Firm Networks and Green Bond Issuances

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Preliminary version

Abstract

This paper examines whether the practice of green bond issuances spreads between issuers via shared directors or executives or officials. Utilizing a sample of all Northern American and European green bond issuers between 2012 and 2021, we find that issuers that have interlocks with previous green bond issuers are approximately 20% more likely to issue green bonds. Empirical evidence also suggests a positive association between green, full network size and centrality ranks and the propensity of green bond issuances. The positive effects are robust to alternative endogeneity explanations, different subsamples, and instrumental approaches. Additional analysis shows that green interlocks and centrality positions are positively associated with firm value and negatively related to issuance costs, demonstrating that the issuance of green bonds can be a value-enhancing and cost-efficient practice for issuers with effective networks.

Keywords: Green bonds, Green interlock, Network centrality, Sustainable finance, Corporate social responsibility (CSR)

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1 Introduction

A large body of literature has examined the role of social interactions through firm interlocks in firm policies, and how network ties affect economic outcomes. A typical line of this research emphasizes the information diffusion of social networks, such as firm interlocks, which facilitate the exchange of information and the spread of corporate practices across firms (Bizjak et al., 2009; Chiu et al., 2013; Fracassi, 2017; Omer et al., 2020).

The firm network may be considered a mechanism of information transmission through which value-improving business innovations can spread (Haunschild & Beckman, 1998). Facilitating the issuance of green bonds, which represents a financial innovation, may derive advantages from a channel of communication or exchange of resources among issuers. This includes considerations such as the financial and social value associated with labelling bonds as green, underwriter choices, and other pertinent factors.

The purpose of this study is to provide evidence with respect to the spread of the practice of green bond issuances. We focus on the role that directors', executives', and officials' (government institutions only) connections played in contributing to the spread of green bond practices. We hypothesize that an organization is more likely to start issuing green bonds if the issuer has a director or executive or officer (for government institutions only) who also serves as a director or top executive or official of another organization during the year that the focal organization starting to issue green bonds, or at any point in the preceding five years ('green interlock'). Under the same line of hypotheses, we also expect that the more firm-level ties with previous green bond issuers ('green network') the issuer has, and the more central the organization is, the more likely it is to issue green bonds in the subsequent years.

Specifically, after collecting all green bonds from Bloomberg and Climate Bond Initiatives (CBI), we restrict issuers to those in the European and Northern American regions because of the scope in the BoardEx and BvD Orbis, where we filter the complete organizational composition profiles of 1124 first-time issuers between 2012 and 2021, including 293 public firms beginning in 2013, 584 private firms and 247 government institutions beginning in 2012.

Consistent with our testable hypotheses, we find empirical evidence that firm-level green interlocks, green network, and centrality positions promote the propagation of green bond issuances. The results show that the likelihood of green bond issuances is on average 20.24% higher at firms with green interlocks than at firms without green interlocks. The quintile ranks of issuer green centrality and specific centrality measured by degree, betweenness and eigenvector are positively associated with the propensity of green bond issuances. We also find statistically significant evidence that better-connected issuers with other issuers in our entire sample (measured by the quintile rank of full network connectedness) are more likely to issue green bonds.

Our empirical results of green interlocks can be vulnerable to the endogenous concerns of causal interpretation (Stuart & Yim, 2010). The first endogeneity concern of employee-firm matching argues that the presence of a director or executive or official on two issuers could reflect an underlying similarity between the two issuers, and it could be this similarity that causes both to have an elevated proclivity to issue green bonds. We alleviate this issue by presenting robust results to alternative interlock measures restricted to cross-industry pairings and to cross-country and cross-industry pairings, and controlling for geographic proximity within connected issuers. The second concern is the possibility of reverse causality by which issuers that desire green bond issuances may intentionally recruit employees with green bond issuance experiences (refer to issuer stacking). To address this concern, we control for the presence of migrated employees who joins the focal issuer after their previous issuers have issued green bonds through which they can obtain related experience, as well as the presence of short-tenured connected employees.

Apart from our green interlock measures, network and centrality measures are also vulnerable to the endogeneity concerns, where larger issuers tend to have larger network with a higher propensity of issuing green bonds than smaller issuers. Our composite centrality scores (in baseline specifications) capturing the quintile ranks of centrality positions take the influence of firm size into consideration. The results are consistent when we compute size-adjusted network measures employing the residual approach, utilize different samples (e.g., respective private and public firms), and calculate our firm-level network measures based on either independent non-executive directors only or top executive directors only. Moreover, following Cai et al. (2021) and Fracassi (2017), we estimate a two-stage-least-squares model with the instruments being deaths and sudden departure of directors or executives as exogenous shocks to our network measures and confirm our baseline findings.

