsilon_i) \quad (11)$$

In which  $i = 1, \dots, 129$  firms,  $t = 2010, \dots, 2020$ ,  $\mu_i$  represents the random effects, and  $\varepsilon_i$  the error term.

random effects, and  $\varepsilon_i$  the error term.

In addition to conducting an individual analysis of market-based and firm accounting-based factors, together with the environmental technology innovation factor, the behavior of the factors was assessed as a whole, using principal component analysis to create aggregate factors, i. e., size (market size and firm size), performance (market performance and firm performance), and liquidity (market liquidity and size liquidity).<sup>8</sup> Therefore, the aggregated models are:

$$Logit : \Pr \left( GB = 1 \middle| X_{it} = Size\_factor_{it}, Performance\_factor_{it}, Liquidity\_factor_{it}, Green\_TECH_{it} \right) = G(X_{it}\beta + \nu_i + \varepsilon_i) = 1 + \exp \left\{ - (X_{it}\beta + \nu_i + \varepsilon_i) \right\}^{-1} \quad (13)$$

In which  $i = 1, \dots, 129$  firms,  $t = 2010, \dots, 2020$ ,  $\nu_i$  represents the random effects, and  $\varepsilon_i$  the error term.

$$Probit : \Pr \left( GB = 1 \middle| X_{it} = Size\_factor_{it}, Performance\_factor_{it}, Liquidity\_factor_{it}, Green\_TECH_{it} \right) = G(X_{it}\beta + \nu_i + \varepsilon_i) \quad (12)$$

<sup>8</sup> Each aggregate variable has two main components (PC1 and PC2). The calculation to construct the aggregate variables was based on the following criteria: i) principal components with eigenvalues >1 were used for the calculation process (Kaiser rule); ii) the components used in i) had to pass the Kaiser-Meyer-Olkin test of sample adequacy, i.e., the eigenvectors of each principal component had to have values > 0.5 (Kaiser and Rice, 1974). Given these criteria, the aggregate variables of Market\_factor and Performance\_factor were based on PC1, while the aggregate variable of Liquidity\_factor was based on PC1 and PC2 resulting from the following equation (Liow and Song, 2020):  $Liquidity\_factor = \frac{(PC1 + \text{variance of } PC1 + PC2 + \text{Variance of } PC2)}{(\text{Variance of } PC1 + \text{Variance of } PC2)}$ . The results are available upon request from the authors.

$$Cloglog : \Pr \left( \begin{matrix} GB = 1 \\ Green\_TECH_{it} \end{matrix} \middle| X_{it} = Size\_factor_{it}, Performance\_factor_{it}, Liquidity\_factor_{it} \right) = G(X_{it}\beta + \nu_i + \varepsilon_i) = 1 - \exp \left\{ - \exp(X_{it}\beta + \nu_i + \varepsilon_i) \right\} \quad (14)$$

In which  $i = 1, \dots, 129$  firms,  $t = 2010, \dots, 2020$ ,  $\nu_i$  represents the random effects, and  $\varepsilon_i$  the error term.

**Table 2**  
Correlation matrix and VIF.

	GB	Market_SIZE	Market_PERFORMANCE	Market_LIQUIDITY	Firm_SIZE	Firm_PERFORMANCE	Firm_LIQUIDITY	Green_TECH	VIF
GB	1.0000								
Market_SIZE	0.1794**	1.0000							4.5652
Market_PERFORMANCE	0.0082	0.4721**	1.0000						1.0111
Market_LIQUIDITY	0.0632*	0.3312**	0.1905**	1.0000					1.7411
Firm_SIZE	0.1841**	0.8420**	0.0538	0.3882**	1.0000				4.3293
Firm_PERFORMANCE	0.0114	0.3541**	0.4077**	-0.0705*	0.1247**	1.0000			1.0543
Firm_LIQUIDITY	-0.0132	0.1356**	0.1988**	0.1189**	0.0618*	0.1274*	1.0000		1.0300
Green_TECH	0.1959**	0.0997**	-0.0377	0.1232**	0.1913**	0.0152	-0.0232	1.0000	1.0684
Average									2.1142

Notes: The table displays the VIF coefficients and correlation coefficients between the study’s variables. VIF stands for Variance Inflation Factor and is used to measure multicollinearity; coefficients less than or equal to 10 indicate no evidence of multicollinearity. The correlation matrix displays Spearman’s Correlation coefficients with values ranging from -1 to 1; \*Indicates significance at 5%, \*\*Indicates significance at 1%.

