Risk disclosure in green bond prospectuses and its impact on initial pricing: An EU Study

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Abstract

Green bonds are an important part of the sustainable debt market, as the proceeds allow issuers to finance climate action and sustainable development projects. Despite the tremendous growth in issuance (from $1 bn in 2007 to $500 bn in 2021), primarily from European financial and non-financial corporates, relatively little is known regarding the dynamics of risk and the pricing of these bonds. The most extensive disclosure in the green bond issuance process is the prospectus, where issuers must declare specific, material, and corroboratory risk factors to investors. The evidence to date highlights that debt investors react to new, financial and idiosyncratic risk factors. Corporate bond underpricing represents money left on the table for issuers while substantially boosting investor financial returns. Risk disclosure in prospectuses may aggravate or alleviate the need for underpricing depending on its multifaceted nature. The purpose of this study is to examine unique risk disclosure in corporate green bond prospectuses and assess how this risk manifests into the initial pricing of the bonds. A holistic conceptual framework has been devised to investigate the phenomena. Incentive theories will probe issuer intent as to whether risk factors signal their managerial prowess and reduce the information gap between investors. The information theories of underpricing probe the existence of the phenomenon in a green bond context. Using a deductive positivist approach, LDA will extract the unique risk factors from approximately 1,800 EU corporate green bond prospectuses from 2014 to 2021. An event study and regression models will determine how risk disclosure impacts green bond initial pricing. Preliminary findings suggest that regulatory, verification and asset risk factors are unique to green bond issues. The findings will contribute to the academic literature where there has been a paucity of research concerning sustainable finance instrument risk and initial pricing. The results will also interest issuers, regulators and investors as they navigate the EU Green Deal.

Keywords: sustainable finance, corporate disclosures, capital markets, asset pricing

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1. Introduction

The Paris Agreement and the EU Green Deal translate into substantial reductions in greenhouse gas emissions of 40 percent and 50 percent, respectively, for the European Union (EU) up to 2030 (European Commission, 2019; United Nations Framework Convention on Climate Change, 2015). In addition, both policies prescribe the achievement of 'net zero' emissions by 2050[1]. However, these emission reductions will require a significant amount of financing, which the European Commission estimates to be in the region of €180 billion per year up to 2030 and €260 billion per year up to 2050 (European Commission, 2018a; 2019a). This level of investment is beyond the reach of the public sector and will require unprecedented levels of investment from the private sector (Campiglio, 2016; OECD, 2015a; 2016; 2017). Indeed, recently, this climate change investment gap was described as "the biggest capital reallocation since the Industrial Revolution" (Tett and Mundy, 2021).

Against this backdrop, sustainable finance has risen from niche status to a dominant topic for policy makers and practitioners in capital markets (Ahlstrom and Monciardini, 2021; Nath, 2019). Although there are various definitions as to what this term encompasses (e.g. European Commission, 2018b), conceptually, the term represents "efforts to […] adjust risk perceptions in order to boost environmentally-friendly investments and reduce environmentally harmful ones" (G20 Green Finance Study Group, 2016, p. 3). The rise of sustainable finance is particularly evident in the debt capital markets, with the birth and growth of the green bond market. The market has grown from zero in 2006 to more than $500 billion in issues in 2021 (Climate Bond Initiative, 2020; 2021; 2022a).

Inherent in this growth is the EU's position as the home of green bonds, with the first issue by the European Investment Bank (EIB) in 2007, followed by several sovereign nations (e.g. Poland, France, Germany) (Climate Bond Initiative, 2022a; EIB, 2017). The EU green bond market is the most developed and largest globally, representing half of global issues in 2019, 2020 and 2021 (Climate Bond Initiative, 2020; 2021; 2022a). Underpinning this development is the EU's ambition to become the world leader in sustainable finance (e.g. Sustainable Finance Disclosure Regulations, EU Green Bond Standard, EU Taxonomy), which is intrinsically linked to the EU Green Deal. Indeed, the European Commission issued the largest green bond to date in October 2021, signalling its support for the market (Stubbington and Khan, 2021). However, the growth of non-financial and financial corporate issuers from

[1] Net-zero has become a confusing term, some use the term to focus solely on CO^2 emissions, others focus on all greenhouse gases including methane (Rogelj, Geden, Cowie and Reisinger 2021)

Europe continues to stimulate the market. Notably, in Europe, financial and non-financial corporates account for two-thirds of green bond issues from 2014 to 2021 (Climate Bond Initiative, 2022b). Nevertheless, there has been definitional ambiguity regarding what the term green bonds encompasses due to their innate similarities to other fixed-income instruments (e.g. Banahan, 2018; Park, 2018; Wang, 2018).

Green bonds have similar features to conventional bonds, including a credit rating, a maturity and a coupon or interest payment (OECD, 2015b). Typically, corporate green bonds are investment grade with a maturity of 8 years and pay investors an annual coupon (Flammer, 2021). Green bonds have four unique features. First, the stipulation that proceeds are used on environmental initiatives. Second, the use of impact reporting. Third, verification of the environmental aspects of the bond (Climate Bond Initiative 2019; International Capital Markets Association, 2021a). Verification is recommended but not a requirement; however, 86 percent of issuers engaged in some form of verification in 2021 (Climate Bond Initiative, 2022a). Fourth, optional certification is also available from the *Climate Bond Initiative*, where pre- and post-issuance verification is required (Climate Bond Initiative, 2019). However, certification remains low, accounting for 20 percent of issues in 2021 (Climate Bond Initiative, 2022a). These four unique features distinguish green bonds from conventional bonds and have intrinsic attractions and demerits for issuers and investors.

For issuers, green bonds can help diversify their investor base and send proactive messages to stakeholders of their commitment to environmental sustainability (Flammer, 2021; Tang and Zhang, 2020). However, issuers incur additional costs compared to traditional bonds, which arise from third-party certification, verification and ongoing monitoring and compliance costs to ensure proceeds are assigned as planned (Ehlers and Packer, 2017). Yet, precisely what constitutes 'green' is a challenge with the risk of greenwashing and reputational risk if the proceeds are allocated to assets with little or dubious environmental value (Larcker and Watts, 2020).

For investors, green bonds can serve as a tool to satisfy green mandates and hedge against climate-related risks in their portfolios (Reboredo, 2018; Reboredo, Ugolini and Aiube, 2020; Tolliver, Keeley and Managi, 2020). The combination of environmental benefits, financial returns, and increased disclosure makes them unique and attractive to investors (Fatica and Panzica, 2021; Russo, Mariani and Caragnano, 2020). However, the risk of moral hazard and a lack of standardisation in reporting and third-party opinions present additional *ex-post* risks to investors (Tripathy, 2017; Wang, Chen, Li, Yu and Zhong, 2020).

Much of the empirical work to date is concerned with the green bond premium – when the yield on a green bond is lower than that of a conventional bond (Larcker and Watts, 2020; Zerbib, 2019). Others examine the market reaction to corporate issuance (Flammer, 2021; Tang and Zhang, 2020) and their relationship with other financial markets (Reboredo, 2018; Reboredo *et al.*, 2020). Little is known regarding the dynamics of risk and the pricing of these bonds.

This study aims to examine unique *ex-ante* risk disclosure in EU corporate green bond prospectuses and investigate how these risks impact the initial pricing of the bonds. A holistic conceptual framework has been devised that draws on incentive theories from the finance literature to probe unique green bond risk disclosure. The conceptual framework extends the information theories of underpricing to investigate the existence of the phenomenon in a green bond context. To address the objective of this study, the following research question (RQ) will be answered. RQ: Does unique *ex-ante* risk disclosure in EU corporate green bond prospectuses impact the initial pricing of the bonds? Using a deductive positivist approach, a corresponding quantitative methodology is proposed to answer the RQ. First, the unique risk factor disclosure in EU green bond prospectuses will be measured using topic modelling. Specifically, Latent Dirichlet Allocation (LDA) - an unsupervised technique developed by Blei, Ng and Jordan (2003). Second, an event study used by Cai Helwege and Warga (2007) will measure initial pricing using green bond excess returns over a value-weighted index during a short event window. Finally, to determine whether *ex-ante* risk disclosure manifests into initial pricing, a regression model will measure the effect green bond risk topics have on initial returns. The sample will cover the January 2014 to December 2021 timeline and will be cross-referenced with the *Climate Bond Imitative* database to ensure comparability and consistency.

The importance of this research is two-fold. First, despite the vast growth in issuance, very little is known of the risks of green bonds. Indeed, if sustainable finance can be conceptualised as adjusting risk perceptions to consider environmental initiatives (G20 Green Finance Study Group, 2016), then a fruitful line of inquiry lies in assessing risk and risk compensation in a sustainable finance setting. Second, a commonly cited attraction of green bonds is the increased disclosure (e.g. Maltais and Nykvist, 2020; Monk and Perkins, 2020). Nevertheless, there has been a paucity of research into the content of green bond disclosure. The research will generate findings relevant to a wide range of stakeholders, including academics, regulators, issuers, intermediaries, investors and society. The envisaged contribution is five-fold.

First is a contribution to theoretical knowledge. Incorporating traditional finance incentive theories to explain unique green bond risk disclosure strategies is innovative and facilitates insights into the decision-making process of green bond issuers. The approach is novel, as it extends both the agency (Jensen and Meckling, 1976) and signalling (Spence, 1973) theory frameworks to probe issuer intentions in sustainable finance risk disclosures. This study uses the three competing hypotheses from the accounting literature (Kravet and Muslu, 2013) supplemented with the *ex-ante* uncertainty theory of underpricing (Beatty and Ritter, 1986) to assess how risk disclosure impacts green bond underpricing. The first outcome is that risk disclosures resolve known risk factors and reduce the need for investor risk compensation – the convergence hypothesis. The second outcome is that risk disclosures introduce unknown risk factors and increase the need for investor risk compensation, the divergence hypothesis. The third outcome is that risk disclosures are boilerplate and do not impact investor risk perceptions – the null or boilerplate hypothesis. To date, the need for risk compensation for green bond investors, especially green-orientated investors, remains unknown. This study also extends and tests the information (Booth and Smith, 1986; Benveniste and Spindt, 1989; Rock's 1986) theories of corporate bond underpricing to a green bond setting. This setting offers an innovative test of the information theories to explain corporate bond underpricing. Overall, the holistic theoretical lens adopted offers a substantial contribution to knowledge regarding issuer, investor, intermediary and pricing perspectives of green bond risk disclosure and could be used in similar contexts (e.g. equity initial public offerings in the EU).

Second is a contribution to the corporate bond underpricing empirical literature. Taken together, this literature suggests that riskier corporate bond issues are systematically underpriced (Cai *et al*., 2007; Datta, Iskandar and Patel, 1997; Helwege and Wang, 2021; Nikolova, Wang and Wu, 2020; Rischen and Theissen, 2021). On the one hand, corporate green bonds may suffer from larger underpricing than traditional bonds to compensate investors for the increased uncertainty (e.g. greenwashing concerns). In contrast, green bonds may be less underpriced than traditional bonds due to the issuer's increased disclosure, the larger number of intermediaries involved, and more attentive investors. This may alleviate the information problems experienced in corporate bond issues. Therefore, this study offers an advancement of this literature by being the first to comprehensively assess whether European green bonds are underpriced.

Third is a contribution to the risk disclosure and underpricing empirical literature, which has investigated the relationship between risk disclosures and initial public offering

(IPO) underpricing. Taken together, this literature concludes that there is a variance in underpricing depending on unique content (Ding, 2016; Hanley and Hoberg, 2010) and the types of risk disclosed in IPO prospectuses (Hussein, Zhou and Deng, 2020). However, this literature has exclusively examined the impact of risk disclosure and underpricing among equity IPOs. Risk disclosure may be more pertinent to debt investors as downside risk information is relevant to the payoff functions of credit pricing (Bai, Bali and Wen, 2019; Defond and Zhang, 2014; De Franco, Vasvari and Wittenberg-Moerman, 2009). Indeed, Armstrong, Guay and Weber (2010) argue that bondholders are likely to demand the most reliable and up to date information regarding the risk of the issue. Therefore, the risks disclosed in bond prospectuses, and consequently green bond prospectuses, offer a unique vehicle to assess the impact of risk disclosure on debt investor risk perceptions as proxied by underpricing. This study also responds to the call for more research into the dynamics of risk disclosure for debt investors (e.g. Elshandidy, Shrives, Bamber and Abraham, 2018; Kravet and Muslu, 2013).

Fourth is a methodological contribution. This study will use topic modelling to discover unique green bond risk factors. The topic modelling method is becoming increasingly popular in the finance literature to extract risk factors (e.g. Bao and Datta, 2014; Li, Feng, Li and Sun, 2020; Li, Li, Liu, Zhu and Wei, 2022; Li, Li, Zhu and Yao, 2020; Wei, Li, Zhu, Sun and Li, 2019) as an alternative to the factor model method (e.g. Bai *et al.*, 2019; Fama and French 1993; Lin, Wang and Wu, 2011). However, the approach has not been used to extract risk factors for an asset class to date. Other green and sustainable finance instruments are becoming prevalent among market participants, including green equity IPOs and green mutual funds (e.g. Cleverley, Diaz-Rainey and Helbing, 2020; Ibikunle and Steffen, 2017). Therefore, this study will provide a new sustainable finance risk dictionary that can be used with previous risk dictionaries in the literature (e.g. Campbell, Chen, Dhaliwal, Lu and Steele, 2014) and may be applicable in similar contexts.

Fifth is a contribution to practice. The findings of this study will be of interest to national regulators in the EU and the European Securities Market Authority (ESMA). To date, the risk disclosure literature has been exclusively focused on a US context (e.g. Beatty, Cheng and Zhang, 2019; Bonsall and Miller, 2017; Campbell *et al.*, 2014; Chiu, Guan and Kim, 2018). However, the EU operates a different regime for risk disclosure under the Prospectus Directive 2003/71 and the more recent Prospectus Regulations 2007/1129. One of the reasons for implementing the Prospectus Regulation in 2019 was the concern that risk factors had become uninformative to investors (Burn, 2018). Therefore, the findings of this

study will be of interest to regulators as they navigate the implementation of the new Prospectus Regulations. Furthermore, the findings will also interest green bond issuers, intermediaries, investors and society. The green bond market is still in its infancy; therefore, the risks and pricing accuracy remain unclear. This study will help inform the behaviour of green bond market participants as to how they assess, react and price sustainable finance risk. Indeed, as the EU Green Deal is implemented, green bonds will be valuable financing channels for corporations and important assets under management for fund managers over the next three decades. Thus, it is pivotal to enhance understanding of the risk factors associated with green bonds. Finally, green bonds have been proposed as instruments that may reduce the adverse effects of climate change (Bhandary, Gallagher and Zhang, 2021). However, if information problems are currently manipulating risk perceptions and initial pricing in the green bond market, this could eventually cause the market to fail. This result would impede progress on reducing greenhouse gas emissions and impact society as a whole. Therefore, this study will inform society about the current mechanics of the market and inform the debate on the role green bonds will play in combating climate change.