Our empirical findings support the interpretation that past experiences that can be transmitted across the links in the firm network contribute to the spread of green bond issuances. To investigate the implications of green connections, in later sections, we examine how firm interlocks and network characteristics affect the financial value and costs associated with green bond issuances. Employing an event window of [-3,+3] and a standard event study approach, we show that firm value are greater for public green bond issuers with green interlocks and higher green centrality, compared to those without green interlocks and lower centrality. This is demonstrated in the difference in average cumulative average returns (CARs) across subsamples split by the presence of green interlocks and based on the top versus bottom quintiles of centrality measures, which is statistically significant at the 5% level or above. We also conduct multivariate regression analysis and document that green interlocks and centrality positions are positively and significantly associated with the firm wealth (measured by CARs) generated by the green bond issuances.

To investigate the impact of green network measures on the issuance costs associated with green bond issuances, we capture issuance costs in two dimensions: yield spreads and gross spreads. Utilizing the public and private firm sample, we document a consistently negative impact of green interlocks, network size and betweenness, and green (full) centrality ranks on the issuance costs across two measures. The magnitude of such effect is stronger for first-time issues than all issues. This implies that green bond investors value green connections of issuers in the role of mitigating information asymmetry.

Our study makes several contributions to the literature. First, we contribute to the growing stream of scholarly studies examining the effects of social network in different areas of finance. A growing body of research (e.g., Cai, 2012; Cohen et al., 2008; Engelberg et al., 2012; Stuart & Yim, 2010) examines the role of firm networks in corporate financial policy. Our findings can show that knowledge and experience gained through director networks also influence firm green bond policy. Firm networks serve as conduits for information that influences green bond policies.

Second, our understanding of the impact of firm networks on the likelihood of green bond issuances adds to the literature on the relation between social networks and CSR activities (e.g., Amin et al., 2020; Nandy et al., 2020). Taking the issuance of green bonds as a typical example of CSR involvement (Tang & Zhang, 2020), our study suggests that spreads of green bond practices can be facilitated by expanding firm-level interlocks and taking more central positions, which can potentially boost firm value and lower costs. We provide evidence that the issuance of green bonds as a CSR policy can be a value-enhancing practice for firms with effective networks.

The paper proceeds as follows. Section 2 provides a review of literature on firm networks and green bond issuances as a part of firm financial policies. Section 3 discusses green (full) interlocks, network, and centrality measures and other data used in the paper. Section 4 presents the empirical results and Section 5 provides various robustness checks. Section 6 and 7 explore possible channels through which green network and centrality benefit issuers. Section 8 concludes.

2 Literature Review

Firms can benefit from interlocks strategically in different dimensions: as an indicator of firm's reputation (Kang, 2008); reducing environmental uncertainty and dependence (Useem, 1984); quicker and easier access to more effective information, especially in cases of M&A and strategic alliances (Haunschild & Beckman, 1998); inter-learning and diffusion of good corporate practices (Palmer et al., 1993). Such statements are well backed by resource-dependence theory (RDT) (Pfeffer, 1972) and social network theory (Freeman, 1978).

2.1 Social networks and financial policies

2.1.1 Firm interlocks and financial policies

The impact of firm interlocks has been demonstrated in the diffusion of numerous financial policies, such as poison pills (Davis, 1991), option backdating (Bizjak et al., 2009), financial reporting behaviour (Chiu et al., 2013), disclosure policy (Cai et al., 2014), R&D investment policy (Helmers et al., 2017), and etc.

The analysis of Stuart & Yim (2010) reports that firm interlocks in the boardroom affect the companies' likelihood of becoming targets in change-of-control transactions. Extending to investment policies, Cai (2012) presents evidence that a common director shared between acquirers and targets contributes to higher announcement returns in M&A transactions.

2.1.2 The impact of firm network on financial policies and CSR

Firm-level network centrality sheds light on the information advantage to the firm. Chang & Wu (2021) find that well-connected boards have a positive effect on innovation activities and quality. Fracassi (2017) finds that the similarity of the capital investment policy between two companies increases with the number of connections these two share with each other. Firms more centrally located in the network have a less idiosyncratic financial policy and hence display greater firm performance.

By employing the centrality measures to capture the well-connectedness of the firm, Amin et al. (2020) and Nandy et al. (2020) both document a positive relation between networks and CSR performances.

2.1.3 Firm network and bond characteristics

A growing stream of research focuses on the impact of firm networks on sources of financing for firms. Benson et al. (2018) and Skousen et al. (2018) suggest a positive relationship between networks and bond credit ratings, proxied as firms' default risks. Chuluun et al. (2014) extend the impact of board ties t to the cost of corporate debt, proxied by the difference between corporate bond yield spread at issuance with matching treasury. Qiu et al. (2019), focusing on unique social ties in China, find similar conclusions that higher centrality regarding top management teams (TMTs) is negatively related to lower bond yield spreads.

2.2 Green bonds

To tackle the climate crisis, green bonds are introduced as an innovative type of debt instruments that differ from conventional bonds only in that the issuer pledges to use the proceeds to finance projects that are supposed to generate favourable environmental outcomes (ICMA, 2021). Against this backdrop, scholarly literature on green bonds is divided into two mainstreams: the implications and the determinants of green bond issuances.