**Table 3**  
Hausman test.

Hausman Test	H0: Difference in coefficients is not systematic
$\chi^2(7)$	1.26
p-value	0.9885

Notes: The table displays the Hausman (1978)’s test to verify model mis-specifications. The test determines if the random effects model is preferable to fixed effects. This test employs a chi-square distribution with k degrees of freedom. k is a positive integer greater than or equal to two. The P-value denotes the corresponding probability value.

$$Poisson : Pr\left(GB = 0, 1 \mid X_{it} = Size\_factor_{it}, Performance\_factor_{it}, Liquidity\_factor_{it}, Green\_TECH_{it}\right) = E(Y_{it} \mid X_{it}, \mu_i) = \mu_i \cdot \exp(X_{it}\beta + \varepsilon_i) \tag{15}$$

In which  $i = 1, \dots, 129$  firms,  $t = 2010, \dots, 2020$ ,  $\mu_i$  represents the random effects, and  $\varepsilon_i$  the error term.

The models expressed in Eqs. (8)–(11) reveal the effect of each variable in both the market-based and firm accounting-based contexts on the decision to issue green bonds, together with the environmental technology innovation factor (Green\_tech). The models expressed in Eqs. (12)–(15) assess the combined effects of the main factors determining a decision to issue green bonds and environmental technological innovation.

#### 4. Results and robustness check

##### 4.1. Main results

Table 2 shows the coefficients of Spearman’s correlation test<sup>9</sup> from the first descriptive analysis. The pairwise tests show correlations with coefficients below 0.5, except for the Market\_SIZE/Firm\_SIZE pair; the high correlation coefficient is usual, because the proxies for firm size, both market- and accounting-based, are prominent in the analysis of corporate finance (Dang et al., 2018)<sup>10</sup>. Collinearity in the estimation of the econometric models was not found, all values being below 10 (Hair

<sup>9</sup> The Spearman’s correlation test is used because it is non-parametric; therefore, there was no need to adhere to assumptions regarding normal distributions.

<sup>10</sup> Although market\_SIZE and Firm\_size showed a high correlation (e.g., in Dang et al., 2018, these two variables have a correlation of 0.85), the behavior of one variable does not imply the behavior of another. In fact, market\_SIZE identifies the conditions of the share market and Firm\_Size measures the firm’s resources (Dang et al., 2018).

et al., 1995; Singh and Delios, 2017; Wooldridge, 2020).

The Hausman (1978)’s test is used to implement the model estimation procedure and examine the alternative option of estimating the model with random or fixed effects. The results shown in Table 3 are from the random effects model, since the  $\chi^2$  test did not reject the null hypothesis, indicating that the difference in coefficients was not systematic. Therefore, random effects were included in the LDV model estimates to determine the likelihood of issuing green bonds.<sup>11</sup>

We used four LDV models to identify more accurately factors that influence decisions to issue green bonds (i.e., the probit, logit, cloglog,

and Poisson models). To ensure more accurate results, the LDV models present different cumulative distribution functions (CDF), where the probit model assumes a standard normal CDF, the logit model assumes a logistic CDF, the cloglog model assumes a CDF with Gumbel distribution properties, and the Poisson model assumes a CDF with Gamma distribution properties.<sup>12</sup>

Taking the results from estimating the various models as a reference (Table 4), the firm market-based characteristic analysis revealed that market size contributed to a positive, significant increase in green bond issuance for all LDV models. In the probit, logit, and Poisson models, market size showed statistical significance at the 5% level, but the cloglog model showed statistical significance at the 10% level. This led to non-rejection of  $H_1$ . Market performance contributed to reduced green bond issuance without associated statistical significance. In addition, market liquidity influenced green bond issuance, contributing to a reduced likelihood of issuing green bonds, with statistical significance at the 5% level for all LDV models. These results rejected  $H_4$  and  $H_7$ .

Second, in accounting-based characteristics analysis, both firm size and firm performance had a negative effect on green bond issuance,

<sup>11</sup> The Mundlak (1978)’s test was performed as an alternative to the Hausman (1978)’s test. The test did not reject the null hypothesis, (i.e., no correlation was found between the non-observable, time-invariant variables and the explanatory variables, so random effects are preferable). Moreover, the use of fixed effects is not recommended owing to this meaning a significant reduction in the number of observations, because fixed effects estimates likely result if there is variability of 0 and 1 within-firm, which was not found in this case.

<sup>12</sup> The Poisson model was used both to ensure more robust and accurate results, and to reduce bias in estimating standard errors (Xiang et al., 2020, 2022).