The remainder of this paper is organised as follows. Section 2 examines the institutional background, including the green bond issuance process and the EU Prospectus risk disclosure regulations. Section 3 presents the conceptual framework used to illustrate green bond risk disclosure and its impact on underpricing. Section 4 details the data sample and methodology. Section 5 presents the preliminary results of the data analysis. Finally, Section 6 concludes the paper.

2. Institutional Background

2.1. The Green Bond Issuance Process

Figure 1 presents the green bond issuance process in the EU, along with the stakeholders involved. This green bond issuance process is the author's interpretation of the description provided by Kaminker and Majowski (2018). The process commences with the issuer identifying green projects to finance or re-finance, which are disclosed in The Green Bond Framework and reviewed by pre-issuance verifiers. These pre-issuance verifiers – who are third parties from accountancy firms, rating agencies, ESG data providers and environmental organisations - evaluate the environmental features of the intended use of proceeds (International Capital Markets Association, 2021b). Next, the issuer and their chosen underwriter and legal advisors prepare the prospectus, which is a legal requirement in the EU for all securities offered to the public or admitted for trading on a regulated market (Burn,

2016). The prospectus is approved by a national regulator from the issuer's member state, who evaluates the minimum disclosure requirements of the document to allow an investor to make an informed investment decision (Buttigeg, 2020). Like other securities, green bonds receive a rating from a credit rating agency. Ratings are assigned to bonds based on extensive economic analysis by agencies such as Moody's and Standard and Poor's (S&P) (Weinstein, 1977). Bond-level ratings synthesise the information on the issuer's financial condition, operating performance, risk-management strategies, and specific bond characteristics such as the coupon rate, seniority, and other features (White, 2010).

If the issuer chooses to certify the issuance through the *Climate Bond Initiative*, external post-issuance verification is also required to achieve the Climate Bond Standard designation (Climate Bond Initiative, 2019). Issuers may also list the bond on an exchange, with many offering designated green bond segments (e.g. Migliorelli and Dessertine, 2019). As prescribed in the Green Bond Principles, the issuer must also commit to impact reporting at least annually on how proceeds have contributed to environmental initiatives (International Capital Markets Authority, 2021a).

In summary, the green bond issuance process is characterised by a sequence of disclosures and verifications of these disclosures. The most extensive disclosure in the process is the prospectus, which is a legal requirement in the EU and is the focus of the following section.

[Insert Figure 1 here]

2.2. EU Prospectus Risk Disclosure Regulations

The Prospectus Directive 2003/71 (Prospectus Directive) served as the primary legal framework for disclosure rules applicable to firms entering capital markets from 2005 to July 2019. The purpose of the Directive was to harmonise requirements for drafting, approving and distributing a prospectus in the European Union (EU) to facilitate fundraising efforts in a uniform European capital market and ensure investor protection (Sergakis, 2018). The introduction of the Prospectus Directive established a mandatory risk factor section for all prospectuses published in the EU. Further details were defined in Commission Regulation 809/2004. According to Article 25, paragraph 1, issuers should describe the risk factors linked to the issuer and the type of security covered by the issue in a specific section entitled *Risk Factors* in the prospectus. Article 2, paragraph 3 of Commission Regulation 809/2004 defines

risk factors as "a list of risks specific to the issuer and/or the securities and which are material for making investment decisions" (p. 6). In essence, the Prospectus Directive Regime legally mandated the disclosure of specific and material risks associated with the issuer and the issue to aid investor decision making.

The EU Prospectus Regulations 2007/1129 replaced the Prospectus Directive in July 2019. The main aim of the Prospectus Regulation reforms was to ensure market efficiency and investor protection while enhancing the internal EU market for capital (Busch, Ferrarini and Franx, 2020). Consistent with this aim, the EU Prospectus Regulations introduced a new regime for risk factor disclosure in EU prospectuses, making four significant changes. First, Article 16 prescribes that the most material risk factor in a condensed number of categories must be presented first.[2] Materiality is further defined in Article 16 as the probability of the risk occurring and the extent of the impact. Therefore, a renewed focus on materiality and specificity forms the cornerstone of the EU Prospectus Regulations. The new stipulation on risk factors is seen as a regulatory reaction to the market practice of supplying "lengthy anodyne statements that are not specific risks" (Burn, 2018, p. 529). Second, Article 16 allows (but does not legally require) the issuer to use a qualitative scale (low, medium, high) to demonstrate the materiality of their risk factors. However, this practice is not expected to gain much traction among practitioners due to legal risk (Burn, 2018). Third, according to Commission Delegated Regulation 2019/980, the risk factor section should be prominent in the prospectus (after the summary or general description), further illustrating the importance of this information for regulators. Fourth, Article 16, paragraph 1 provides a new definition of risk factors as "the risk factors featured in a prospectus shall be limited to risks which are specific to the issuer and/or to the securities and which are material for making an informed investment decision, as corroborated by the content of the registration document and the securities note" (p. 33). This new definition introduces the concept of corroboration, which national regulators must include in assessing the prospectus. Furthermore, Article 16, paragraph 4 proposes that ESMA provide competent national authorities with guidelines to review the specificity, materiality and presentation of risk factors in the prospectus. Consequently, whenever the materiality of the risk factor is not apparent from the disclosure, the potential negative impact is not disclosed, or the inclusion of mitigating language

[2] ESMA (2019) provide guidelines on the types of categories for risk factors including (1) risks related to the issuer; risks related to the issuer's financial situation; risks related to the issuer's business activities and industry; legal and regulatory risk; internal control risk; environmental, social and governance risks, and (2) risks related to the nature of the securities; risks related to the underlying; risks related to the guarantor and the guarantee; risks related to the offer to the public and/or admission of the securities to trading on a regulated market.

compromises the materiality, the competent national authority should challenge the prospectus (ESMA, 2019).

The Prospectus Directive and the Prospectus Regulations prescribe that risk factor disclosures in EU green bond prospectuses are mandatory. Nevertheless, this mandatory disclosure creates friction for issuers, regulators and investors. For issuers, the contractionary definition of risk factors in the Prospectus Directive may lead to a trade-off between disclosing material risk factors that are also specific. Indeed, the concepts of materiality and specificity are difficult to define (e.g. Bernstein, 1967; Hope, Hu and Lu, 2016). The Prospectus Regulations further complicate the disclosure of risk factors, where materiality, specificity, and corroboration must be incorporated into these decisions. For regulators, challenging the prospectus for completeness, comprehensibility, and consistency proved difficult under the Prospectus Directive (e.g. Buttigeg, 2020). The new regime also asks regulators to challenge the materiality, specificity, corroboration and categorisation of risk factors. For investors, EU risk factor disclosure legislation could allow an informed assessment of the risks associated with the issuer and the issue to make an informed investment decision. However, due to the conflicting intentions of issuers and regulators, this could also lead to uninformative disclosure of risk factors for investors. Nevertheless, prospectuses allow for the standardisation of disclosure between issuers and securities, thus aiding investors in judging their comparability (De Franco, Kothari and Verdi, 2011; Shi, Pukthuanthong and Walker, 2013). Yet, what exactly encompasses the term *risk* has received considerable debate in the finance literature (Ang, Chen and Xing, 2006; Roy, 1952).

3. Conceptual Framework

3.1. Defining Risk

Risk can be defined in several ways, including downside (negative outcome), upside (opportunity or positive outcome), or both (e.g. Ibrahim and Hussainey, 2019; Kaplan and Garrick, 1981; Roy, 1952). However, debt investors face a combination of three risk factors when investing in corporate bonds. First, the primary concern for debt investors is whether the issuer will honour their interest payments and repay the bond at maturity (Armstong *et al.*, 2010; Beatty *et al*., 2019; Chiu *et al*., 2018). Thus, default and credit risks are prominent downside risks for bondholders with no upside potential (e.g. Longstaff, Mithal and Neis, 2005). Second, macroeconomic risks, including interest rate or term risk, can present in longer maturity corporate bonds from unexpected changes in interest rates (e.g. Antoniou, Zhao and Zhao, 2009; Bali, Subrahmanyam and Wen, 2021). This can lower the value of the interest

payment to debt investors, which is another downside risk. For instance, Fama and French (1993) find that default and term risks capture the variation in excess returns of highly rated corporate bonds from 1963 to 1991. This suggests that corporate bond investors require a risk premium for bonds with higher default/credit and interest rate risks. Third, corporate bonds trade infrequently (once or twice a week), implying low liquidity levels (e.g. Feldhutter, 2012; Hong and Warga, 2000). This is due to corporate bonds being suitable for risk-averse, buy-and-hold institutional investors (Kozhemiakin, 2007). This presents liquidity risk for debt investors, which is also primarily a downside risk. For example, Lin, Wang and Wu (2011) extend the conclusion of Fama and French (1993) and find that liquidity risk (along with default and term risk) is a strong determinant of excess corporate bond returns from 1994 to 2009. Finally, Bai *et al.* (2019) extend Fama and French (1993) and Lin *et al*. (2011) and find that downside, coupled with credit and liquidity risks, explain the majority of excess corporate bond returns from 2002 to 2016. Therefore, the literature provides strong evidence that corporate bond investors are faced with credit/default, term/interest rate and liquidity risks which are predominately downside risks.

The unique risks of green bonds are empirically unknown. However, there may be increased reputation, litigation and liquidity risks (e.g. Banahan, 2018; Trompeter, 2017; Zerbib, 2019). These unique risks for green bond investors would also constitute downside risks, as reputation/litigation risk could reduce the issuer's financial capacity. In addition, green bond investors may seek risk compensation for the heightened liquidity risk. Therefore, defining risk in downside terms clarifies the risks that green bondholders are likely to incorporate into their investment decision.

Consistent with defining risk in downside terms, this study uses the definition of risk disclosure offered by Ibrahim and Hussainey (2019, p. 134). Consequently, risk disclosure is defined as "any information about the past, present or potential loss, failure, collapse, crisis, deterioration, breakdown, accident, emergency, hazard, danger, harm, threat, or exposure that enables present and potential users to identify and assess the current and potential negative outcomes". The rationale for using this definition to encompass risk disclosure in the present context is two-fold. First, the Prospectus Directive and the Prospectus Regulations define risk factors included in the prospectus as material, specific and corroboratory. Downside risks are more likely to be material, specific and corroboratory to debt investors and, therefore, approved by national regulators before disseminating the prospectus. Second, debt investors have a higher demand for negative information than equity investors (Defond and Zhang, 2014; De Franco *et al.*, 2009; Derrien, Kecskes and Mansi, 2016; Wittenberg-Moerman,

2008). Consequently, if issuers disclose upside risk factors in the prospectus, this is unlikely to inform debt investors, who are unlikely to impound this information into their investment decisions. Therefore, defining risk disclosure in downside terms clarifies the risks that green bondholders extract from the prospectus and incorporate into their investment decisions. Downside risk disclosure could also reduce *information asymmetry* between green bond issuers and investors – this forms the cornerstone of the following section.

3.2. Risk Disclosure Incentives

The green bond issuer must comply with the Prospectus Directive/Prospectus Regulations and disclose material, specific and corroboratory risk factors that are scrutinised by a national regulator. This study uses agency and signalling theories to probe managerial intent when disclosing risk factors in green bond prospectuses. Therefore, following the argument put forward by Bergh, Ketchen, Orlandi, Heugens and Boyd (2019), this study uses information asymmetry as an assumption in the conceptual framework. This study assumes that green bond investors are also informationally disadvantaged due to information asymmetry with issuers. There could be two reasons for this. First, the green bond market is still in its infancy since its inception in 2007; this could lead to increased uncertainty due to the unclear mechanics of the market (the structural barrier - Bergh *et al.,* 2019). Second, the green bond issuer commits to using the proceeds on environmental initiatives *ex-post* (e.g. ICMA, 2021a). However, some green bond investors may have greenwashing concerns – the practice of making unsubstantiated or misleading claims about the company's environmental commitment – (Flammer, 2021), which could add increased uncertainty (the uncertainty barrier – Bergh *et al.,* 2019). This study does not view information asymmetry as a mechanism. Rather, information asymmetry is the foundational assumption for building theoretical reasoning to probe managerial intent when disclosing risk factors in the green bond prospectus.

Agency theory would explain that managers report on their risks to reduce the information gap between informed and uninformed investors to reduce agency costs and mitigate information asymmetries (Ntim, Lindop and Thomas, 2013; Watts and Zimmerman, 1983). The agent in this study is the green bond issuing manager, while the principal is the potential green bondholder. Tension exists due to the conflicting motivations of green bond issuers and investors. On the one hand, green bond issuers wish to raise capital to fund their environmental initiatives at preferential costs. On the other hand, green bond investors wish to receive a return on their capital while benefiting the environment. Due to information

asymmetry, the potential green bondholders may perceive that issuing managers have hidden information regarding the issue, resulting in opportunistic behaviour (Eisenhardt, 1989; Krishnaswami, Spindt and Subramaniam, 1999). Therefore, due to adverse selection, there is potential for monitoring costs to be high. Recognising this, managers have incentives to disclose informative risk factors to potential green bond investors to mitigate information asymmetry and reduce monitoring costs (Francis, Khurana and Pereira, 2005; Yu, 2005).