2.2.1 The implications of green bond issuances

The impact of green bond financing can be summarized to superior financial performances (e.g., Flammer, 2021; Tang & Zhang, 2020) in the form of announcement returns on the stock market, operating performances, and increasing institutional ownership, lower costs of issuances (Hyun et al., 2020; Zerbib, 2019), and favorable ESG performances (e.g., Sinha et al., 2021; Wang et al., 2022; Wei et al., 2022).

One strand of the literature focuses on the effects of green bond issues on ex-post company performances. Tang & Zhang (2020) and Flammer (2021) find that corporate green bond issuances are associated with positive stock market reactions which attract an investor clientele that values the long term and the environment. Another stream focuses on the pricing of green bonds. Zerbib (2019) presents evidence that pro-environmental preferences can translate into positive market outcomes in lower yield spreads of green bonds. Hyun et al. (2021) argue that a lower issuance cost captured by yield spreads is only identified for certified green bonds, not for self-labelling green bonds.

2.2.2 The determinants of green bond issuances

A growing number of studies have analysed the roles of bond specific characteristics and issuers' financial features in different regions (e.g., Cicchiello et al., 2022; Lin & Su, 2022), national institutions (e.g., Mertzanis & Tebourbi, 2023), and governance characteristics (e.g., Daubanes et al., 2021; García et al., 2023) in the determination of green bond issuances.

Dutordoir et al. (2022) document that firms with lower costs of disclosure, higher reputational gains from labelling themselves as green, and a stronger focus on innovation are more likely to issue green instead of conventional bonds. García et al. (2023) find suggestive evidence of a positive association between board governance (e.g., a higher percentage of female directors and independent directors) and the likelihood of green bond issuances.

2.3 Hypothesis development

The decision of issuing green bonds is considered not only a financial policy in the choice of financing vehicles, but also a CSR policy (Tang & Zhang, 2020). As firm interlocks and network centrality are demonstrated in prior research to have a positive influence on CSR performances (e.g., Amin et al., 2020) and financial policies (e.g., Omer et al., 2020), we hypothesize that an organization is more likely to start issuing green bonds if the issuer has a director or executive or officer (for government institutions only) who also serves as a director or top executive or official of another organization during the year that the focal organization starting to issue green bonds, or at any point in the preceding five years (referred to green interlock). Under this line of conjecture, we also expect that the more firm-level ties with previous green bond issuers (referred to green network) the organization has, and the more central the organization (referred to green centrality) is, the more likely it is to issue green bonds in the subsequent years.

H1: Issuers with interlocks with previous green bond issuers and higher green centrality are more likely to start to issue green bonds.

3 Data collection, Firm Network Measures and Methodology

3.1 Bond and sample selection

To examine the effect of the new issuers' network with previous green bond issuers on the likelihood of firms beginning to issue green bonds, we match bond issues with corresponding issuer IDs on data sources, including Capital I&Q for financial characteristics, BoardEx for issuer's network and other governance characteristics, Orbis Europe (BvD Orbis) for the supplement of financial and network characteristics, and Thomson Eikon for governance characteristics.

Firstly, after collecting all green bonds issued between 2008 and 2021 from Bloomberg and Climate Bond Initiative (CBI), for each bond issue with available International Securities Identification Number (ISIN), we match each ISIN with their company IDs on Capitial I&Q and Thomson Eikon. For those ISINs unable to match corresponding issuers on other data sources or issuers with missing ISINs, we manually check the specific issuers.

Secondly, to map our issuer network, we obtain detailed information on top key executives and directors on board from BoardEx. Two executives or directors are connected if they serve in the same firm in the same year. BoardEx, compiled by the Management Diagnostics Limited, works as the leading database on the firm composition for over 28,000 publicly listed and large private firms, and it provides a list of all current and past board positions and current and past employers, with specific information on job description and dates started in the organization and in the current role. Nevertheless, we admit its coverage is more comprehensive for European and Northern American companies, lower for companies in other regions. [3] We therefore limit our green bond sample to European and Northern American issuers. The initial bond sample matches filter 1323 unique issuers based on ISIN and name matches between CBI and Bloomberg where 1181 and 779 unique issuers are identified, respectively. We match tickers for publicly listed firms and equity primary issue ISINs for private firms, and for the issuers with missing identifiers, by implementing the Levenshtein algorithm on Python following Engelberg et al. (2013), we match the company name with the BoardEx most recent name and also hand-search issuer names provided by Bloomberg or CBI or have

[3] Fernandes et al. (2013) use BoardEx data to primarily compare the U.S., European and Canadian companies in their sample.

matched by Capital I&Q on the BoardEx website. [4] We focus on past directors and top-key-executive-level positions because midlevel management are less involved in the overall corporate finance policy decision-making policy (Fracassi, 2017). We also supplemented company composition of European companies with the Orbis Europe database (BvD Orbis). [5] We further identified 138 issuers on BvD orbis by matching their ISINs and Legal Entity Identifiers (LEIs). The final sample includes 1124 unique issuers. [6]

3.2 Measures characterizing issuer interlocks and networks

In this section, we describe our interlock and centrality measures characterizing issuer network measures as well as financial and governance characteristics.