**Table 4**  
Baseline models.

Dependent Variable = GB	Probit RE (1)	Logit RE (2)	Cloglog RE (3)	Poisson RE (4)
Market_SIZE	0.7706** [2.30]	1.3929** [2.13]	1.0164* [1.95]	1.0540** [2.18]
Market_PERFORMANCE	-0.2281 [-1.16]	-0.4196 [-1.02]	-0.2895 [-0.83]	-0.4136 [-1.16]
Market_LIQUIDITY	-0.1575** [-2.17]	-2.5598** [-2.26]	-2.3622** [-2.40]	-1.4419** [-2.04]
Firm_SIZE	-0.1575 [-0.45]	-0.1541 [-0.22]	0.1217 [0.20]	-0.14107 [-0.27]
Firm_PERFORMANCE	-0.8831 [-0.79]	-1.7317 [-0.74]	-1.4095 [-0.59]	-1.2347 [-0.69]
Firm_LIQUIDITY	2.2138 [1.31]	3.7131 [1.02]	2.8287 [0.81]	1.6775 [0.52]
Green_TECH	0.5406*** [3.08]	0.9994*** [3.04]	0.7817*** [3.16]	0.6452*** [3.18]
C	-14.9542*** [-3.92]	-29.9532*** [-4.18]	-27.9124*** [-4.55]	-22.1978*** [-5.60]
Wald Test for joint significance	18.46**	21.43***	26.91***	37.85***
BIC	235.1478	234.9294	234.8221	247.9145
LL	-85.5138	-85.4046	-85.3509	-91.8971
Pseudo R-squared	0.2240	0.2222	0.2230	0.1928

Notes: The table shows four Limited Dependent Variable models in which GB is a binary variable with zero and one values. The explanatory variables Market\_SIZE, Market\_PERFORMANCE, Market\_LIQUIDITY, Firm\_SIZE, Firm\_PERFORMANCE, and Firm\_LIQUIDITY are logarithmized continuous variables. Green\_TECH is a discrete explanatory variable. The Probit model with Random Effects estimates is shown in Column 1. The Logit model with Random Effects estimates is presented in Column 2. The Cloglog model with Random Effects estimates is displayed in Column 3. The Poisson model with Random Effects estimates is provided in Column 4. The Wald test for joint significance indicates that all explanatory variables are significant in the models. Z statistics are displayed in square brackets. The Wald test for joint significance implies that all explanatory variables are significant in the models. LL denotes the maximized log-likelihood value. BIC refers to Bayesian Information Criteria. \*Indicates significance at 10%. \*\*Indicates significance at 5%. \*\*\*Indicates significance at 1%.

**Table 5**  
Size, performance, and liquidity aggregate factor models.

Dependent Variable = GB	Probit RE (1)	Logit RE (2)	Cloglog RE (3)	Poisson RE (4)
Size_factor	0.7111*** [3.95]	1.5112*** [4.37]	1.4329*** [4.54]	1.2719*** [5.06]
Performance_factor	-0.0411 [-0.28]	-0.1133 [-0.36]	-0.1065 [-0.36]	-0.1490 [-0.55]
Liquidity_factor	0.2624 [1.44]	0.4590 [1.18]	0.3973 [1.10]	0.3307 [0.94]
Green_TECH	0.2107** [2.18]	0.4073** [2.29]	0.3622** [2.39]	0.3070** [2.15]
C	-3.2573*** [-7.22]	-6.3866*** [-7.38]	-6.2259*** [-7.95]	-5.2680*** [-11.06]
Wald Test for joint significance	17.30***	21.24***	23.23***	28.28***
BIC	225.8089	225.3792	225.2881	234.6571
LL	-91.5310	-91.3162	-91.2706	-95.9551
Pseudo R-squared	0.1694	0.1684	0.1691	0.1571

Notes: The table displays four Limited Dependent Variable models in which GB is a binary variable with zero and one values. The independent variables, Size\_factor, Performance\_factor, and Liquidity\_factor, are logarithmized continuous variables. The independent variable Green\_TECH is a discrete variable. These variables are aggregate factors generated from Principal Component Analysis of Market\_SIZE and Firm\_SIZE, Market\_PERFORMANCE and Firm\_PERFORMANCE, and Market\_LIQUIDITY and Firm\_LIQUIDITY, respectively. The Probit model with Random Effects estimates is shown in Column 1. The Logit model with Random Effects estimates is presented in Column 2. The Cloglog model with Random Effects estimates is displayed in Column 3. The Poisson model with Random Effects estimates is provided in Column 4. The Wald test for joint significance indicates that all explanatory variables are significant in the models. Z statistics are displayed in square brackets. The Wald test for joint significance implies that all explanatory variables are significant in the models. LL denotes the maximized log-likelihood value. BIC refers to Bayesian Information Criteria. \*Indicates significance at 10%. \*\*Indicates significance at 5%. \*\*\*Indicates significance at 1%.

without any associated statistical significance. Additionally, firm liquidity had a positive effect on the likelihood of issuing green bonds, but there was no statistically significant association. These results rejected  $H_2$  and  $H_5$ . To summarize, accounting-based firm characteristics were not dominant in the decision to issue green bonds.