In contrast, signalling theory would explain that managers disclose informative risk factors to tactically signal to investors their ability to manage risk and distinguish themselves from lower-quality firms (Akerlof, 1970; Elshandidy, Fraser and Hussainey, 2013). The signaller in this setting is the green bond issuer who wishes to borrow capital at favourable rates from investors to fund green initiatives. The receiver of the signal is the potential green bondholders who wish to gain a return on their investment that is beneficial to the environment and need more information on the issuers underlying quality and intentions. The green bond issuer can reduce information asymmetry by providing informative risk disclosure that signals their quality and ability to manage risk to potential bondholders. This setting is consistent with the two tenets of signalling theory. First, the disclosure of risk factors in the green bond prospectus is observable and known in advance. The prospectus containing the risk factor disclosure is disseminated to potential green bondholders who observe the signal before making an investment decision. Second, the prospectus is costly to compile for the green bond issuer. Indeed, the European Commission (2015) estimates that under the Prospectus Directive, the cost of preparing a prospectus was, on average, €1 million plus up to 15 percent of the capital raised. This disclosure cost may dissuade issuers from this financing channel (e.g. Dhaliwal, Khurana and Pereira, 2011). The cost of disclosing risk factors is also potentially high for green bond issuers, as a balance must be reached between materiality, specificity, and corroboration. In addition, the green bond issuer assumes the legal risk for the content of the prospectus. Therefore, any inaccuracies or omissions in risk factor disclosure may lead to potential litigation in the future (e.g. Lowry and Shu, 2002). In summary, risk factor disclosure can be viewed through the signalling theory lens, as it is a signalling device, which is scrutinised for quality, observable to potential green bond investors, and costly to imitate.

Both agency and signalling theories have been adopted in prior literature to explain managerial incentives to voluntary disclose risk factors with mixed results (Barakat and Hussainey, 2013; Marshall and Weetman, 2007; Ntim *et al*., 2013). However, there are also managerial incentives when the mandatory disclosing of risk is required (e.g. Jorgensen and

Kirschenheiter, 2003; 2012; Kravet and Muslu, 2013). Indeed, the Prospectus Directive and the Prospectus Regulations both establish that a risk factor section is required in the prospectus. However, the regulations do not stipulate a particular standard beyond prescribing that the risk factors should be material, specific, and corroboratory. In other words, green bond issuers have incentives to make risk factors informative or uninformative depending on their intentions. These incentives are the choice of risk factor disclosed, the language used to convey risk, and the tone of the language used. Thus, this study follows Jorgensen and Kirschenheiter (2003; 2012) and others and argues that mandatory risk disclosures also provide incentives to green bond issuers.

In summary, agency theory explains that green bond issuing managers disclose risk factors to reduce monitoring costs. Signalling theory explains that green bond issuing managers disclose risk factors to signal their ability to manage risk and distinguish themselves from other firms. Therefore, both agency and signalling theories offer utility (Bacharach, 1989) in the current setting. Indeed, risk disclosure is potentially one of the most important types of information provided by issuers to investors (e.g. Campbell *et al.,* 2014; Hope *et al.,* 2016). Nevertheless, how investors react to this information remains unclear and is discussed in the following section.

3.3. Debt Investor Risk Compensation

Due to competing incentives for issuers to disclose risk factors in prospectuses, investors could perceive this information in a number of ways. The accounting literature observes how the disclosure of risk factors impacts investor risk perceptions using the three hypotheses offered by Kravet and Muslu (2013). The first hypothesis is that "risk disclosures resolve known contingencies and risk factors, users will converge in their predictions and increase their confidence level" – the convergence hypothesis (Kravet and Muslu, 2013, p. 1089). The second hypothesis is that "risk disclosures introduce unknown contingencies and risk factors, users will diverge in their predictions of future performance, and users' confidence in their predictions will decrease" - the divergence hypothesis (Kravet and Muslu, 2013, p. 1089). The third hypothesis is "that risk disclosures are boilerplate" – the null hypothesis (boilerplate hypothesis) (Kravet and Muslu, 2013, p. 1089).

Taken together, the literature that evaluates the impact of risk factor disclosures for debt investors provides conflicting evidence. On the one hand, risk factor disclosures are suggested to increase investor risk perceptions through the divergence hypothesis (e.g. Bonsall and Miller, 2017; Chiu *et al.*, 2018). In contrast, risk factors are also suggested to

reduce information asymmetry and uncertainty (e.g. Chiu *et al*., 2018). On the other hand, risk factor disclosures are also suggested to be boilerplate, which do not elicit a response from investors (e.g. Beatty *et al.*, 2019). The commonality between the analyses suggests that investors react to new, specific, idiosyncratic and financial risk factors, especially for informationally uncertain issuers (e.g. Beatty *et al*., 2019; Chiu *et al*., 2018).

However, risk perceptions can also be conceptualised as underpricing, where underpricing acts as risk compensation to investors (Beatty and Ritter, 1986). In this regard, corporate green bond underpricng is defined in similar terms to Cai *et al.* (2007, p. 2026) as the "excess return of an individual bond over the return on a bond index during the same period". In the underpricing literature, *ex-ante* uncertainty theory argues that underpricing results from information asymmetry between issuers and investors. Beatty and Ritter (1986, p. 221) conceptualise that the risk associated with the offering is due to informational differences among issuers and investors, as "riskier firms should have higher average initial returns than firms that are easier to evaluate". Therefore, the theory argues that "there is an equilibrium relation between the expected underpricing and the ex-ante uncertainty about its value" (Beatty and Ritter, 1986, p. 213). This perceived *ex-ante* uncertainty from investors primarily manifests due to the uncertainty of the future financial performance of the securities in the secondary market *ex-post* (Engelen and van Essen, 2010). Consequently, if investors perceive higher levels of risk associated with the issuer and the issue *ex-ante,* then additional risk compensation is sought from underpricing (Banerjee, Dai and Shrestha, 2011). From the opposite perspective, *ex-ante* uncertainty theory can also be interpreted as issuers and underwriters intentionally underpricing securities to compensate investors for the additional risk to entice their demand (Ritter, 1984).

In this setting, the *ex-ante* uncertainty theory of underpricing would argue that in the presence of information asymmetry, issuers and underwriters will underprice green bond issues to compensate investors for the increased level of risk assumed. In this scenario, risk can be measured from the unique risk factors disclosed in the green bond prospectus. However, due to the conflicting impact of risk disclosure on investor risk perceptions (convergence, divergence, boilerplate), the expected outcome is unknown *a priori*. Consequently, *ex-ante* uncertainty theory would predict similar outcomes to the three hypotheses from the accounting literate.

The convergence argument would explain that green bond investors respond positively to the information revealed by risk factor disclosure as the information reduces a previously known risk (Brown, Tian and Tucker, 2018). The convergence hypothesis would indicate that

risk factor disclosure in the green bond prospectus has reduced information asymmetry. Thus, green bond investors perceive a reduction in potential agency problems and value managerial ability to manage risk. This argument can also be interpreted as managers of superior firms increasing their public information and the precision of their disclosure to reduce investor risk compensation and receive an efficient cost of capital (e.g. Biddle and Hilary, 2006; Easley and O'Hara, 2004). Hence, the risk factor disclosure regime in the EU can be viewed as an increase in disclosure precision (e.g. Bhat Callen and Segal, 2016). Thus, the convergence hypothesis would also suggest that green bond investors are more informed regarding default risk, which has lowered their information risk premium (e.g. Duffie and Lando, 2001) and, consequently, the need for risk compensation.

The divergence hypothesis would explain that green bond investors respond negatively to risk factor disclosure, making them aware of previously unknown risks (Bao and Dattta, 2014). Risk disclosure can be perceived as negative information as it highlights an issuer's uncertainties or unexpected events (e.g. Kothari, Li and Short 2009). A long list of risks could discourage risk-averse investors from investing in the issue because the focus is on threats and uncertainties and not on possibilities or opportunities (Garfinkel, 2009; Malmendier and Tate, 2005). Therefore, the divergence hypothesis would suggest that investors become alarmed by the disclosure of risk, reducing their confidence in the future performance of the issuer and their securities (Shalen, 1993). Although information asymmetry can be reduced through risk disclosure (e.g. Campbell *et al*., 2014), this hypothesis would suggest that anticipated agency conflicts are exacerbated for investors who lose confidence in managerial capacity to manage the increased level of risk (Elshandidy and Shrives, 2016). Therefore, the divergence argument would explain that investors will require larger risk compensation for taking part in the issue (e.g. Bonsall and Miller, 2017).

The null or boilerplate hypothesis would explain that risk disclosures do not impact green bond investor risk perceptions. This would suggest that green bond issuers use vague and boilerplate risk factor disclosures to catalogue every potential risk that might surface to hedge future legal risk (e.g. greenwashing concerns). This type of disclosure is uninformative to green bond investors, does not impact their risk perceptions, and is not associated with risk compensation. However, *ex-ante* uncertainty theory fails to explain information asymmetry between different types of investors in corporate bond issues. The underpricing theory provided by Rock (1986) offers a valuable lens for viewing this tension.

According to Rock's (1986) model of underpricing, some investors are more informed about the issue than others. This winner's curse arises when more informed traders (such as

institutional investors) avoid issues of bad firms, and uninformed investors win an allotment of an issue only when it is an overpriced offering (Kennedy, Sivakumar and Vetzal, 2006). This creates an adverse-selection setting problem, as the theory assumes that the prices fluctuate according to changes in the demand for the securities (Rock, 1986). Therefore, to get all investors to participate in the issue, underwriters must underprice the securities to compensate the uninformed investors for the winner's curse. However, to date, there has been no support for Rock's theory in the corporate bond underpricing literature (e.g. Cai *et al*., 2007; Datta *et al*., 1997). The difficulty lies in measuring informed versus uninformed investors. This suggests that the theory may be more applicable in an investor preference setting (e.g. Fama and French, 2007).

In this setting, Rock's (1986) theory of underpricing would explain that underwriters will underprice green bond issues to increase uninformed investor demand for the issue. The underpricing literature typically assumes that retail investors are uninformed compared to institutional investors (e.g. Cai *et al*., 2007). Institutional investors purchase the vast majority of corporate bond issues in the primary market (e.g. Bai *et al.,* 2019; Nikolova *et al*., 2020). This leaves retail investors the option of purchasing green bonds in the secondary market or from an exchange. Consequently, Rock's theory would predict that green bond underpricing will be more prominent in the secondary market or for listed bonds. However, a further distinction can be made between informed and uninformed investors in the green bond setting. Green-orientated investors may be uninformed regarding the issue if they have non-pecuniary motives (e.g. Zerbib, 2019). On the other hand, green-orientated investors may be more informed regarding the issue if they incorporate both financial and environmental information into their investment decision (Chowdhry, Davies and Waters, 2019). Thus, an interesting test of Rock's theory is to distinguish the levels of underpricing between retail, green and traditional investors. Yet, securities issues do not solely comprise of issuer and investor informational tensions (Ritter and Welch, 2002). Other intermediaries are involved in the capital markets (Healy and Palepu, 2001), which offer alternative theories of green bond underpricing.

Information problems may impede the efficiency of capital markets, causing market imperfections or failures (La Porta, Lopez-De-Silanes and Shleifer, 2006). Crucial to this is using reputation to certify issuer qualities that can be communicated to prospective investors (Bergh *et al*., 2019). The underlying logic is that reputable intermediaries are likely to adopt stringent screening standards, which can reduce information asymmetries between issuers and investors (Chemmanur and Fulghieri, 1994). In essence, the intermediary stakes their future

reputation on certifying the initiative they have been contracted to complete (Booth and Smith, 1986). Investors may view the issuer initiative more positively with the knowledge that the intermediary has acted as a certifier (Cox and de Goeij, 2020). However, the certification hypothesis has received mixed support in the corporate bond underpricing literature. For example, Datta *et al.* (1997) find that the presence of prestigious underwriters results in the overpricing of corporate bonds in the US market. In contrast, Rischen and Theissen (2021) do not find the underwriter's reputation to be a significant factor in EU corporate bond underpricing.

In the green bond market, certification of quality for issuers can be interpreted in two ways. First, quality may be interpreted as the environmental reputation of the issuer. Therefore, investors may perceive green bond issuers with superior environmental rankings as a certification mechanism. Second, issuers who avail of third-party reviews and certification for their green issues can be viewed as higher quality than issuers who do not engage in these green assessments. Indeed, verification has been growing in the green bond market. In 2015, 65 percent of green bonds were externally reviewed; this increased to 77 percent in 2016, 82 percent in 2019 and 86 percent in 2021; however, considerable heterogeneity exists as there remains no single standard for verification (Climate Bond Initiative, 2020; 2021; 2022a, McInerney and Bunn, 2019). Thus, the certification hypothesis of underpricing would explain that issuers with superior environmental records who avail of third-party verification/certification will underprice by a smaller margin than issuers who do not avail of these assessments. In contrast, the theory would suggest that low-quality issuers who do not have certification signals have an incentive to underprice green bonds. Yet, the level of information asymmetry between intermediaries and investors may also be a factor in the underpricing of corporate green bonds.

The bookbuilding theory of underpricing (Benveniste and Spindt, 1989) would explain that, in the presence of information asymmetry, underwriters will reward green bond investors with underpricing for truthfully providing demand information. Green bond issuers report increased investor attention at roadshows compared to traditional bonds (e.g. Maltais and Nykvist, 2020). This engagement is a notable change for investors in debt markets and is shifting how the market operates (e.g. Monk and Perkins, 2020). This would suggest that investors provide more information to underwriters during green versus traditional issues, resulting in higher underpricing. On the other hand, bookbuilding theory would also suggest that seasoned green bond issues will be underpriced less than first-time issues as underwriters will not need to reward investors for supplying demand information.

Figure 2 summarises and presents the conceptual framework highlighting risk disclosure in green bond prospectuses and underpricing from the issuer, intermediary, investor and pricing perspectives. The data and methodology used to investigate these phenomena are discussed in the following section.

[Insert Figure 2 here]

4. Data and Methodology

4.1. Data

To compile an initial dataset of EU corporate green bonds, a list is extracted from the *Thomson Reuters Eikon* database. This yields an initial sample of 2,438 green bonds. Issues by supranational agencies, governments and municipalities are then excluded along with Islamic bonds (*Sukuk).* This restricts the sample to 1,899. The sample is further restricted by excluding certificates of deposit, commercial paper and convertible bonds. This exclusion restricts the sample to 1,874 green bonds from European corporate issuers. Another 13 bonds appear to be mislabelled by *Thomson Reuters Eikon* as they were issued between 1985 and 2004 and are also excluded. Finally, 14 green bonds appear to have been issued prior to the Green Bond Principles; these are also excluded to ensure consistency. The exclusion criteria results in a final sample of 1,847 corporate green bonds from 518 EU issuers from 1st January 2014 to 31st December 2021. Table 1 summarises the exclusion criteria and the final sample.