3.2.1 Green interlock and network

To define our interlocking relations between previous issuers and new green bond issuers, we follow Stuart & Yim's (2010) approach to code $GREEN\ INTERLOCK_{i,t}$ for issuer j at year t. Specifically, before moving forward to the next issuer-year observation, we check whether the focal issuer j shares a director with a previous green bond issuer i at year t, t-1, t-2, t-3, t-4. If yes, then $GREEN\ INTERLOCK_{j,t} = 1$ and if no, $GREEN\ INTERLOCK_{j,t} = 0$. We employ a multi-year moving window as in Stuart & Yim (2010) because we also assume that directors carry their previous learning, experience, and contacts with them to the boards on which they currently and subsequently serve and, therefore, the connections in the network need not be contemporaneous to exert influence.

[4] Some issuers can be manually found on BoardEx, but it includes very few employees and also has no start and end dates in their roles. For example, Portland Water District, as a US private firm, has its company profile on BoardEx website, but it only provides one employee's name, age and gender without the role descriptions and employment history available. We drop such issuers as their inclusion may result in selection bias in the database coverage underestimating the network measures.

[5] The Oribis Europe database is compiled by the Bureau van Dijk Electronic Publishing (BvD), which covers over 50 million companies in European countries, of which 99% are private companies. We employ the employee-name-matching algorithm (Falato et al., 2014) based on each employee's last and first name and middle initial to remove duplicate appearances on both BoardEx and BvD Orbis.

[6] Despite the first green bond was issued in late 2008 by World Bank, we specify the sample period as 2012-2021 as there are a handful of issues in the starting phase and most of them are issued by supranational organizations. Spanning our sample period, we consider supranational organizations when calculating the directors' or executives' concurrent professional network with previous green bond issuers.

In a similar manner, we also consider a discrete green network variable $GREENET_{j,t}$, taking the natural logarithm of 1 plus the total number of firm-level ties of an issuer j with previous green bond issuers already issuing green bonds in prior years over the period between t-4 and t. $GREENET_{j,t}$, as a directed network measure, allows us to count the number of ingoing connections in which the new green bond issuer is invited to issue green bonds.

[Insert Figure 1 here]

Figure 1 presents an illustrative example and description of how green interlocks are characterized and how we create our green interlock and network variables. The network example in 2021 consists of six issuers (Swedbank, Klovern, Landesbank Baden-Wuerttemberg, NCC Treasury AB, Landshypotek Bank, and Credit Suisse AG) connected with Alandsbanken Abp at the centre node. The inner direction of arrows indicate that these six issuers, who issued green bonds prior to 2021 and are thus previous green bond issuers relative to Alandsbanken Abp, transfer information with respect to green bond issuances through shared directors or executives. We calculate the $GREEN\ INTERLOCK$ of Alandsbanken Abp in 2021 as 1 and the $GREENET$ as 6.

3.2.2 Green network centrality and full network centrality

Firm-level network centrality sheds light on the information advantage to the firm. Several centrality concepts in the Social Network Analysis (SNA) literature capture different aspects of social and economic networks. Apart from $GREENET_{j,t}$, we make use of three centrality measures (Degree, Betweenness, and Eigenvector) measured in both the green network composed of previous green bond issuers over the last five-year period ($GREEN\ DEGREE_{j,t}, GREEN\ BETWEEN_{j,t}, GREEN\ EIGEN_{j,t}$) and composed of all issuers in our entire sample at year t ($ALLNET_{j,t},\ ALL\ BETWEEN_{j,t},\ ALL\ EIGEN_{j,t}$). The underlying concept is that the higher the number of connections an issuer has with previous green bond issuers or with other issuers in our sample, the more centrally located it is.

To compute the centrality measures each year, we first need to construct an adjacency matrix, which is an N × N matrix (in which N is the number of issuers in the network at year t). Take the green network as an example, each cell in the matrix takes a value of one if two issuers have been interlocked through common directors or executives or officials (for government institutions only) over the considered five-year period. In the case of directed networks $GREENET_{j,t}$, it matters whether another issuer i has influenced the focal issuer j into green bond issuances. In this sense, each cell in the adjacency matrix takes a value of one only if issuer i has influenced issuer j to participate in green bond issuances (i.e., $x_{i,j} = 0$ and $x_{j,i} = 1$). By contrast, centrality measures, as undirected networks, do not consider the information with respect to which green bond issuer is the lead. Thus, at year t, if issuers j and i both have participated in green bond issuances for the first time at any point in the preceding five years, it follows that $x_{j,i} = x_{i,j} = 1$. Degree, Betweenness, and Eigenvector use only undirected networks.