Third, environmental technological innovation was observed to be important in green bond issuance decisions, with a positive and highly significant effect, at 1% in all LDV models, which indicates non-rejection of  $H_{10}$ .

Table 5 presents the results obtained for the aggregated factors based on the determinant characteristics' green bond issuance decisions. First, it is notable that Size\_factor drove green bond issuance, with positive and statistically significant effects at the 1% level. Performance\_factor had a negative effect on green bond issuance, but the effect was not statistically significant. Liquidity\_factor had a positive effect, but was also not statistically significant. Market liquidity was statistically significant; however, when combined with firm liquidity, the association was not statistically significant. These results suggest that managers and investors capture information from the share market, and firms' operational liquidity is independent of green bond issuance decisions. Environmental technological innovation showed a positive effect

(Table 5), with statistical significance at 5%.

It is notable that the size characteristic had the largest positive effect on green bond issuance decisions, which adds to the importance of environmental technology innovation.

The results' accuracy and robustness are notable because the models considered different CDFs. In this case, there is no need to choose the best-fit model, either through information criteria or log likelihood. Table 6 summarizes the main results.

4.2. Robustness check and endogeneity issues

We examined the robustness of independent variable effects on the dependent variable and tested for reverse causality (recommended in the corporate finance literature) using instrumental variables because endogeneity provides an incorrect statistical inference and economic diagnosis (Nyborg and Wang, 2021).

In the baseline models' robustness checks (Table 7) the model presented in Column (1) is a complementary econometric test of panel probit econometric methodology robustness to determine the sign and statistical significance effects on green bond issuance decisions. We observed that market size and environmental technology innovation had

**Table 6**  
Firm market-based factors, firm-accounting-based factors and innovation effects on green bond issuance.

Hypotheses	Covariates	Expected	Outcomes	Hypotheses testing
H1	Market SIZE	+	+	NR
H2	Firm SIZE	+	-	R
H3	Size_factor	+	+	NR
H4	Market PERFORMANCE	+	-	R
H5	Firm PERFORMANCE	+	-	R
H6	Performance_factor	+	-	R
H7	Market Liquidity	+	-	R
H8	Firm LIQUIDITY	-	+	R
H9	Liquidity_factor	-	+	R
H10	Environmental Technology innovation	+	+	NR

Notes: The table shows the results (effects) of the baseline and aggregate factor model estimations, as well as the predicted results of the study hypotheses. NR stands for Non-rejected; R stands for Rejected; + denotes a significantly positive effect; - denotes a significantly negative effect.

a positive effect, significant at the 1% level; and, conversely, market liquidity and market performance had a negative effect on green bond issuance, significant at the 5% and 10% levels, respectively.

Second, the models presented in Columns (2) and (3) test the main model’s endogeneity using instrumental variables to determine whether the estimators are consistent and resolve potential error-in-variables (Wooldridge, 2020), adding standard errors adjusted to heteroskedasticity and autocorrelation clustered by firm (Morais et al., 2021; Goenner and Lee, 2022). The models applied for the robustness check were also presented as pooled.<sup>13</sup> Therefore, market size and firm size were endogenous variables because they are correlated above 50%.<sup>14</sup> The instrumental variables were a lag of the endogenous variables (Column 2) and a lag of the endogenous variables and liquidity proxies (Column 3) (i.e., market liquidity and firm liquidity).<sup>15</sup> Consequently, the models in Columns (2) and (3) show a similar result, indicating that market size and environmental technology innovation produce a significant positive effect at 5% and 1%, significance, respectively, and market liquidity has a negative effect at 10% significance. For the Wald  $\chi^2$  test, the null hypothesis was not rejected, indicating that the probit model (without instrumental variables) was the most suitable.

Although the Wald  $\chi^2$  test did not reject the null hypothesis, it tests the weakness of the instrumental variables using a first-stage F-statistic, which indicates, first, if the instrumental variables influenced the endogenous variables, and second, the instruments’ weakness level. The F-statistic was above 10 and significant, which indicates that the

<sup>13</sup> Models in Columns (2) and (3) of Tables 7 and 8 are presented in pooled form, since the literature contains no available approach for IV-probit in panel data.

<sup>14</sup> In addition to the question of correlation between variables, endogeneity between Market Size and Firm Size (i.e., Firm Size implies Market Size) may originate in scale economies and diminished information asymmetry (Cheung et al., 2015).

<sup>15</sup> In the endogenous variables, lags were taken into consideration, based on the traditional application of instrumental variables (e.g., Morais et al., 2021; Goenner and Lee, 2022). Lags referring to liquidity variables are based on liquidity improving share performance as the transaction volume reaches optimal negotiation (Hillert et al., 2016). In addition, increased cash holdings can be used as an instrument for buying back assets in the case of short behavior in markets (Nyborg and Wang, 2021).

instrumental variables had strong control over the endogenous variables,<sup>16</sup> and showed no weakness (Stock et al., 2002; Stock and Yogo, 2005; Wooldridge, 2020).