The green bond sample will be cross-referenced with the *Climate Bond Initiative* and *Bloomberg* databases to ensure accuracy and comparability. The green bond prospectuses will be sourced from the ESMA website, issuer websites, listing venues (if listed) and the *Bloomberg* database. Pricing data will also be sourced from the *Thomson Reuters Eikon* database.

[Insert Table 1 here]

4.2. Methodology

To address the objective of this study, the following RQ will be answered using a three-stage quantitative approach. Does unique *ex-ante* risk disclosure in EU corporate green bond prospectuses impact initial pricing? In the first stage, this study will extract unique risk factors from green bond prospectuses using topic modelling.

Probabilistic topic models are a suite of algorithms whose aim is to discover the hidden thematic structure in extensive archives of documents (Blei, 2012). These models allow for the categorisation of a large number of documents in an objective and replicable manner (Dyer, Lang and Stice-Lawrence, 2017). One such topic model is Latent Dirichlet Allocation (LDA), an unsupervised technique developed by Blei *et al.* (2003). In its simplest terms, LDA is an automatic statistical model that extracts topics from documents and assigns a likelihood to each identified topic. LDA determines the number of words in a document using the bag-of-words technique, which collapses a text into rows of words and columns of word counts (Loughran and McDonald, 2016). Therefore, singular words are typically the unit of analysis in LDA models. The model assesses the probability of clusters of words co-occurring within documents to identify sets of topics and their associated word grouping (Hoberg and Lewis, 2017). Hence, LDA is a generative model that identifies topics that best fit the data (Lewis and Young, 2019).

LDA models have become popular in the finance literature to discover risk factor topics in annual reports. For example, Wei *et al.* (2019) use LDA to extract 66 risk factors for 840 US energy companies from 2010 to 2016. Similarly, Li, Feng *et al.* (2020) use LDA to identify 30 risk factors associated with US tourism companies from 2006 to 2019. These studies use risk factor headings as the unit of analysis in the LDA model. This suggests that LDA is particularly appropriate for identifying risk factor topics and is possibly "more suitable for dealing with short documents" (Wei *et al.,* 2019, p. 454).

However, the headings in this study are generally non-informative and do not identify the risk beyond categorising them as the risks associated with green bonds. The unique risks associated with green bonds typically appear in a section of the prospectus entitled *Risk Factors Relating to the Notes* under a heading entitled *Risks associated with Notes with a specific use of proceeds, such as Green Bonds* or a similar variation. Therefore, this study uses LDA to extract the risk factors using the text below the heading, which is typically *The Risks associated with Green Bonds*.

Another approach was considered earlier in this study. First, the bag-of-words method using the risk dictionary from Campbell *et al.* (2014) was considered.[3] This method would count the risk keywords in the five categories in green bond prospectuses. The outcome would determine which of the five risk categories (e.g. idiosyncratic/legal and regulatory) is

[3] Campbell *et al.* (2014) compiled a risk keyword dictionary from previous literature and LDA in five categories: financial risk, idiosyncratic risk, legal and regulatory risk, systematic risk and tax risk. See Campbell *et al.* (2014) pages 444 – 452.

conspicuous in green bond prospectuses. However, it would fail to extract the unique risk factors in green bond prospectuses. Consequently, this study proposes that LDA is the best method to identify unique risk factors in green bond prospectuses.

Specifically, this study follows previous literature and pre-processes the text from the prospectuses prior to LDA analysis (e.g. Loughran and McDonald, 2016). The pre-processing stage involves six steps using a *Python* coding environment. First, special and single characters, numbers and more than single whitespaces are removed. Second, each word is tokenised and converted into a bag of single words list. Third, the stop words are removed using the updated list provided by Loughran and McDonald (2022)[4]. Fourth, the remaining words are converted into bigrams – which are two words that frequently occur together (at least five times) in the prospectuses. One of the limitations of LDA is the use of single words, which removes the context from the textual information (e.g. Lewis and Young, 2019; Miller, 2017). Bigrams allow some of the context to remain in the green bond risk factors. Fifth, the bigrams are lemmatized using the *spaCY* package. Lemmatization converts words with affixes to their natural or base form. For example, 'reviewers' and 'reviews' would be converted to 'review'. Sixth, as the end goal is to present the least amount of informative terms to the LDA model, the top 20 percent of bigrams are also removed from the dataset as these are likely to be boilerplate disclosure.

Following the six pre-processing steps, the remaining dataset is prepared for the LDA model. First, the text is converted into a Term Document Frequency Matrix, which collapses the bigrams into rows of words and columns of word counts along with the weights per prospectus. Second, the LDA model is operationalised using the *Gensim* package. The parameters are initially set to return 8, 10 and 12 topics using a random state of 20. Third, the LDA model returns the number of topics and computes a coherence score for each model.[5] Fourth, the best model that fits the dataset is calculated by *Gensim* to find the optimal number of topics and parameters which are reported to allow for replicability. Finally, the dominant topic number and dominant topic percentage contribution are assigned to each prospectus in preparation for the next stage of analysis.

In the second stage of analysis, first, an event study used by Cai *et al*. (2007) and others will measure initial pricing using green bond excess returns over a value-weighted index

[4] Stop words are words that are meaningless on their own. For example, 'the', 'and' 'of'. To check the full visit Loughran and McDonald (2022) https://sraf.nd.edu/textual-analysis/stopwords/

[5] The coherence score is a statistical estimate of whether a human reader would consider the topics to be 'coherent'. The score lies on a scale of between 0 (no coherence) and 1 (fully coherent).

during a short event window. Following Rischen and Theissen (2021), this study uses a 40-day event window. While a one-day window is commonly used to measure the underpricing of equity IPOs, corporate bonds trade less often (e.g. Feldhutter, 2012; Hong and Warga, 2000) and may therefore require a more prolonged event window. Similar to Rischen and Theissen (2021), the expected return $E(R_{i,t})$ is assumed to be equal to the total return of the corresponding S&P Green Bond Index $R_{m,t}$. The abnormal return is defined in Equation (1) below. Following Bessembinder, Kahle, Maxwell and Xu (2009), $R_{i,t}$ is calculated in equation (2) below. The price $P_{i,t}$ is the end-of-day mid-quote and $AI_{i,t}$ is the accrued interest at time t. Equation (3) presents the event study calculation.

$$(1)\ AR_{i,t} = R_{i,t} - E(R_{i,t})$$

$$(2)\ R_i(t_1, t_2) = (P_i,t_2 - P_i,t_1) + AI_{i,t2} / P_{i,t1} + A_{Ii,t1}$$

$$(3)\ CAR_i(t_1,t_2) = R_i(t_1,t_2) - R_m(t_1, t_2)$$

Finally, in the third stage of the analysis, the unique risk factor topics obtained in the LDA model will be analysed with the green bond underpricing findings. This will involve a regression model to assess how unique risk factors manifest into underpricing in the EU green bond market. Equation (5) presents the risk disclosure and underpricing regression model.

$$(4)\ CAR_{it} = \alpha + \beta_1 UniqueRiskTopic_{it} + \beta_n Controls_{it} + \varepsilon_{it}$$

The dependent variable is the underpricing measure from Equation (3). The independent variables are the dominant risk topics (and the percentage contribution) from each prospectus returned in the LDA model ($\beta_1 UniqueRiskTopic_{it}$). Additionally, bond and issuer characteristics will be controlled for ($\beta_n Controls_{it}$), while ε_{it} is the random error term.

5. Preliminary Results

This section discusses the preliminary results from the LDA analysis for 159 green bond prospectuses from issuers in the utilities sector. Tables 2, 3, 4 and 5 present summary statistics for the utilities sector, including bond level statistics, the number of words used to describe green bond risk factors and the type of prospectus used. Table 2 shows that the growth of green bond issuances in the EU utilities sector follows a trajectory similar to the global issuance growth. Specifically, the number of bonds, issuers and amount raised has increased yearly (apart from a slight drop in the amount issued in 2016) from 2015 to 2021. Table 3

illustrates that green bonds typically raise $0.47 billion from investors, have a tenor of 8 years and pay a coupon of 1.5 percent. These summary statistics are comparable to global evidence provided by Flammer (2021), except that there appears to be four perpetual bonds in the sample that skews the mean tenor[6]. At the prospectus level, Table 4 illustrates that, on average, issuers use 849 words to describe their risk factors for green bonds. Although there is considerable heterogeneity in this practice as this ranges from 34 to 3,231 words. Finally, Table 5 shows that the EU base prospectus regime is the most popular method for disclosing risk factors to investors, accounting for almost two-thirds of the sample.

[Insert Table 2 here]

[Insert Table 3 here]

[Insert Table 4 here]

[Insert Table 5 here]

The initial sample consists of 135,881 words relating to the risks associated with green bonds. The textual data are then pre-processed using the steps discussed in the previous section. First, special/single characters, numbers and more than single whitespaces are removed. Second, each word is converted into a bag-of-words list. Third, the stop words are removed. Fourth, the remaining words are converted into bigrams. Fifth, the bigrams are lemmatized. Sixth, the top 20 percent of bigrams are also removed. This yields a final sample of 394 unique bigrams, which will be analysed in the LDA model. Table 6 presents a summary of the six pre-processing steps.

[Insert Table 6 here]

The remaining bigrams are prepared for the LDA model. First, the text is converted into a Term Document Frequency Matrix. Second, the LDA model is operationalised using the *Gensim* package. The parameters are initially set to return 8, 10 and 12 topics using a

[6] There are four perpetual green bonds in the sample. Three from Orsted in 2017, 2019 and 2021. One from European Energy in 2020

random state of 20. Table 7 presents the coherence score returned in each of the three LDA models. Evidently, the coherence score increases in LDA models with fewer topics. The topics are visualised with an intertopic distance map using *pyLDAvis* and presented in Figures 3, 4 and 5. In particular, there appears to be considerable overlap in the 12 topic and 10 topic LDA models in Figures 3 and 4, respectively. Figure 5, the eight topic model, shows the most dispersion. Thus, the expectation is that the optimal number of topics that fit the dataset is less than 8 topics.

[Insert Table 7 here]

[Insert Figure 3 here]

[Insert Figure 4 here]

[Insert Figure 5 here]

As expected, *Gensim* estimates that a three topic model will return the highest coherence score for the data. Table 8 reports the parameters of the optimal LDA model to ensure reproducibility and validity. Figure 6 presents the intertopic distance map of the three topic LDA model using *pyLDAvis*. Clearly, there are three distinct topics in this model without overlap, along with a respectable coherence score reported in Table 8.

[Insert Table 8 here]

[Insert Figure 6 here]

Figures 7, 8 and 9 show word clouds of dominant topics discovered by the LDA analysis. An initial interpretation of each of the three risk topics is as follows. First, the commonality between the bigrams in topic 1 (Figure 7) suggests that the risks associated with the regulation of green bonds in the EU are a material risk factor for green bond issuers in the utility sector. Notably, this includes the European Commission and the Technical Expert Group, which have been tasked with implementing policies and legislative proposals to regulate green bonds in Europe, including the EU Taxonomy and The EU Green Bond Standard. This reflects an understandable risk factor by the issuer, as a proposal from the

Technical Expert Group is to establish that the EU Taxonomy underpins all EU green bond issues (EU Technical Expert Group, 2020). However, anecdotal evidence estimates that potentially 70 per cent of current issuance outstanding would not be compliant with the EU Taxonomy (Bowman, 2019). Therefore, the associated EU regulatory risk appears to be a reasonable risk factor for green bond issues to disclose.

[Insert Figure 7 here]

Second, the commonality between the bigrams in topic 2 (Figure 8) suggests that the risks associated with the verification of green bonds is also a significant risk factor for green bond issuers in the utilities sector (e.g. external review). Indeed, the methodologies used by green bond verifiers can lack transparency (Freeburn and Ramsay, 2020), which can pose additional risks to both issuers and investors. For example, Banahan (2018) surveyed four of the most prominent external reviewers and found that none had ever issued a negative recommendation for a green bond. In this regard, the European Commission has proposed that external reviewers must be registered and will be subject to ESMA supervision under the forthcoming EU Green Bond Standard. Consequently, the disclosure of verification risk by green bond issuers reflects a unique integral risk for these issues.

[Insert Figure 8 here]

Third, the commonality between the bigrams in the third topic (Figure 9) suggests that the assets financed with the green bonds are a pertinent risk for issuers in the utilities sector. For example, renewable energy, green assets and the issuers framework appear to be pronounced bigrams in this topic. Indeed, a challenge for green bond issuers is what exactly constitutes a green or environmental initiative (Park, 2018). For example, biomass has received considerable attention in the environmental science literature on whether the practice is beneficial or detrimental to the environment (e.g. Hall and Scrase, 1998). However, Gibon, Popescu, Hitaj, Petucco and Benetto (2020) find that biomass plants financed with green bonds had negligible effects on greenhouse gas emissions. The problem with renewable energy technologies is due to the fluidity of environmental practices and education. The question for issuers is how can they be assured that a project will still benefit the environment in ten to twenty years as scientific knowledge progresses. Thus, green asset risk factors appear to be a pertinent risk for utility issuers of these instruments.

[Insert Figure 9 here]

A current limitation of the analysis is the relatively low level of coherence in the optimal model, which makes topic 3 challenging to interpret. This is due to the small sample size (N = 159). LDA has been shown to return more informative and coherent topics when larger amounts of documents are used (Blei, 2012). Therefore, as the sample size grows in the current setting, the expectation is that a larger number of topics with a higher level of coherence will be returned.

Finally, Tables 9 and 10 present the results of the LDA model in numerical form, which have been assigned to green bond prospectuses. Evidently, there is heterogeneity in the dominant risk topics and the percentage contribution of each topic in the green bond prospectuses. This will allow for a robust analysis of how each risk topic impacts green bond underpricing, which is forthcoming in version 2 of this paper.