Degree centrality is the most intuitive and straightforward centrality measure. It counts the total direct number of connections that an issuer has within the specified network. We calculate two measures of degree centrality based on different scopes of network - $\text{GREEN DEGREE}_{j,t}$ and $\text{ALLNET}_{j,t}$. The formula is as below:

$$\text{GREEN DEGREE}_{j,t} \text{ or } \text{ALLNET}_{j,t} = \sum_{j \neq i} x_{j,i} \qquad \text{Eq.[1]}$$

Where $\text{GREEN DEGREE}_{j,t}$ calculates the number of links between t-4 and t with issuers that have already issued green bonds. [7] And $ALLNET_{j,t}$ calculates the number of direct links an issuer has to its adjacent issuers available in our full sample at year t, not just to issuers already issuing green bonds in previous years. For a given issuer j at year t, we take the natural logarithm of 1 plus the total number of issuer links. Analogous to $GREEN\ INTERLOCK_{j,t}$ but measured within the entire sample, we calculate another interlock measure, $FULLINTERLOCK_{j,t}$, measured as an indicator variable taking on a value of one if the issuer j has any links to any other organization(s) in our full sample at time t, and zero otherwise. This is a general measure of a firm's connectedness in the firm interlock network.

If an issuer has high degree centrality but most of its connections who are not well connected, then the power exercised by the issuer over the network is somewhat limited. If the issuer is tied to other issuers who themselves are well connected (more central), this issuer has a greater influence in the network. This concept is captured by the Eigenvector centrality (Bonacich, 1987), which is a variation of Degree centrality in which connections are weighted by their relative importance in the network. In other words, Eigenvector does not simply count the number of ties that an issuer has, but it weighs each connection by its centrality. A higher Eigenvector measure indicates that an issuer could be able

[7] Despite its frequent use in the measurement of the size of the whole network, $GREEN\ DEGREE_{j,t}$ does not provide more information than $GREENET_{j,t}$ concerning the central position of the issuer in the network, and empirically, $GREEN\ DEGREE_{j,t,}$ and $GREENET_{j,t}$ generate similar results. For the sake of brevity, we do not report $GREEN\ DEGREE_{j,t,}$ in analysis.

to disseminate and extract information more efficiently as the information flows through other issuers that are more central and informed.

$$GREEN\ EIGEN_{j,t}\ or\ ALL\ EIGEN_{j,t} = \lambda \sum_{i=1}^{N} x_{j,i} e_i \quad \text{Eq.[2]}$$

Where λ is a constant represented by the biggest eigen-value of the adjacency matrix and e is the eigenvector centrality score.

Betweenness centrality (Freeman, 1977) is measured as the shortest connections through which two issuers are connected and estimating the number of shortest paths passing through the issuer j. It evaluates the positioning advantage of an issuer in the entire network. Given the total number of possible paths between two other issuers, the higher the number of cases in which the shortest path passes through a given issuer, the higher is that issuer's betweenness. Betweenness centrality of issuer j is the sum of its betweenness ratios that defined as the number of geodesic paths from issuer i to issuer k passing through issuer j, divided by the number of geodesic paths from i to k. Formally, Betweenness for issuer j at year t is

$$GREEN\ BETWEEN_{j,t}\ or\ ALL\ BETWEEN_{j,t} = \sum_{i<k} {p_{jik}}/{p_{ik}} \quad \text{Eq.[3]}$$

Where the $GREEN\ BETWEEN_{j,t}$ is measured over the period of t-4 and t within the network of previous green bond issuers that have already issued green bonds in prior years. $ALL\ BETWEEN_{j,t}$ is measured at year t within the network of all issuers available in our entire sample.

3.2.3 Composite network

To make two categories of network centralities comparable over time, following the approach described in Larcker et al. (2013), the sample is divided into five quintiles based on AT (proxy for firm size) each year and then firms are sorted within each AT quintile into quintiles according to each of the three types of centralities. Formally, two composite network scores (ranging from 1 to 5) for each organization are computed as below:

$$\text{GREENSCORE}_{i,t} = \text{Quint}\ [\tfrac{1}{3}\ \{\text{Quint}\left(\text{GREEN DEGREE}_{i,t}\right) + \text{Quint}\left(\text{GREEN EIGEN}_{i,t}\right) + \text{Quint}\ (\text{GREEN BETWEEN}_{i,t})\}] \quad \text{Eq.[4]}$$

$$\text{ALL NSCORE}_{i,t} = \text{Quint}\ [\tfrac{1}{3}\ \{\text{Quint}\left(\text{ALLNET}_{i,t}\right) + \text{Quint}\left(\text{ALL EIGEN}_{i,t}\right) + \text{Quint}\ (\text{ALL BETWEEN}_{i,t})\}] \quad \text{Eq.[5]}$$

3.3 Financial and governance characteristics

We use Capital I&Q to identify green bond issuers' company types. In total, we have 247 government institutions, 584 private firms and 293 public firms. As government institutions, private and public firms are all main categories of green bond issuers, varying in terms of operational purposes and profit nature, the sample size in each analysis varies depending on the scope of the sample we examine and model specification we use.