Table 8 shows the robustness checks for size, performance, and liquidity factors, following an empirical approach similar to that shown in Table 7. The results showed that green bond issuance decisions were based on the Size\_Factor and environmental technology innovation, with a positive sign and significance at 1% (except for environmental technology innovation, Green\_TECH in Column 1). An identical situation to that described in Table 7 was found concerning the endogeneity tests, indicating that the instrumental variables do not present weakness.<sup>17</sup>

In summary, the models were robust for two reasons. First, the study variables show positive and significant effects on the decision to issue green bonds. Second, there was no evidence of endogeneity, suggesting that the panel probit model was the most suitable.

## 5. Discussion

Green bonds are important instruments in corporate and public policies to support the transition towards sustainable energy based on environmental technological innovation. This finance channel also reinforces corporate reputation; positioning the firm as environmentally friendly, sustainable, and responsible; sending a powerful signal of the firm’s ESG approach, which is increasingly valued by investors, consumers, and policymakers.

Even though the green bond market has been accelerating, there is still a lack of understanding of the factors that influence green bond issuance, particularly those relating to market size, performance, liquidity and environmental technological innovation, as previously raised in the literature review.

Concerning market size, returning to the traditional literature devoted to conventional bond markets (market debt), two particularly important aspects stand out for discussion of this study’s findings. Firstly, in bull market periods, companies take advantage of this market valorization to obtain finance in debt markets at lower yields (Baker and Wurgler, 2022; Hovakimian et al., 2004). Secondly, observing higher financing costs, companies obtain finance through issuing shares (Bancel and Mittoo, 2004; Kuvshinov and Zimmermann, 2022). The literature on sustainable finance also contains strong support for a firm with a greater market size showing greater financial capacity and being more likely to apply funds to pursue its ESG and CSR activities, which

<sup>16</sup> Appearing as a complementary test to the first-stage F-statistic the Stock and Yogo (2005) test assesses the weakness of the instrumental variables based on bias estimator and size distortion concerning the Wald test statistic. The Stock and Yogo (2005) statistical test is based on the Cragg and Donald (1993) statistic. For instrumental variables that are not weak, the minimum Cragg and Donald (1993) eigenvalue statistic must be above the critical values. The minimum Cragg-Donald eigenvalue statistic (Column 2) was 1057.52, while the critical values (because the model is just-identified, no critical values of the bias distortion were found) of 10% of size distortion, at 5% significance Wald test, was 7.03. The minimum Cragg-Donald eigenvalue statistic (Column 3) was 528.31, while the critical values of 5% of relative bias of the 2SLS was 11.04; and 10% of size distortion, at 5% significance Wald test was 16.87. The null hypothesis is therefore rejected. By not confirming weakness tests of instrumental variables in economic approaches with binary dependent variables, the tests presented derive from linear regressions, and so the data should be interpreted with some caution (Morais et al., 2021), despite concluding that the instrumental variables do not present weakness.

<sup>17</sup> The minimum Cragg-Donald eigenvalue statistic (Column 2) was 761.95, while the critical values (as the model is just-identified, not finding critical values of the bias distortion) of 10% of size distortion at 5% significance Wald test was 7.03. The minimum Cragg-Donald eigenvalue statistic (Column 3) was 388.89 while the critical values of 5% of relative bias of the 2SLS was 11.04, and 10% of size distortion at 5% significance Wald test was 16.87. Therefore, the null hypothesis was rejected.

**Table 7**  
Baseline models' robustness checks.

Dependent Variable = GB	Pooled	Endogeneity	
	Pooled Probit (cluster-robust) (1)	IV Probit (cluster-robust) (2)	IV Probit (cluster-robust) (3)
Market_SIZE	0.7033*** [2.79]	0.7901** [2.20]	0.7944** [2.22]
Market_PERFORMANCE	-0.3051* [-1.84]	-0.4427 [-1.58]	-0.4453 [-1.56]
Market_LIQUIDITY	-0.6386** [-2.10]	-0.4775* [-1.71]	-0.4802* [-1.67]
Firm_SIZE	-0.2563 [-1.02]	-0.2913 [-0.84]	-0.2955 [-0.87]
Firm_PERFORMANCE	-0.6964 [-1.13]	-0.3586 [-0.71]	-0.3619 [-0.63]
Firm_LIQUIDITY	1.4544 [1.21]	1.5722 [1.23]	1.5698 [1.10]
Green_TECH	0.3884*** [3.57]	0.3847*** [2.88]	0.3870*** [2.88]
C	-10.8345*** [-6.60]	-11.9057*** [-5.65]	-11.9029*** [-5.84]
Wald Test for joint significance	76.14***	87.27***	109.65***
BIC	241.016	1897.354	1895.238
LL	-92.0101	-846.9753	-831.8893
Pseudo-R Squared	0.2927		
Endogenous Variables		Market_SIZE Firm_SIZE	Market_SIZE Firm_SIZE
Instruments		Lagged Market_SIZE Lagged Firm_SIZE	Lagged Market_SIZE Lagged Firm_SIZE Lagged Market_LIQUIDITY
$\chi^2$ Wald Test for exogeneity ( <i>p-value</i> )		4.50 (0.1052)	4.27 (0.1185)
First-Stage F-statistic			
MV		6000.08***	3091.21***
SIZE		18505.1***	10164.9***