6. Conclusion

Corporate green bonds have been proposed as instruments that may reduce the adverse effects of climate change (Bhandary *et al*., 2021). However, to date, the unique risk factors and how investors react to these risks remains unclear. Using topic modelling, this study uncovers three previously undocumented risk factors for green bond issuers in the utilities sector. Specifically, the model discovers heightened EU regulatory risk, verification risk and green asset risk as significant risk factors for green bond issuers. The forthcoming event study and regression analysis will assess how these unique risks impact initial pricing. The findings will contribute to the academic literature where there has been a paucity of research regarding sustainable finance instrument risk. Additionally, the findings will interest issuers, regulators and investors as they navigate the EU Green Deal.

References

Ahlström, H. and Monciardini, D. (2021) 'The Regulatory Dynamics of Sustainable Finance: Paradoxical Success and Limitations of EU Reforms', *Journal of Business Ethics* [Preprint]. doi:10.1007/s10551-021-04763-x.

Akerlof, G. A. (1970) 'The Market for "Lemons": Quality Uncertainty and the Market Mechanism', *The Quarterly Journal of Economics*, 84(3), pp. 488–500. doi: 10.2307/1879431.

Ang, A., Chen, J. and Xing, Y. (2006) 'Downside Risk', *The Review of Financial Studies*, 19(4), pp. 1191–1239. doi:10.1093/rfs/hhj035.

Antoniou, A., Zhao, H. and Zhou, B. (2009) 'Corporate debt issues and interest rate risk management: Hedging or market timing?', *Journal of Financial Markets*, 12(3), pp. 500–520. doi:10.1016/j.finmar.2009.03.001

Armstrong, C.S., Guay, W.R. and Weber, J.P. (2010) 'The role of information and financial reporting in corporate governance and debt contracting', *Journal of Accounting and Economics*, 50(2), pp. 179–234. doi:10.1016/j.jacceco.2010.10.001

Bacharach, S. B. (1989) 'Organizational Theories: Some Criteria for Evaluation', *Academy of Management Review*, 14(4), pp. 496–515. doi: 10.5465/amr.1989.4308374.

Bai, J., Bali, T.G. and Wen, Q. (2019) 'Common risk factors in the cross-section of corporate bond returns', *Journal of Financial Economics*, 131(3), pp. 619–642. doi:10.1016/j.jfineco.2018.08.002.

Bali, T.G., Subrahmanyam, A. and Wen, Q. (2021) 'The Macroeconomic Uncertainty Premium in the Corporate Bond Market', *Journal of Financial and Quantitative Analysis*, 56(5), pp. 1653–1678. doi:10.1017/S0022109020000538.

Banahan, C. M. (2018) 'The Bond Villains of Green Investment: Why an Unregulated Securities Market Needs Government to Lay Down the Law', *Vermont Law Review*, 43, pp. 841–869.

Banerjee, S., Dai, L. and Shrestha, K. (2011) 'Cross-country IPOs: What explains differences in underpricing?', *Journal of Corporate Finance*, 17(5), pp. 1289–1305. doi:10.1016/j.jcorpfin.2011.06.004.

Bao, Y. and Datta, A. (2014) 'Simultaneously Discovering and Quantifying Risk Types from Textual Risk Disclosures', *Management Science*, 60(6), pp. 1371–1391. doi: 10.1287/mnsc.2014.1930.

Barakat, A. and Hussainey, K. (2013) 'Bank governance, regulation, supervision, and risk reporting: Evidence from operational risk disclosures in European banks', *International Review of Financial Analysis*, 30, pp. 254–273.

Beatty, A., Cheng, L. and Zhang, H. (2019) 'Are Risk Factor Disclosures Still Relevant? Evidence from Market Reactions to Risk Factor Disclosures Before and After the Financial Crisis', *Contemporary Accounting Research*, 36(2), pp. 805–838. doi: 10.1111/1911-3846.12444.

Beatty, R.P. and Ritter, J.R. (1986) 'Investment banking, reputation, and the underpricing of initial public offerings', *Journal of Financial Economics*, 15(1), pp. 213–232. doi:10.1016/0304-405X(86)90055-3.

Benveniste, L.M. and Spindt, P.A. (1989) 'How investment bankers determine the offer price and allocation of new issues', *Journal of Financial Economics*, 24(2), pp. 343–361. doi:10.1016/0304-405X(89)90051-2.

Bergh, D.D., Ketchen, D.J., Orlandi, I., Heugens, P.P.M.A.R. and Boyd, B.K. (2019) 'Information Asymmetry in Management Research: Past Accomplishments and Future Opportunities', *Journal of Management*, 45(1), pp. 122–158. doi: 10.1177/0149206318798026.

Bernstein, L. A. (1967) 'The Concept of Materiality', *The Accounting Review*, 42(1), pp. 86–95.
Bessembinder, H., Kahle, K.M., Maxwell, W.F. and Xu, D. (2009) 'Measuring Abnormal Bond Performance', *The Review of Financial Studies*, 22(10), pp. 4219–4258. doi:10.1093/rfs/hhn105.
Bhandary, R. R., Gallagher, K. S. and Zhang, F. (2021) 'Climate finance policy in practice: a review of the evidence', *Climate Policy*, 21(4), pp. 529–545. doi: 10.1080/14693062.2020.1871313.
Bhat, G., Callen, J.L. and Segal, D. (2016) 'Testing the transparency implications of mandatory IFRS adoption: The spread/maturity relation of credit default swaps', *Management Science*, 62(12), pp. 3472–3493.
Biddle, G.C. and Hilary, G. (2006) 'Accounting Quality and Firm-Level Capital Investment', *The Accounting Review*, 81(5), pp. 963–982.
Blei, D.M. (2012) 'Probabilistic topic models', *Communications of the ACM*, 55(4), pp. 77–84. doi:10.1145/2133806.2133826.
Blei, D.M., Ng, A.Y. and Jordan, M.I. (2003) 'Latent dirichlet allocation', *the Journal of Machine Learning Research*, 3, pp. 993–1022.
Bonsall, S. B. and Miller, B. P. (2017) 'The impact of narrative disclosure readability on bond ratings and the cost of debt', *Review of Accounting Studies*, 22(2), pp. 608–643. doi: 10.1007/s11142-017-9388-0.
Booth, J.R. and Smith, R.L. (1986) 'Capital raising, underwriting and the certification hypothesis', *Journal of Financial Economics*, 15(1), pp. 261–281. doi:10.1016/0304-405X(86)90057-7.
Bowman, L. (2019) 'ESG: green bonds have a chicken and egg problem', [Online]. Available at: https://www.euromoney.com/article/b1fxdsf5kpjxlg/esg-green-bonds-have-a-chicken-and-egg-problem (Accessed 20th August 2021).
Brown, S. V., Shaolee Tian, X. and Wu Tucker, J. (2018) 'The Spillover Effect of SEC Comment Letters on Qualitative Corporate Disclosure: Evidence from the Risk Factor Disclosure', *Contemporary Accounting Research*, 35(2), pp. 622–656. doi: 10.1111/1911-3846.12414.
Burn, L. (2016) 'Capital Markets Union and regulation of the EU's capital markets', *Capital Markets Law Journal*, 11(3), pp. 352–386. doi: http://dx.doi.org/10.1093/cmlj/kmw011.
Burn, L. (2018) 'The effect of recent EU legislation on EU retail bond markets', *Capital Markets Law Journal*, 13(4), pp. 518–533. doi: 10.1093/cmlj/kmy022.
Busch, D., Ferrarini, G. and Franx, J. P. (2020) *Prospectus Regulation and Prospectus Liability*', Oxford: Oxford University Press.
Buttigieg, C. P. (2020) 'EU regulation and supervision of securities business: a critical analysis of the challenges faced by the National Competent Authorities of small EU and EEA EFTA Member States', *Law and Financial Markets Review*, 14(1), pp. 5–21. doi: 10.1080/17521440.2019.1602695.
Cai, N. (Kelly), Helwege, J. and Warga, A. (2007) 'Underpricing in the Corporate Bond Market', *The Review of Financial Studies*, 20(6), pp. 2021–2046. doi:10.1093/rfs/hhm048.
Campbell, J.L., Chen, H., Dhaliwal, D.S., Lu, H. and Steele, L.B. (2014), "The information content of mandatory risk factor disclosures in corporate filings", *Review of Accounting Studies*, Vol. 19 No. 1, pp. 396–455. https://doi.org/10.1007/s11142-013-9258-3

Campiglio, E. (2016) 'Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy', *Ecological Economics*, 121, pp. 220–230. doi:10.1016/j.ecolecon.2015.03.020.

Chemmanur, T.J. and Fulghieri, P. (1994) 'Investment Bank Reputation, Information Production, and Financial Intermediation', *The Journal of Finance*, 49(1), pp. 57–79. doi:10.1111/j.1540-6261.1994.tb04420.x.

Chiu, T., Guan, Y. and Kim, J. (2018) 'The Effect of Risk Factor Disclosures on the Pricing of Credit Default Swaps', *Contemporary Accounting Research*, 35(4), pp. 2191–2224. doi: 10.1111/1911-3846.12362.

Chowdhry, B., Davies, S.W. and Waters, B. (2019) 'Investing for Impact', *The Review of Financial Studies*, 32(3), pp. 864–904. doi:10.1093/rfs/hhy068.

Cleverley, F., Diaz-Rainey, I. and Helbing, P. (2020) 'Green versus brown initial public offerings: How do green IPOs fare?' *Paper presented at the 3rd Annual Global Research Alliance for Sustainable Finance and Investment Conference*, 8-11 September, Columbia University, New York [Online]. Available at: https://www.susfinalliance2020.org/paper-presentation-6a (Accessed 20th August 2021).

Climate Bond Initiative (2019) 'Climate Bond Standard, Version 3.0', [Online]. Available at: <https://www.climatebonds.net/files/files/climate-bonds-standard-v3-20191210.pdf> (Accessed 2nd June 2020).

Climate Bond Initiative (2020) 'Green bonds global state of the market 2019', [Online]. Available at: https://www.climatebonds.net/files/reports/cbi_sotm_2019_vol1_04d.pdf (Accessed 20th August 2021).

Climate Bond Initiative (2021) 'Sustainable debt: Global state of the market 2020', [Online]. Available at: https://www.climatebonds.net/resources/reports/sustainable-debt-global-state-market-2020 (Accessed 20th August 2021).

Climate Bond Initiative (2022a) 'Sustainable debt: Global state of the market 2020', [Online]. Available at: https://www.climatebonds.net/files/reports/cbi_global_sotm_2021_02f.pdf (Accessed 28th April 2022).

Climate Bond Initiative (2022b) 'Interactive Data Platform', [Online]. Available at: https://www.climatebonds.net/market/data/#issuer-type-charts (Accessed 28th April 2022).

Cox, R. and de Goeij, P. (2020) 'Regulatory certification, risk factor disclosure, and investor behavior', *Review of Finance*, 24(5), pp. 1079–1106.

Datta, S., Iskandar-Datta, M. and Patel, A. (1997) 'The Pricing of Initial Public Offers of Corporate Straight Debt', *The Journal of Finance*, 52(1), pp. 379–396. doi:10.2307/2329569.

De Franco, G. D., Vasvari, F. P. and Wittenberg-Moerman, R. (2009) 'The Informational Role of Bond Analysts', *Journal of Accounting Research*, 47(5), pp. 1201–1248. doi: 10.1111/j.1475-679X.2009.00348.x.

De Franco, G., Kothari, S. p. and Verdi, R.S. (2011) 'The Benefits of Financial Statement Comparability', *Journal of Accounting Research*, 49(4), pp. 895–931. doi:10.1111/j.1475-679X.2011.00415.x.

Defond, M. L. and Zhang, J. (2014) 'The timeliness of the bond market reaction to bad earnings news', *Contemporary Accounting Research*, 31(3), pp. 911–936.

Derrien, F., Kecskés, A. and Mansi, S.A. (2016) 'Information asymmetry, the cost of debt, and credit events: Evidence from quasi-random analyst disappearances', *Journal of Corporate Finance*, 39, pp. 295–311. doi:10.1016/j.jcorpfin.2016.05.002.

Dhaliwal, D.S., Khurana, I.K. and Pereira, R. (2011) 'Firm Disclosure Policy and the Choice Between Private and Public Debt*', *Contemporary Accounting Research*, 28(1), pp. 293–330. doi:10.1111/j.1911-3846.2010.01039.x.

Ding, R. (2016) 'Disclosure of Downside Risk and Investors' Use of Qualitative Information: Evidence from the IPO Prospectus's Risk Factor Section', *International Review of Finance*, 16(1), pp. 73–126. doi: https://doi.org/10.1111/irfi.12066.

Duffie, D. and Lando, D. (2001) 'Term Structures of Credit Spreads with Incomplete Accounting Information', *Econometrica*, 69(3), pp. 633–664. doi: 10.1111/1468-0262.00208.

Dyer, T., Lang, M. and Stice-Lawrence, L. (2017) 'The evolution of 10-K textual disclosure: Evidence from Latent Dirichlet Allocation', *Journal of Accounting and Economics*, 64(2–3), pp. 221–245. doi: 10.1016/j.jacceco.2017.07.002.

Easley, D. and O'hara, M. (2004) 'Information and the Cost of Capital', *The Journal of Finance*, 59(4), pp. 1553–1583. doi:10.1111/j.1540-6261.2004.00672.x.

Ehlers, T. and Packer, F. (2017) 'Green bond finance and certification'. *BIS Quarterly Review*, pp. 89 – 104. [Online]. Available at: https://www.bis.org/publ/qtrpdf/r_qt1709h.pdf

Eisenhardt, K. M. (1989) 'Agency theory: An assessment and review', *Academy of Management Review*, 14(1), pp. 57–74.

Elshandidy, T. and Shrives, P. J. (2016) 'Environmental incentives for and usefulness of textual risk reporting: Evidence from Germany', *The International Journal of Accounting*, 51(4), pp. 464–486.

Elshandidy, T., Fraser, I. and Hussainey, K. (2013) 'Aggregated, voluntary, and mandatory risk disclosure incentives: Evidence from UK FTSE all-share companies', *International Review of Financial Analysis*, 30, pp. 320–333. doi: 10.1016/j.irfa.2013.07.010.

Elshandidy, T., Shrives, P.J., Bamber, M. and Abraham, S. (2018) 'Risk reporting: A review of the literature and implications for future research', *Journal of Accounting Literature*, 40, pp. 54–82. doi: 10.1016/j.acclit.2017.12.001.