[Insert Table 1 here]

Some firms issue green bonds for more than one year. These observations are removed from the sample after the initial year of green bond issuances to avoid multiple counting of green issues. Table 1 provides summary statistics between 2012 and 2021 for two subsamples of issuers – new green bond issuers identified each year (Panel A) and issuers have not issued green bonds (and will issue green bonds during our sample period) (Panel B), categorized by government institutions (GOV), private firms (PRIVATE), and public firms (PUBLIC). [8] In each year, more private firms become new green bond issuers than government institutions and public firms, which imply that private institutions play important roles in the green bond market. Table 1, Panel A and B also report the percentage (%Links) and average number of links (Avg links) to other firms in our entire sample, and the percentage (%Green links) and average number of links to other firms in our sample that have issued green bonds in previous years (Avg green links). The %Links and Avg links are similar between two subsamples across company types, but compared with non-green-issuers, a higher percentage of new green bond issuers have connections with previous green bond issuers and the average number of green links is higher in the new green issuer sample. For example, 17.78% of government institutions, 53.77% of private firms and 81.82% of public firms as new green bond issuers are linked through green interlocks to previous green bond issuers in 2020 compared to 16.07% (GOV), 44.32% (PRIVATE) and 67.65% (PUBLIC) of non-green-bond issuers. Similarly, new issuers of GOV, PRIVATE and PUBLIC have respectively 0.29, 2.93 and 4.98 firm links on average to previous issuers in 2020, compared to 0.25, 2.12, and 2.29 firm links for non-green-bond issuers. Moreover, we observe that there is a higher percentage of public firms having links with previous green bond issuers and demonstrating a higher average number of green links than the other two company types.

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[8] Despite that our full green bond sample starts in 2008, when the World Bank issued the first green bond, we follow Bizjak et al's (2009) approach to identify the subsequent year when a firm is identified as a new green bond issuer. It is noteworthy, however, there was only a handful of green bond issues before 2012, and initially mostly issued by municipalities and governments, therefore, our government and private firm sample of new green bond issuers begins in 2012 and public firm sample begins in 2013, marking the first public corporate green bond in the market. Spanning the period between 2008 and 2011, 3 government institutions and 7 private firms issue green bonds.

Overall, this is consistent with the notion that firm interlocks playing a role in the spread of green bond issuances.

We collect the private and public firm financial data are from Capital I&Q, which is also used by Acharya & Xu (2017) and Shive & Forster (2020) in their studies of the U.S. public and private firms. For the missing financial characteristics in European private firms, we use BvD Orbis to fill the gap, which is also used by Wang et al. (2015). *AT* is measured as the natural logarithm of total assets. Firm profitability (*ROA*) is captured by net income divided by total assets. We use interest-bearing debt divided by total assets to measure firm leverage (*LEV*). For public firms only, *MTB* is computed as market value over the book value of total assets, where market value of total assets is book value of total assets plus market value of common stock minus book value of common stock. *TANGIBILITY* is measured as net property, plant and equipment (PP&E) scaled by total assets and *FIRM AGE* is the number of years since the firm is founded. We also measure *DEBT MATURITY* as the ratio of long-term debt over total debt to examine the issuers' rollover risks.

Since private firms have limited coverage in terms of governance characteristics and are different in governance structures and regulations to publicly listed firms, we include governance characteristics as controls using private and public firm distinct subsamples for which we have complete data. We employ *BOARD SIZE* as the total number of directors on board and *%INDEP* as the ratio of independent directors over total number of directors on board to control for board characteristics that are proxies for the strength of monitoring by the board in prior literature. We also control for CEO power using *CEO TENURE*, defined as the total years that CEO serves in this role. For public firms only, *%INST* is measured as the percentage of institutional ownership.

[Insert Table 2 here]

Panel C, Table 1 presents the summary statistics of network and financial characteristics for all organizations available in our entire sample, and three distinct categories of organizations - government institutions, public firms, and private firms. On average, issuers have 0.933 firm green links with previous green bond issuers. Government institutions, public firms and private firms have respectively 0.105, 1.406, and 0.967 green links on average.

Table 2 shows the number of non-green-bond issuer-year observations (Non-Green) and the number of green bond issuers (Green) by country and industry in the private and public firm sample, where industries are categorized in terms of their one-digit SIC sector. [9] The number of green bond issuers from the United States is the largest for both private firms (74) and public firms (47), followed by Sweden (56 private and 40 public firms). With respect to industry distributions, there are the largest number of green bond issuers from finance, insurance, and real estate industry, 296 private issuers and 150 public issuers. By contrast, the Agriculture, Forestry and Fishing industry has the smallest number of private (3) and public green bond issuers (1).