Notes: The table shows two Probit models in Pooled data that re-estimate the Baseline model (Table 4). The Pooled Probit model is shown in Column (1). Pooled Probit estimates with Instrument Variables for endogeneity control are shown in columns (2) and (3). As a result, the model in column (2) included two Instrument Variables: Market\_SIZE and Firm\_SIZE, both of them lagged one period. The model in column (3) displays the Pooled Probit estimates with three Instrument Variables: Market\_SIZE; Firm\_SIZE; and Market\_LIQUIDITY delayed one period. The  $\chi^2$  Wald test for exogeneity evaluates the null hypothesis of no endogeneity. The F-statistic in its first stage evaluates the strength (greater correlation) of instrument variables with endogenous variables. Z statistics are presented in square brackets. Clustered-robust standard errors are applied to control heteroskedasticity and autocorrelation by Firm. The Wald test for joint significance shows that all explanatory variables are significant in the models. LL denotes the maximized log-likelihood value. BIC refers to Bayesian Information Criteria. \*Indicates significance at 10%. \*\*Indicates significance at 5%. \*\*\*Indicates significance at 1%.

**Table 8**  
Size, performance and liquidity factor robustness checks.

Dependent Variable = GB	Pooled	Endogeneity	
	Pooled Probit (cluster-robust)(1)	IV Probit (cluster-robust) (2)	IV Probit (cluster-robust) (3)
Size_factor	0.5794*** [6.18]	0.6680*** [4.80]	0.6659*** [4.70]
Performance_factor	-0.1022 [-1.16]	-0.1033 [-1.42]	-0.1049 [-1.54]
Liquidity_factor	0.1497 [1.05]	0.0111 [0.04]	0.0204 [0.10]
Green_TECH	0.1421** [2.50]	0.1495*** [4.91]	0.1496*** [5.26]
C	-2.6056*** [-14.85]	-2.7657*** [-11.49]	-2.7641*** [-10.84]
Wald Test for joint significance	49.26***	47.02***	45.76***
BIC	230.74	1133.81	1144.85
LL	-97.5570	-496.7637	-488.2583
Pseudo-R Squared	0.2500		
Endogenous Variables		Size_factor Liquidity_factor	Size_factor Liquidity_factor
Instruments		Lagged Size_factor Lagged Liquidity_factor	Lagged Market_SIZE Lagged Firm_SIZE Lagged Market_LIQUIDITY Lagged Firm_LIQUIDITY
$\chi^2$ Wald Test for exogeneity ( <i>p-value</i> )		2.29 (0.3183)	2.88 (0.2365)
First-Stage F-statistic			
Size_factor		23513.4***	12497.5***
Liquidity_factor		186.956***	99.8533***

Notes: The table displays two Probit models in Pooled data re-estimating the aggregate factors model (Table 5). The Pooled Probit model is shown in Column (1). Pooled Probit estimates with Instrument Variables for endogeneity control are shown in columns (2) and (3). As a result, the model in column (2) included two Instrument Variables: Size\_factor; and Liquidity\_factor; which were one lagged period. Column (3) provides the Pooled Probit predictions with four Instrument Variables: Market\_SIZE; Firm\_SIZE; and Market\_LIQUIDITY; which were one lagged period. The  $\chi^2$  Wald test for exogeneity evaluates the null hypothesis of no endogeneity. The F-statistic in its first stage evaluates the strength (greater correlation) of instrument variables with endogenous variables. Z statistics are presented in square brackets. Clustered-robust standard errors are applied to control heteroskedasticity and autocorrelation by Firm. The Wald test for joint significance shows that all explanatory variables are significant in the models. LL denotes the maximized log-likelihood value. BIC refers to Bayesian Information Criteria. \*Indicates significance at 10%. \*\*Indicates significance at 5%. \*\*\*Indicates significance at 1%.

contribute to lessening environmental damage and sustainable development (Nelling and Web, 2009; Garcia et al., 2017; Raghutla et al., 2021; Zhang et al., 2021).