Engelen, P.-J. and van Essen, M. (2010) 'Underpricing of IPOs: Firm-, issue- and country-specific characteristics', *Journal of Banking & Finance*, 34(8), pp. 1958–1969. doi:10.1016/j.jbankfin.2010.01.002.

European Commission (2015) 'Commission staff working document, Impact assessment, Proposal for a Regulation of the European Parliament and of the Council on the prospectus to be published when securities are offered to the public or admitted to trading', [Online]. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015SC0255&from=en (Accessed 26th July 2021).

European Commission (2018a) 'A clean planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy', [Online]. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN (Accessed 12th October 2021).

European Commission (2018b) 'Action plan: financing sustainable growth', [Online]. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0097&from=EN (Accessed 19th October 2021).

European Commission (2019) 'The European Green Deal' [Online]. Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF (Accessed 20th August 2021).

European Investment Bank (2017) 'CAB Newsletter 10th Anniversary', European Investment Bank, [Online]. Available from < https://www.eib.org/attachments/fi/2017-cab-newsletter-10years.pdf> (Accessed 20th April 2020).

European Securities and Market Authority (2019) 'Guidelines on risk factors under the Prospectus Regulations', [Online]. Available at: https://www.esma.europa.eu/sites/default/files/library/esma31-62-1293_guidelines_on_risk_factors_under_the_prospectus_regulation.pdf (Accessed 23rd July 2021).

European Union Technical Expert Group on Sustainable Finance (EUTEG) (2020) 'Usability guide: EU Green Bond Standard', [Online]. Available at: https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/200309-sustainable-finance-teg-green-bond-standard-usability-guide_en.pdf (Accessed 20th August 2021).

Fama, E.F. and French, K.R. (1993) 'Common risk factors in the returns on stocks and bonds', *Journal of Financial Economics*, 33(1), pp. 3–56. doi:10.1016/0304-405X(93)90023-5.

Fama, E.F. and French, K.R. (2007) 'Disagreement, tastes, and asset prices', *Journal of Financial Economics*, 83(3), pp. 667–689. doi:10.1016/j.jfineco.2006.01.003.

Fatica, S. and Panzica, R. (2021) 'Green bonds as a tool against climate change?', *Business Strategy and the Environment*, 30(5), pp. 2688–2701. doi: 10.1002/bse.2771.

Feldhütter, P. (2012) 'The Same Bond at Different Prices: Identifying Search Frictions and Selling Pressures', *The Review of Financial Studies*, 25(4), pp. 1155–1206. doi:10.1093/rfs/hhr093.

Flammer, C. (2021) 'Corporate green bonds', *Journal of Financial Economics*, 142(2), pp. 499–516. doi:10.1016/j.jfineco.2021.01.010.

Francis, J. R., Khurana, I. K. and Pereira, R. (2005) 'Disclosure incentives and effects on cost of capital around the world', *The Accounting Review*, 80(4), pp. 1125–1162.

Freeburn, L. and Ramsay, I. (2020) 'Green bonds: legal and policy issues', *Capital Markets Law Journal*, 15(4), pp. 418–442. doi: 10.1093/cmlj/kmaa018.

G20 Green Finance Study Group (2016) 'G20 Green Finance Synthesis Report'. [Online]. Available at: http://www.g20.utoronto.ca/2016/green-finance-synthesis.pdf (Accessed 28th April 2022).

Garfinkel, J.A. (2009) 'Measuring Investors' Opinion Divergence', *Journal of Accounting Research*, 47(5), pp. 1317–1348. doi:10.1111/j.1475-679X.2009.00344.x.

Gibon, T., Popescu, I.-Ş., Hitaj, C., Petucco, C. and Benetto, E. (2020) 'Shades of green: life cycle assessment of renewable energy projects financed through green bonds', *Environmental Research Letters*, 15(10), pp. 104045. https://doi.org/10.1088/1748-9326/abaa0c

Hall, D. O. and Scrase, J. I. (1998) 'Will biomass be the environmentally friendly fuel of the future?', *Biomass and Bioenergy*, 15(4), pp. 357–367. doi: 10.1016/S0961-9534(98)00030-0.

Hanley, K. W. and Hoberg, G. (2010) 'The Information Content of IPO Prospectuses', The Review of Financial Studies, 23(7), pp. 2821–2864. doi: http://www.jstor.org/stable/40782968.

Healy, P. M. and Palepu, K. G. (2001) 'Information asymmetry, corporate disclosure, and the capital markets: A review of the empirical disclosure literature', *Journal of Accounting and Economics*, 31(1), pp. 405–440. doi: 10.1016/S0165-4101(01)00018-0.

Helwege, J. and Wang, L. (2021) 'Liquidity and price pressure in the corporate bond market: evidence from mega-bonds', *Journal of Financial Intermediation*, 48, p. 100922. doi:10.1016/j.jfi.2021.100922.
Hoberg, G. and Lewis, C. (2017) 'Do fraudulent firms produce abnormal disclosure?', *Journal of Corporate Finance*, 43, pp. 58–85. doi:10.1016/j.jcorpfin.2016.12.007.
Hong, G. and Warga, A. (2000) 'An Empirical Study of Bond Market Transactions', *Financial Analysts Journal*, 56(2), pp. 32–46. doi:10.2469/faj.v56.n2.2342.
Hope, O.-K., Hu, D. and Lu, H. (2016) 'The benefits of specific risk-factor disclosures', *Review of Accounting Studies*, 21(4), pp. 1005–1045. doi: 10.1007/s11142-016-9371-1.
Hussein, M., Zhou, Z. and Deng, Q. (2020) 'Does risk disclosure in prospectus matter in ChiNext IPOs' initial underpricing?', *Review of Quantitative Finance and Accounting*, 54(3), pp. 957–979. doi: 10.1007/s11156-019-00812-9.
Ibikunle, G. and Steffen, T. (2017) 'European Green Mutual Fund Performance: A Comparative Analysis with their Conventional and Black Peers', *Journal of Business Ethics*, 145(2), pp. 337–355. doi: 10.1007/s10551-015-2850-7.
Ibrahim, A. E. A. and Hussainey, K. (2019) 'Developing the narrative risk disclosure measurement', *International Review of Financial Analysis*, 64, pp. 126–144. doi: 10.1016/j.irfa.2019.05.006.
International Capital Markets Association (2021a) 'The Green Bond Principles, London: International Capital Markets Association, [Online]. Available at: https://www.icmagroup.org/assets/documents/Sustainable-finance/2021-updates/Green-Bond-Principles-June-2021-140621.pdf (Accessed 20th August 2021).
International Capital Markets Association, (2021b) 'Guidelines for green, social, sustainability and sustainability-linked bonds external review', [Online]. Available at: https://www.icmagroup.org/assets/documents/Sustainable-finance/Guidelines-for-GreenSocialSustainability-and-Sustainability-Linked-Bonds-External-Reviews-February-2021-170221.pdf (Accessed 20th March 2021).
Jensen, M.C. and Meckling, W.H. (1976) 'Theory of the firm: Managerial behavior, agency costs and ownership structure', *Journal of Financial Economics*, 3(4), pp. 305–360. doi:10.1016/0304-405X(76)90026-X.
Jorgensen, B.N. and Kirschenheiter, M.T. (2003) 'Discretionary Risk Disclosures', *The Accounting Review*, 78(2), pp. 449–469.
Jorgensen, B.N. and Kirschenheiter, M.T. (2012) 'Interactive Discretionary Disclosures*', *Contemporary Accounting Research*, 29(2), pp. 382–397. doi:10.1111/j.1911-3846.2011.01070.x.
Kaminker, C. and Majowski, C. (2018) Green Bonds-Ecosystem, Issuance Process and Case Studies, [Online]. Available at: https://webapp.sebgroup.com/mb/mblib.nsf/a-w/3c57af239091dddfc125822400522b99 (Accessed 31st March 2020).
Kaplan, S. and Garrick, B. J. (1981) 'On The Quantitative Definition of Risk', *Risk Analysis*, 1(1), pp. 11–27. doi: 10.1111/j.1539-6924.1981.tb01350.x.
Kennedy, D.B., Sivakumar, R. and Vetzal, K.R. (2006) 'The implications of IPO underpricing for the firm and insiders: Tests of asymmetric information theories', *Journal of Empirical Finance*, 13(1), pp. 49–78. doi:10.1016/j.jempfin.2004.10.003.
Kothari, S.P., Li, X. and Short, J.E. (2009) 'The Effect of Disclosures by Management, Analysts, and Business Press on Cost of Capital, Return Volatility, and Analyst Forecasts: A Study Using Content Analysis', *The Accounting Review*, 84(5), pp. 1639–1670.

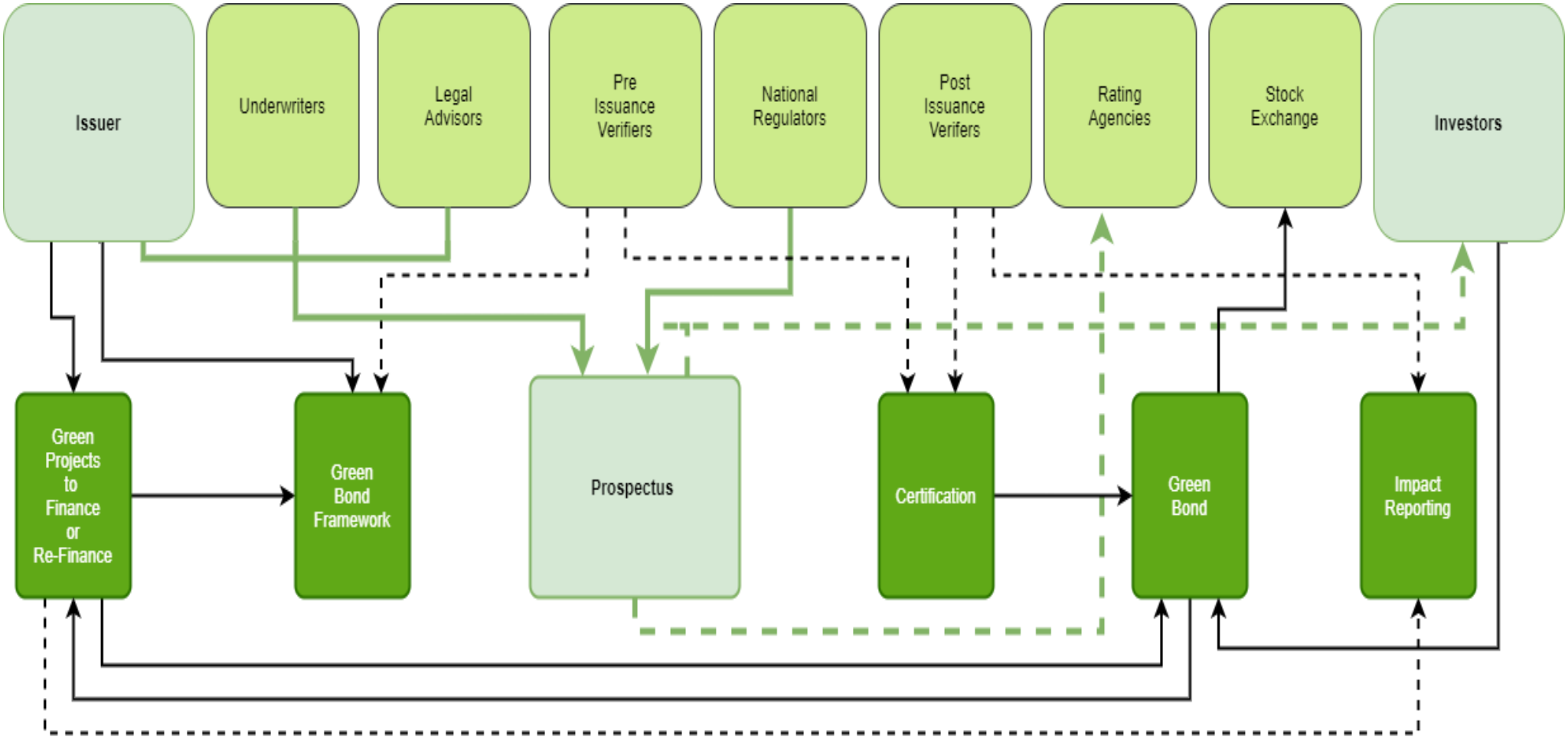
Kozhemiakin, A.V. (2007) 'The Risk Premium of Corporate Bonds', *The Journal of Portfolio Management*, 33(2), pp. 101–109. doi:10.3905/jpm.2007.674796.
Kravet, T. and Muslu, V. (2013) 'Textual risk disclosures and investors' risk perceptions', *Review of Accounting Studies*, 18(4), pp. 1088–1122. doi: 10.1007/s11142-013-9228-9.
Krishnaswami, S., Spindt, P.A. and Subramaniam, V. (1999) 'Information asymmetry, monitoring, and the placement structure of corporate debt', *Journal of Financial Economics*, 51(3), pp. 407–434. doi:10.1016/S0304-405X(98)00059-2.
La Porta, R., Lopez-De-Silanes, F. and Shleifer, A. (2006) 'What Works in Securities Laws?', *The Journal of Finance*, 61(1), pp. 1–32. doi:10.1111/j.1540-6261.2006.00828.x.
Larcker, D. F. and Watts, E. M. (2020) 'Where's the greenium?', *Journal of Accounting and Economics*, 69(2–3), p. 101312. doi: 10.1016/j.jacceco.2020.101312.
Lewis, C. and Young, S. (2019) 'Fad or future? Automated analysis of financial text and its implications for corporate reporting', *Accounting and Business Research*, 49(5), pp. 587–615.
Li, J., Feng, Y., Li, G. and Sun, X. (2020) 'Tourism companies' risk exposures on text disclosure', *Annals of Tourism Research*, 84, p. 102986. doi:10.1016/j.annals.2020.102986.
Li, J., Li, G., Liu, M., Zhu, X. and Wei, L. (2022) 'A novel text-based framework for forecasting agricultural futures using massive online news headlines', *International Journal of Forecasting*, 38(1), pp. 35–50. doi:10.1016/j.ijforecast.2020.02.002.
Li, J., Li, G., Zhu, X. and Yao, Y. (2020) 'Identifying the influential factors of commodity futures prices through a new text mining approach', *Quantitative Finance*, 20(12), pp. 1967–1981. doi:10.1080/14697688.2020.1814008.
Lin, H., Wang, J. and Wu, C. (2011) 'Liquidity risk and expected corporate bond returns', *Journal of Financial Economics*, 99(3), pp. 628–650. doi:10.1016/j.jfineco.2010.10.004.
Longstaff, F.A., Mithal, S. and Neis, E. (2005) 'Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit Default Swap Market', *The Journal of Finance*, 60(5), pp. 2213–2253. doi:10.1111/j.1540-6261.2005.00797.x.
Loughran, T. and McDonald, B. (2016) 'Textual analysis in accounting and finance: A survey', *Journal of Accounting Research*, 54(4), pp. 1187–1230.
Loughran, T. and McDonald, B. (2022) 'Software Depository for Accounting and Finance', [Online]. Available at: https://sraf.nd.edu/ (Accessed 29th April 2022).
Lowry, M. and Shu, S. (2002) 'Litigation risk and IPO underpricing', *Journal of Financial Economics*, 65(3), pp. 309–335. doi:10.1016/S0304-405X(02)00144-7.
Malmendier, U. and Tate, G. (2005) 'CEO Overconfidence and Corporate Investment', *The Journal of Finance*, 60(6), pp. 2661–2700. doi:10.1111/j.1540-6261.2005.00813.x.
Maltais, A. and Nykvist, B. (2020) 'Understanding the role of green bonds in advancing sustainability', *Journal of Sustainable Finance & Investment*, 0(0), pp. 1–20. doi:10.1080/20430795.2020.1724864.
Marshall, A. and Weetman, P. (2007) 'Modelling transparency in disclosure: the case of foreign exchange risk management', *Journal of Business Finance & Accounting*, 34(5–6), pp. 705–739.
McInerney, C. and Bunn, D. W. (2019) 'Expansion of the investor base for the energy transition', *Energy Policy*, 129, pp. 1240–1244. doi: 10.1016/j.enpol.2019.03.035.
Migliorelli, M. and Dessertine, P. (2019) 'Green Finance Today: Summary and Concluding Remarks', in Migliorelli, M. and Dessertine, P. (eds) *The Rise of Green Finance in Europe: Opportunities and Challenges for Issuers, Investors and Marketplaces*.