3.4 Multiperiod logit models

To identify factors that contribute to the spread of green bond issuances over time, we employ multiperiod logit regressions, which are also applied by prior studies in examining the impact of firm interlock on the adoption of certain financial policies (e.g., Bizjak et al., 2009; Cai et al., 2014). The dependent variable is equal to one for firm-year observations in which the firm initially issues green bonds. After a firm is identified as new green bond issuer, it is dropped from the sample in subsequent years. Our sample consists of 8793 issuer-year observations between 2012 and 2021 from 1124 unique issuers. We include year, geographical region and company type dummy variables in the full sample regressions. [10] For regressions employing the firm sample excluding government institutions, the industry (one-digit SIC) dummy variables are also included.

$$\text{Green }(0/1)_{j,t} = \beta_0 + \beta_1 \text{Interlock and network measures} + \beta_2 \text{ Firm Controls}_{j,t} + \text{Region Dummies} + \text{Company Type Dummies} + \text{Year Dummies} + (\text{Industry Dummies}) + \varepsilon_{jt} \qquad \text{Eq.[6]}$$

$$\text{Green }(0/1)_{j,t} = \beta_0 + \beta_1 \text{ Centrality measures} + \beta_2 \text{ Firm Controls}_{j,t} + \text{Region Dummies} + \text{Company Type Dummies} + \text{Year Dummies} + (\text{Industry Dummies}) + \varepsilon_{jt} \qquad \text{Eq.[7]}$$

In Eq.(1), interlock and network measures include $GREEN\ INTERLOCK_{j,t}$, $GREENET_{j,t}$, $ALLNET_{j,t}$ and $FULL\ INTERLOCK_{j,t}$ (see definitions in Section 3.2). ε_{it} is a random error term.

In Eq.(2), centrality measures include two composite network measures and three undirected network measures: Degree, Eigenvectors (Bonacich, 1972), and Betweenness (Freeman, 1977), measured

[9] The number of private and public green bond issuers is different from that of Table 1 in the availability of SIC data.
[10] We follow Russo et al. (2021) to control for geographical region effect in the research of the determinants of green bond issuances. Our geographical regions include: Northern America, Western Europe, Northern Europe, Eastern Europe, and Southern Europe.

within the network composed of previous green bond issuers over the last five-year period ($GREEN\ DEGREE_{j,t}, GREEN\ BETWEEN_{j,t}, GREEN\ EIGEN_{j,t}$) or within all issuers at year t ($ALLNET_{j,t},\ ALL\ BETWEEN_{j,t},\ ALL\ EIGEN_{j,t}$) in our full sample (See Section 3.2 for more details). ε_{it} is a random error term.

4 Empirical results

4.1 Interlock, network and the propensity of green bond issuances

Table 3 presents the results of logit regressions of green interlock (*GREEN INTERLOCK*), network (*GREENET*), full network (*ALLNET*) and interlock (*FULL INTERLOCK*) on the propensity of green bond issuances. Panel A, Table 3 employs the full sample with all organizations (government institutions, private firms and public firms). The significant and positive coefficient of *GREEN INTERLOCK* indicates that the likelihood that an issuer starts to issue green bonds is significantly and positively associated with the issuer having a director or executive or official (government institutions only) who also serves on an issuer that has previously issued green bonds. Moreover, the significantly positive coefficient of *GREENET* suggests the more connections with previous green bond issuers, the higher propensity that an issuer starts to issue green bonds. The results are robust to employing the public and private firm sample (excluding government institutions) with available financial control variables in Panel B, Table 3. [11] An issuer that is connected to an issuer within four years of when the issuer starts to issue green bonds has a higher propensity of starting to issue green bonds.

[Insert Table 3 here]

This effect is not only statistically significant, but also economically significant. We report the marginal effects of key variables in the table. Table 3, Column 1 reports the marginal effect of *GREEN INTERLOCK* is 0.1393, suggesting that an issuer link to a previous green bond issuer improves the issuer's likelihood of 13.93% of becoming a new green bond issuer. Employing the firm sample in Column 5, the results show that having a connection to previous green bond issuers for firms is 20.24% more likely to issue green bonds. Likewise, as evidenced by *GREENET* in Column 6, issuers with one more link with prior green bond issuers are estimated to have a 19.67% increase in the likelihood of becoming a new green bond issuer. The magnitude of the effect of *GREEN INTERLOCK* is larger

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[11] Our correlation matrix provided in the Table IA.1 and unreported VIF values less than 10 for each regression suggest that multicollinearity is not a major concern in our study. Results available in the Table IA.2 are also consistent when we utilize the sample of government institutions to replicate the baseline regressions.

than that of *GREENET*, implying that establishing the first green link is more effective than add one link to pre-existing ones in turning issuers to be green.