The results shown in this study indicate that increased market size or capitalization contribute to a greater likelihood of issuing green bonds, above all through increasing the environmental and sustainable awareness of economic agents and increasing investors' tendency to pay higher premiums, so that they can reinforce the allocation of green financial products, contributing to diversification of their investment portfolios. It should also be underlined that the evidence obtained here reveals that economic agents give greater emphasis to the aggregate factor formed by asset value and market capitalization, to achieve a higher greenium, so that firms will issue green debt on the market, with lower financing costs.

In the traditional literature on corporate finance, conclusions point towards larger firms resorting more to debt (as a form of financial leverage), through easier access to credit, on more favorable terms and with less likelihood of default (Friend and Lang, 1988; Rajan and Zingales, 1995; Baker and Wurgler, 2002; Mao, 2003; de Jong et al., 2008; Frank and Goyal, 2009; *inter alia*). Considering more recent studies focused on green finance, size, in terms of assets, is an important determinant of green bond issuance (Barua and Chiesa, 2019; Chiesa and Barua, 2019), for two reasons: (i) investors place greater emphasis on asset value than stock market valorization; and (ii) firms obtain finance through equity markets due to the lower cost of financing (Bancel and Mittoo, 2004; Kuvshinov and Zimmermann, 2022). However, the evidence obtained here contrasts with the above reasons. Despite corroborating the significant effect of market size, there is no specific significant evidence associated with firm size, even if the latter may be important for the purpose of financing via equity markets (Chen, 2004).

Furthermore, the performance factor, either aggregated or specific, was not a determinant of green bond issuance. This may be connected to pecking order theory (Huang and Shang, 2019), in that profitable firms emphasize internal funds (Hovakimian et al., 2004). The results also reveal that listed Iberian firms present management policies that guard against future reductions in liquidity by financing securities with risk behavior and transferring firm capital to creditors (de Jong et al., 2008; Udomsirikul et al., 2011).

Firms with a strong implementation of corporate social responsibility present less information asymmetry, and so their actions lead to strengthened liquidity (Egginton and McBrayer, 2019). In addition, firms with high ESG scorings are very attractive to investors, which also contributes to that strengthened liquidity (Luo, 2022).

In contrast, the evidence obtained here reveals that the greater the liquidity, the lower the probability of firms issuing green bonds. This new evidence can indicate two positionings. Firstly, firms with greater liquidity face lower financing costs in the share market than in the bond market, which may cause a greater tendency to have equity shares rather than issuing green debt bonds. Secondly, firms with greater liquidity in the share market tend not to issue green bonds, which may indicate that green bonds can function as a hedging product, to take an offsetting position in an asset or investment that reduces the price risk of an existing position, in scenarios of uncertainty and crisis (Luo, 2022).

It is worth highlighting that environmental technology innovation is the cornerstone of this type of financing/investment channel and may facilitate more efficient resource allocation, especially for R&D (Zhou et al., 2022). Developing environmentally friendly R&D may lead to circular investment in green projects (Russo et al., 2021), where green bonds boost the desired transition to sustainable energy. Moreover, environmental technological innovation is considered an important driver not only of firm performance (Wang et al., 2021, 2022), but also of green bond performance (Agliardi and Agliardi, 2019; Russo et al., 2021). Firstly, the robust effect on firm performance is based on sustainable innovation in its value chain (Wang et al., 2021). Secondly, issuing green bonds allows a discount rate, through reducing the

associated financial restrictions (Wang et al., 2022). In addition, green bond performance derives from the appetite for green financial products to place in economic agents' portfolios (Agliardi and Agliardi, 2019) or considering sustainability factors reported by companies (Russo et al., 2021). The results of this study bring new insights, indicating that when the company chooses to protect the intellectual property rights of an environmental technological innovation, through registering green patents, there is a greater likelihood of issuing green bonds. Furthermore, the new empirical evidence implies that increasing the number of green patents strengthens the capacity of companies holding this type of intangible asset to expand green financing, and thereby be able to contribute to increasing technological progress connected to decarbonization of economic activities. This also shows that companies more directed towards environmental technological development contribute to stimulating energy transition to net zero emissions, which represents a "looping" of environmental technological innovation, with positive network externalities.

Bearing in mind the research gap previously identified in the literature, concerning the lack of studies on the still unexplored simultaneous effects of accounting-based and market characteristics (that is, size, performance, liquidity) and environmental technological innovation, both in aggregate and specific terms, this study makes unique contributions adding new insights to advance knowledge about companies' decision to issue green bonds, namely:

- (i) the size factor, in aggregate terms, expressed through high asset value and stock market capitalization, increases the likelihood of issuing green bonds;
- (ii) companies' market performance and profitability, both as an aggregate and specifically, do not have a significant influence on issuing green bonds;
- (iii) the firm's greater liquidity in the market, in specific terms, tends to affect green bond issuance negatively; and
- (iv) strengthening environmental technological innovation, both as an aggregate and specifically, increases the probability of firms issuing green bonds.