Cham, Switzerland: Springer International Publishing (Palgrave Studies in Impact Finance), pp. 263–271. doi:10.1007/978-3-030-22510-0_11.
Miller, G.S. (2017) 'Discussion of "the evolution of 10-K textual disclosure: Evidence from Latent Dirichlet Allocation"', *Journal of Accounting and Economics*, 64(2), pp. 246–252. doi:10.1016/j.jacceco.2017.07.004.
Monk, A. and Perkins, R. (2020) 'What explains the emergence and diffusion of green bonds?', *Energy Policy*, 145, p. 111641. doi: 10.1016/j.enpol.2020.111641.
Nath, S. (2021) 'The Business of Virtue: Evidence from Socially Responsible Investing in Financial Markets', *Journal of Business Ethics*, 169(1), pp. 181–199. doi:10.1007/s10551-019-04291-9.
Nikolova, S., Wang, L. and Wu, J. (Julie) (2020) 'Institutional allocations in the primary market for corporate bonds', *Journal of Financial Economics*, 137(2), pp. 470–490. doi:10.1016/j.jfineco.2020.02.007.
Ntim, C. G., Lindop, S. and Thomas, D. A. (2013) 'Corporate governance and risk reporting in South Africa: A study of corporate risk disclosures in the pre-and post-2007/2008 global financial crisis periods', *International Review of Financial Analysis*, 30, pp. 363–383.
OECD (2015a) 'Mapping channels to mobilize institutional investment energy', Paris, France: OECD Publishing, [Online]. Available at: https://www.oecd.org/g20/topics/energy-environment-green-growth/mapping-channels-to-mobilise-institutional-investment-in-sustainable-energy-9789264224582-en.htm (Accessed 20th August 2021).
OECD (2015b) 'Green bonds mobilising the debt capital market for a low-carbon transition', Paris, France: OECD Publishing, [Online]. Available at: https://www.oecd.org/environment/cc/Green%20bonds%20PP%20%5Bf3%5D%20%5Blr%5D.pdf (Accessed 20th August 2021).
OECD (2016) 'Green investment bank: scaling up private investment in low-carbon, climate-resilient infrastructure', Paris, France: OECD Publishing, [Online]. Available at: https://www.oecd-ilibrary.org/finance-and-investment/green-investment-banks_9789264245129-en (Accessed 22nd August 2021).
OECD (2017) 'Investing in Climate, investing in growth: A synthesis', Paris, France: OECD Publishing, [Online]. Available at: https://www.oecd.org/environment/cc/g20-climate/synthesis-investing-in-climate-investing-in-growth.pdf (Accessed 20th August 2021).
Park, S. K. (2018) 'Investors as regulators: Green bonds and the governance challenges of the sustainable finance revolution', *Stanford Journal of International Law*, 54(1), pp. 1 – 47.
Reboredo, J. C. (2018) 'Green bond and financial markets: Co-movement, diversification and price spillover effects', *Energy Economics*, 74, pp. 38–50. doi: 10.1016/j.eneco.2018.05.030.
Reboredo, J. C., Ugolini, A. and Aiube, F. A. L. (2020) 'Network connectedness of green bonds and asset classes', *Energy Economics*, 86, p. 104629. doi: 10.1016/j.eneco.2019.104629.
Rischen, T. and Theissen, E. (2021) 'Underpricing in the euro area bond market: New evidence from post-crisis regulation and quantitative easing', *Journal of Financial Intermediation*, 46, p. 100871. doi: 10.1016/j.jfi.2020.100871.
Ritter, J.R. (1984) 'The "Hot Issue" Market of 1980', *The Journal of Business*, 57(2), pp. 215–240.
Ritter, J.R. and Welch, I. (2002) 'A Review of IPO Activity, Pricing, and Allocations', *The Journal of Finance*, 57(4), pp. 1795–1828. doi:10.1111/1540-6261.00478.

Rock, K. (1986) 'Why new issues are underpriced', *Journal of Financial Economics*, 15(1), pp. 187–212. doi:10.1016/0304-405X(86)90054-1.
Rogelj, J., Geden, O., Cowie, A. and Reisinger, A. (2021), 'Three ways to improve net-zero emissions targets', *Nature*, 591, pp. 365–368. doi:10.1038/d41586-021-00662-3.
Roy, A.D. (1952) 'Safety First and the Holding of Assets', *Econometrica*, 20(3), pp. 431–449. doi:10.2307/1907413.
Russo, A., Mariani, M. and Caragnano, A. (2021) 'Exploring the determinants of green bond issuance: Going beyond the long-lasting debate on performance consequences', *Business Strategy and the Environment*, 30(1), pp. 38–59. doi:10.1002/bse.2608.
Sergakis, K. (2018) *The Law of Capital Markets in the EU*, 1st Edn. Basingstoke, UK: Palgrave.
Shalen, C.T. (1993) 'Volume, Volatility, and the Dispersion of Beliefs', *The Review of Financial Studies*, 6(2), pp. 405–434.
Shi, C., Pukthuanthong, K. and Walker, T. (2013) 'Does Disclosure Regulation Work? Evidence from International IPO Markets', *Contemporary Accounting Research*, 30(1), pp. 356–387. doi:10.1111/j.1911-3846.2012.01158.x.
Spence, M. (1973) 'Job Market Signaling', *The Quarterly Journal of Economics*, 87(3), pp. 355–374. doi:10.2307/1882010.
Stubbington, T. and Khan, M. (2021) 'EU launches largest ever green bond', *The Financial Times*, [Online]. Available at: https://www.ft.com/content/18039150-3048-4f67-9ece-9243fac969d1 (Accessed 19th October 2021).
Tang, D. Y. and Zhang, Y. (2020) 'Do shareholders benefit from green bonds?', *Journal of Corporate Finance*, 61, p. 101427. doi: 10.1016/j.jcorpfin.2018.12.001.
Tett, G. and Mundy, S. (2021) 'Climate change economics: 'The biggest capital reallocation since the Industrial Revolution', Financial Times Moral Money [Blog] 10th November. Available at: https://www.ft.com/content/e4690e7c-a2de-488c-83a1-111b8b2a7acf (Accessed 28th April 2022).
Tolliver, C., Keeley, A. R. and Managi, S. (2020) 'Policy targets behind green bonds for renewable energy: Do climate commitments matter?', *Technological Forecasting and Social Change*, 157, p. 120051.
Tripathy, A. (2017) 'Translating to risk: The legibility of climate change and nature in the green bond market', *Economic Anthropology*, 4(2), pp. 239–250.
Trompeter, L. (2016) 'Green Greed Is Good: How Green Bonds Cultivated into Wall Street's Environmental Paradox', *Sustainable Development Law & Policy*, 17(2), pp. 4 – 11.
United Nations Framework Convention on Climate Change (UNFCCC) (2015) 'The Paris Agreement', [Online]. Available at: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf (Accessed 20th August 2021).
Wang, E. K. (2018) 'Financing green: Reforming green bond regulation in the United States', *Brooklyn Journal of Corporate, Financial & Commercial Law*, 12(2), pp. 466–491.
Wang, J., Chen, X., Li, X., Yu, J. and Zhong, R. (2020) 'The market reaction to green bond issuance: Evidence from China', *Pacific-Basin Finance Journal*, 60, p. 101294. doi:10.1016/j.pacfin.2020.101294.
Watts, R. L. and Zimmerman, J. L. (1983) 'Agency problems, auditing, and the theory of the firm: Some evidence', *The journal of Law and Economics*, 26(3), pp. 613–633.
Wei, L., Li, G., Zhu, X., Sun, X. and Li, J. (2019) 'Developing a hierarchical system for energy corporate risk factors based on textual risk disclosures', *Energy Economics*, 80, pp. 452–460. doi:10.1016/j.eneco.2019.01.020.

Weinstein, M.I. (1977) 'The effect of a rating change announcement on bond price', *Journal of Financial Economics*, 5(3), pp. 329–350. doi:10.1016/0304-405X(77)90042-3.
White, L.J. (2010) 'Markets: The Credit Rating Agencies', *Journal of Economic Perspectives*, 24(2), pp. 211–226. doi:10.1257/jep.24.2.211.
Wittenberg-Moerman, R. (2008) 'The role of information asymmetry and financial reporting quality in debt trading: Evidence from the secondary loan market', *Journal of Accounting and Economics*, 46(2), pp. 240–260. doi:10.1016/j.jacceco.2008.08.001.
Yu, F. (2005) 'Accounting transparency and the term structure of credit spreads', *Journal of Financial Economics*, 75(1), pp. 53–84.
Zerbib, O. D. (2019) 'The effect of pro-environmental preferences on bond prices: Evidence from green bonds', *Journal of Banking & Finance*, 98, pp. 39–60. doi: 10.1016/j.jbankfin.2018.10.012.

Figure 1
The Green Bond Issuance Process



Source: Author's interpretation of Kaminker and Majowski (2018)