As previously stated, profitable businesses tend to use internal resources rather than external resources obtained through credit. However, as demonstrated by the current study, market size increases the likelihood of issuing green bonds, indicating a new environmental consciousness on the part of large corporations, which provides a credible signal of these companies' leadership being strongly committed to environmental and social responsibility. It is also revealed that, through finding a high statistical significance associated with market indicators, investors' behavior indicates a desire to diversify and decarbonize their portfolios through investing in new green activities with a higher environmental impact and transparency.

## 6. Concluding remarks

### 6.1. Conclusions

This study analyzed the effects of market- and firm-based business characteristics and environmental technology innovation on the cumulative probability of issuing green bonds in listed Iberian firms. In the current economic and environmental scenario, managers' and stakeholders' primary focus should be on sustainability and efficiency, but above all, on energy transition.

Using LVD models to analyze the period from 2010 to 2020, we obtained empirical evidence that market size is a determinant in the decision to issue green bonds, showing a positive, statistically significant effect. This result indicates that the green bond market and intermediaries in issuing bonds see market capitalization as collateral, because the firm presents more value for investors. Second, market liquidity is the dominant factor in decisions to issue green bonds based

on business characteristics. Market liquidity significantly reduces the likelihood of issuing green bonds, which may indicate that players (traders) negotiating in Iberian markets do not yet have a fully developed pro-environment profile; or that, to some extent, share markets have greater returns than green bond investments. Third, environmental technological innovation is a very important determinant in green bond issuance decisions, showing a significant positive effect at the 1% level. The contribution of environmental technological innovation signals a strong tendency toward technological development and energy transition. Fourth, considering business characteristics as an aggregate, the size factor contributed to an increased likelihood of issuing green bonds, with environmental technology innovation presenting similarly strong performance in market- and accounting-based characteristics. This combined evidence shows that size is a proxy for inverse probability of default bankruptcy, equivalent to the financial expression of *too big to fail*.

## 6.2. Implications

The findings now presented are particularly useful for decision-makers, managers, and investors, because they provide insights into how best to develop policy, strategies, competitive positions, and investment portfolios that consider market and firm characteristics, different market contingencies, financing, and investment directed toward an effective transition to environmentally friendly energy. The results are also relevant for political decision-makers because they provide information for developing green policies and tax credits for transitioning to sustainable energy, based on promoting sustainable and responsible competitiveness by stimulating R&D activities for environmental technology innovation, and through certification and selective financing for firms and institutions that adopt the ESG approach.

In terms of implications for future policy action, it is suggested that a green tax package be released, which would serve as a foundation for future tax credits to companies with certified environmental, social, and sustainable governance; *vulgo* ESG certification. This package should result in a reduction in profit taxes or sales taxes, subject to the condition that these tax credits be invested in green technological advancement activities based on R&D, green innovation, and green intellectual capital strengthening.

Furthermore, it is predicted that the economic burden would be increased to support non-sustainability and energy transition issues. However, as a compensatory incentive mechanism, the state's additional tax receipts must be transferred to companies that issue green bonds, subject to a ceiling value in relation to the activities; that is, companies will benefit from tax breaks if they reach the ceiling value. In this line of policy action, implementation of the green tax package will result in changes in the capital structure of businesses, transferring capital from non-certified businesses to ESG-certified businesses. This new event will contribute to an increased demand for green bonds and obligations issued by companies with ESG certification, resulting in a shift in the selection of asset classes with more diversification and transparency.

## 6.3. Limitations and future research

The study's main limitation is the limited data available to include other indicators, such as green capex, ownership concentration, and investment in R&D. These indicators may be useful in determining whether companies are investing in environmental capital and resources geared toward future ESG certification, via equity or debt, and how this decision affects the likelihood of issuing green bonds. In addition, it would be possible to determine whether the shareholder structure is focused on reducing carbon emissions through issuing green bonds and whether technological intensity is predominant in relation to the number of patents registered, that is, identifying the effects of R&D investment or patent registration on green bond issuance.

Future research could conduct comparative analyses to identify and contrast the determinant factors in decisions to issue green, sustainable, and social bonds. Alternatively, in comparative terms, to investigate the dominance of performance, liquidity, and dimension factors in various ESG bond types. An additional topic may be determining whether the currency used in issuing ESG bonds has an impact on how their performance evolves.

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## CRedit authorship contribution statement

**João Leitão:** Conceptualization, Formal analysis, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing. **Joaquim Ferreira:** Data curation, Methodology, Software, Writing – original draft. **Ernesto Santibanez-González:** Validation, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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