Figure 2 Conceptual Framework
Green Bond Risk Disclosure and Underpricing

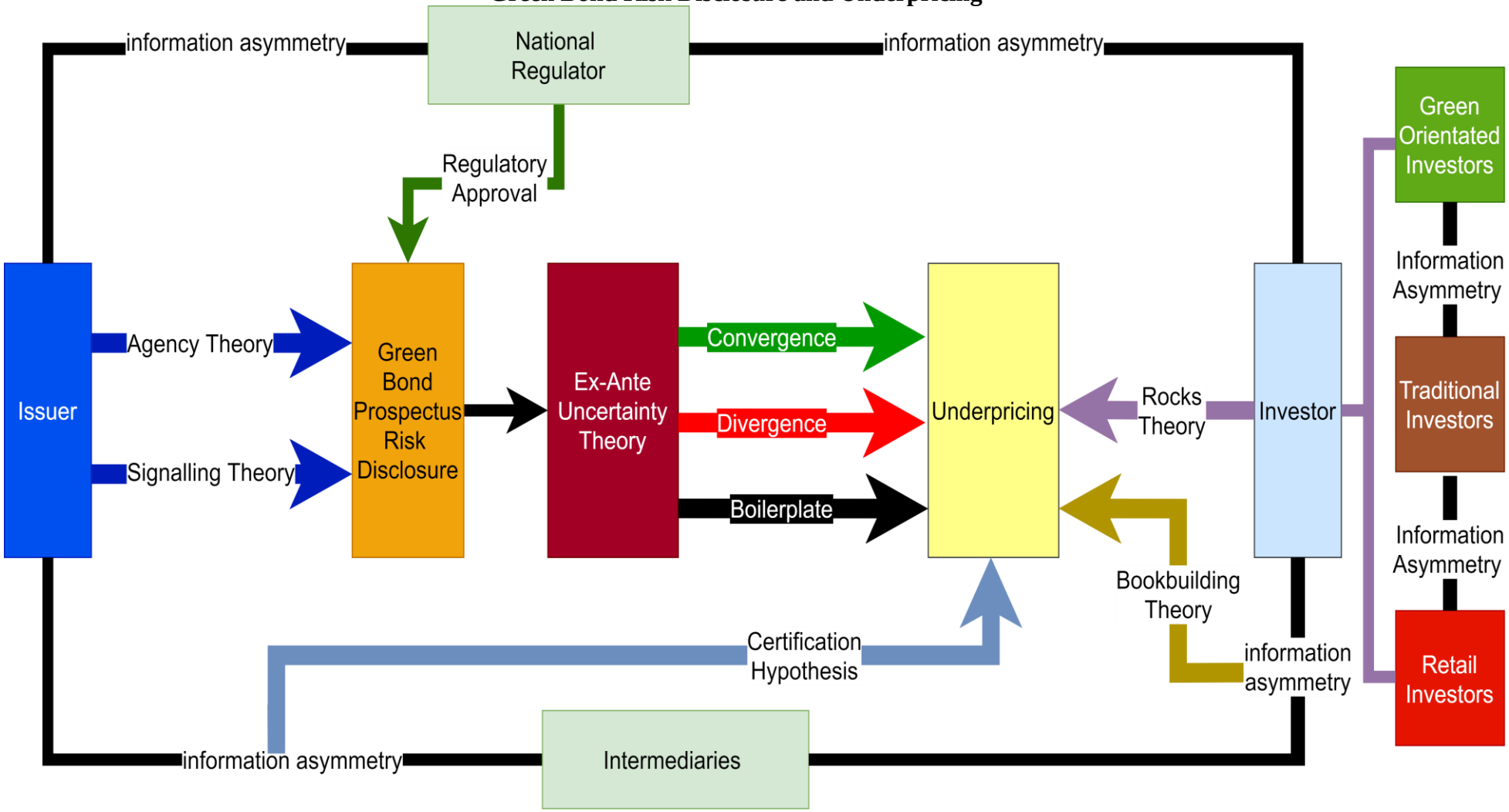


Figure 3
Intertopic Distance Map for 12 Topic LDA Model

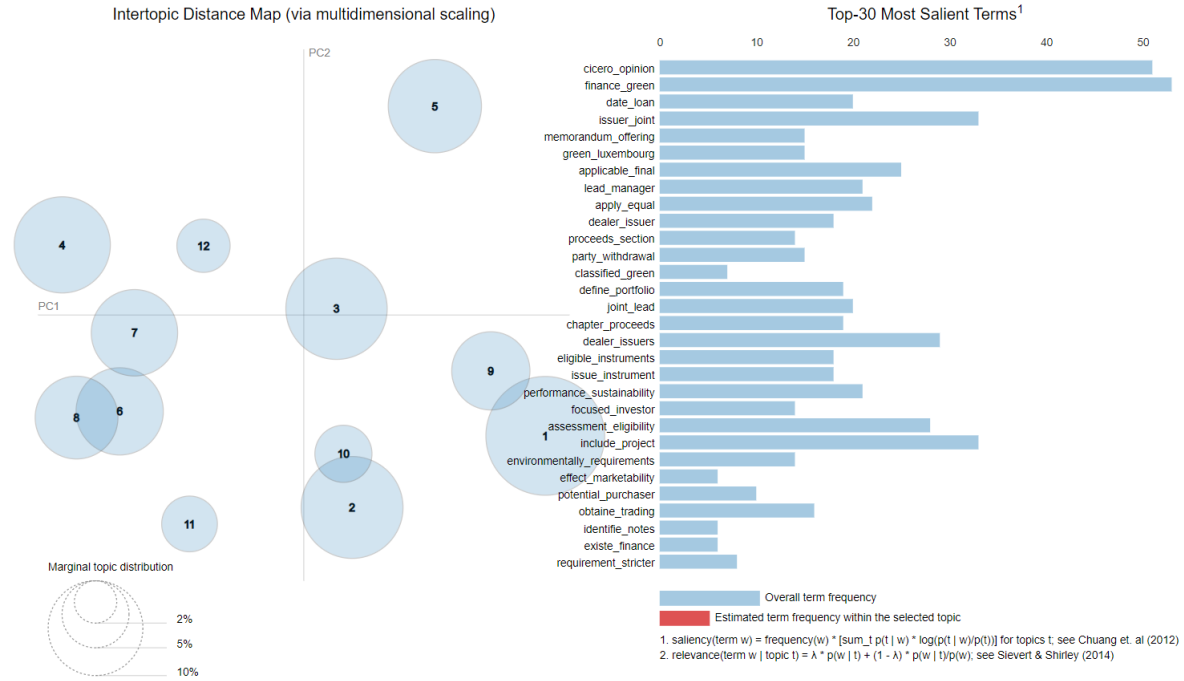


Figure 4
Intertopic Distance Map for 10 Topic LDA Model

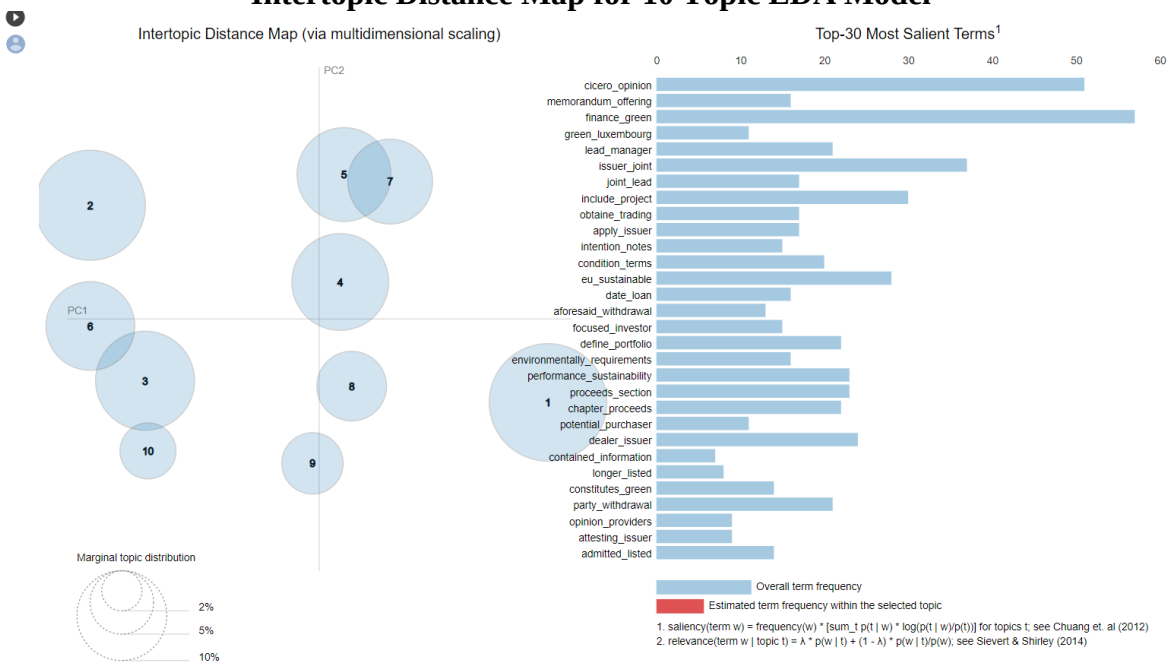


Figure 5
Intertopic Distance Map for 8 Topic LDA Model

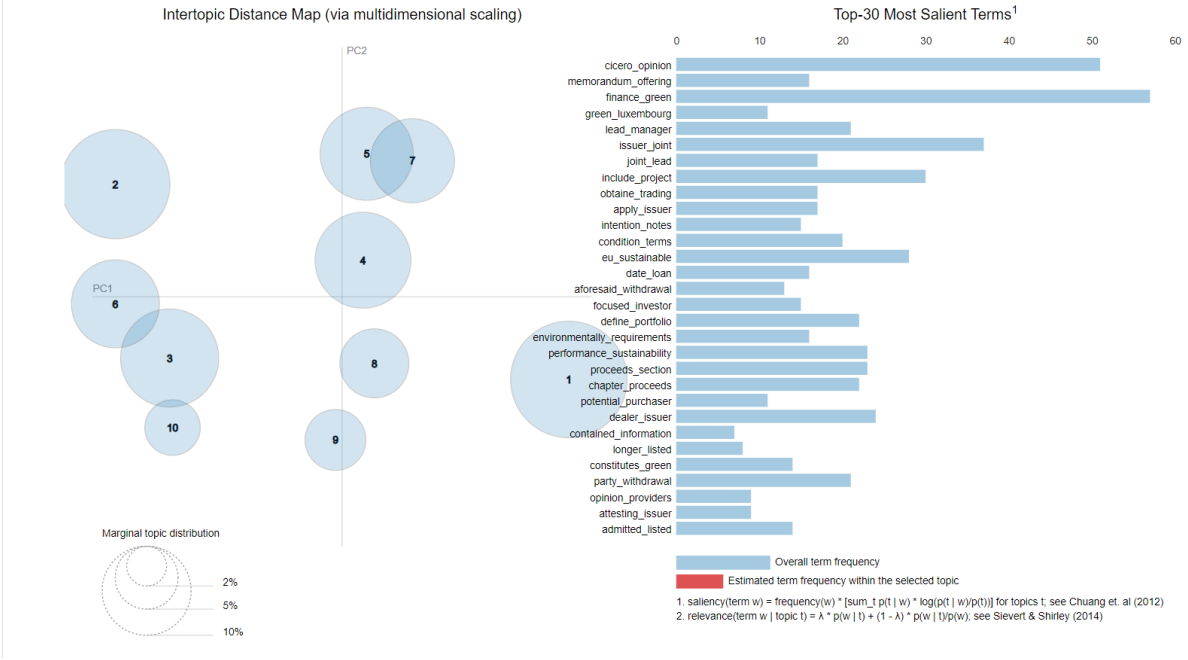


Figure 6
Intertopic Distance Map for 3 Topic LDA Model

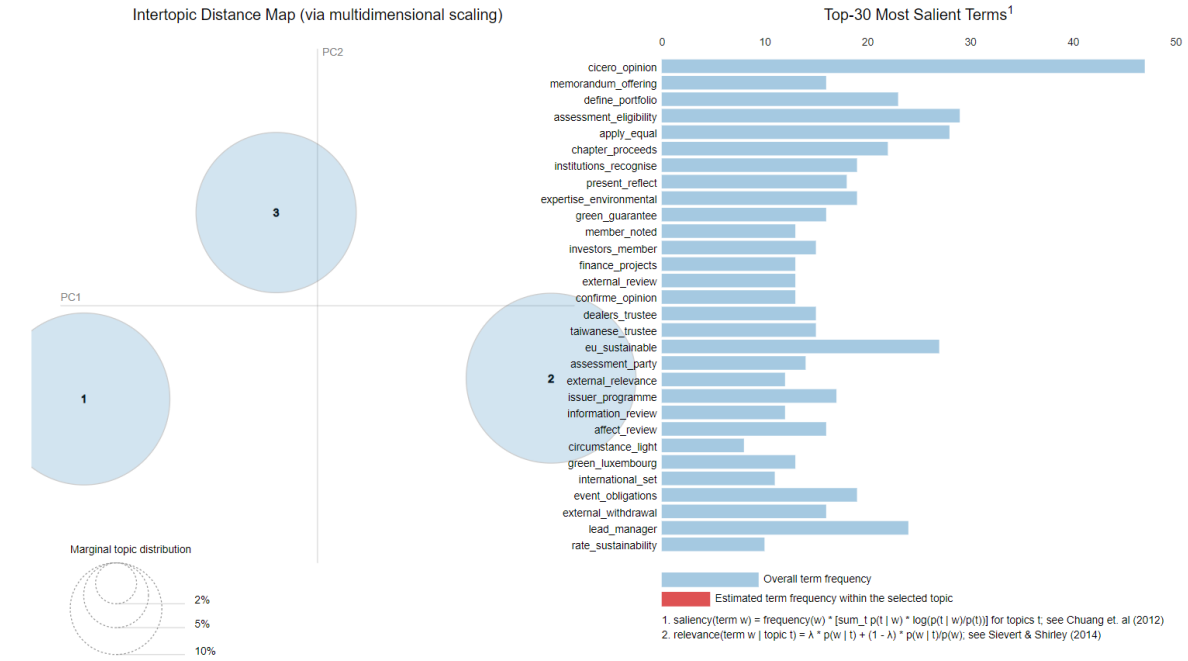


Figure 7
Word cloud of most popular bigrams from Topic 1 of LDA Analysis

Figure 8
Word cloud of most popular bigrams from Topic 2 of LDA Analysis

Figure 9
Word cloud of most popular bigrams from Topic 3 of LDA Analysis

Table 1
Green Bond Exclusions and Sample

Exclusion	Number of Green Bonds
1. Initial List	2,438
2. Exclude supranational, government, municipalities and Islamic green bonds	-539
3. Exclude certificates of deposit, commercial paper and convertible green bonds	-25
4. Exclude green bonds issued from 1985 - 2004	-13
5. Exclude green bonds issued in 2013	-14
6. Final Sample	1,847

Table 2
Number of EU Green Bonds from Issuers in the Utilities Sector 2015 - 2021

Year	#Green Bonds	#Issuers	Amount $Billion
2015	1	1	0.11
2016	1	1	0.03
2017	11	7	4.9
2018	13	8	4.78
2019	35	23	18.08
2020	48	28	18.03
2021	51	35	25.69
Total	**160**	**103**	**71.62**

Table 3
Summary Statistics at the Green Bond Level

	Coupon	Amount Issued $Billion	Tenor
Mean	1.80	0.45	43.75
Median	1.50	0.47	8.00
Standard Deviation	1.58	0.32	172.89
Minimum	0.00	0.03	0.00
Maximum	8.5	1.14	1000.00

Table 4
Number of Words Used to Describe Green Bond Risk Factors

	#Words
Mean	849
Median	793
Standard Deviation	514
Minimum	34
Maximum	3231

Table 5
Types of Green Bond Prospectus Issued 2014 – 2021

Type of Prospectus	Percentage
Base Prospectus	67%
Standalone Prospectus	30%
Registration Statement	3%

Table 6
Pre-processing steps taken before LDA Analysis

Text Prepossessing Steps	Number of words/bigrams
Initial List	135,881
1. Remove special characters, single characters, numbers, more than single whitespace	- 424
Change text to bag-of-words	13,557
2. Remove stop words	- 78,666
3. Make bigrams from words	22,545
4. Lemmatize the bigrams	-2,407
Total Number of unique bigrams	806
5. Remove the top 20 percent most common bigrams	-412
Total number of bigrams used in LDA	**394**

Table 7
LDA Coherence Scores

Number of Topics	Coherence Score
8 Topics	0.45
10 Topics	0.42
12 Topics	0.41

Table 8
Parameters of Optimal LDA Model

Parameters	Percentage
Alpha	0.05
Coherence	0.47
Number of Topics	3
Random State	10

Table 9
Dispersion of Dominant Risk Topics in Green Bond Prospectuses

Topic Number	Percentage
Topic 1	33%
Topic 2	36%
Topic 3	31%

Table 10
Summary Statistics of Dominant Topic Percentages in Green Bond Prospectuses

	Topic 1	Topic 2	Topic 3
Mean	0.92	0.95	0.96
Median	0.99	1.00	1.00
Standard Deviation	0.14	0.11	0.09
Minimum	0.50	0.58	0.57
Maximum	1.00	1.00	1.00