Table 3 also presents the results of the impact of *ALLNET* and *FULL INTERLOCK* measured within the entire sample on the propensity of green bond issuances. Despite of statistically significant and positive coefficients at the 1% and 5% level, respectively, as shown in Columns 3-4, the results are sensitive to controlling for firm financial characteristics when employing the firm sample – in Columns 7-8, *ALLNET* and *FULL INTERLOCK* are no longer statistically significant. Consistent with previous research, large and younger firms with higher leverage are more likely to start to issue green bonds.

[Insert Table 4 here]

4.2 Network centrality and the propensity of green bond issuances

Table 4 presents the results of two composite network measures and four centrality measures using the full sample of all organizations (Columns 1-6) and subset of the public and private firms (Columns 7-12). Firm green centrality is measured by composite network score in Columns 1 and 7, betweenness in Columns 3 and 9, and eigenvector in Columns 5 and 11. In a similar manner, firm full network centrality is measured by composite network score in Columns 2 and 8, betweenness in Columns 4 and 10, and eigenvector in Columns 6 and 12. Nearly all green and full centrality measures are robust to controlling for financial characteristics, except from *ALL BETWEEN*. The statistically significant results of two composite network measures in the firm sample suggest that an increase in the quintile rank of the green (or full) network centrality leads to a higher likelihood of 2.57% (or 1.64%) of becoming a green bond issuer. This is consistent with that issuers with higher-centrality positions either within previous green bond issuers or within our entire sample of all available issuers tend to be more inclined to start to issue green bonds.

Even after controlling for the financial determinants, the coefficients on green interlock and network measures - *GREEN INTERLOCK*, *GREENET, GREEN SCORE, GREEN BETWEEN* and *GREEN EIGEN* remain positive and significant. However, for the firm sample, governance characteristics are also found to be associated with the likelihood of green bond issuances (i.e., García et al., 2023). In Table 5 and 6, we control for the additional impact of board and governance characteristics on the likelihood of green bond issuances. We consider *BOARD SIZE*, *%INDEP*, *CEO TENURE* as common governance measures for respective subsets of public and private firms and %INST for public firms.

We observe in Table 5 that *BOARD SIZE* is significantly and negatively associated with the propensity of private firms' green bond issuances, but such association is insignificant in public firms, where *%INST* demonstrates a negative association at the 5% level.

[Insert Table 5 here]

Public and private firm subsamples observe a similar effect of *GREEN INTERLOCK* of approximately 3% on the propensity of green bond issuances. An increase in *GREENET* for public (private) firms is associated with an increase of 0.78% (2.69%) in the likelihood of green bond issuances. Establishing any of connections with issuers in our entire sample (*FULL INTERLOCK*) appears to have no significant effect in both firm subsets, but having one more connection for public firms is estimated to be 0.97% more likely to issue green bonds.

[Insert Table 6 here]

An increase in the quintile rank of public (private) firm green centrality is associated with 1% (0.54%) increase in the propensity of green bond issuances. In contrast, we do not find a statistically significant impact of firm full centrality on the likelihood of green bond issuances.

5 Robustness checks

5.1 Employee-firm matching

Our findings thus far show a consistently positive effect of green interlocks and network on the propensity of green bond issuances. Directors or executives or officials carry their experience of green bond issuances to the current issuers they serve on, and their knowledge influences the green bond issuance decisions at other issuers they join. This causal interpretation, however, may be under attack from potential endogeneity concerns. One concern is endogenous employee-firm matching, as the presence of a common director or executive or official on two issuers could reflect an underlying similarity between the two issuers, and it could be this commonality that causes each to have an elevated propensity to issue green bonds. For example, issuers in the same industry, from the same country, or geographically close are likely to have interlocked executives or directors, and they are also likely to decide to issue green bonds. In this section, we attempt to rule out endogenous employee-firm matching as an alternative explanation.

First, in Panel A, Table 7 employing the firm sample, we measure *GREEN INTERLOCK* over a five-year window based on whether the issuer shares a director or executive with a previous green bond issuer from a different industry in Column (1) and from a different industry and country in Column

(2). We continue to find a positive and significant relation between *GREEN INTERLOCK* and the likelihood of green bond issuances even limiting the interlocks to cross-industry pairings and to cross-country and cross-industry pairings.

Second, social interactions among executives and board members are likely to be facilitated by being in the same geographic neighborhood. Geographically close issuers tend to have the same directors or executives and such issuers thus share similar likelihoods of green bond issuances. It is likely that the likelihood of issuing green bonds increases if the person held at least one position at a geographically proximate issuer that have previously issued green bonds. To address this concern, we follow Stuart & Yim's (2010) approach to construct a geographic proximity variable (Proximity) by capturing each issuer's proximity in each year to each of connected previous green bond issuer. [12] To compute the distance between each pair of connected issuers, we obtain the location of the headquarters of 1076 issuers in our sample in the form of latitude and longitude data from Thomson Eikon. The distance between locations is estimated using the haversine formula. [13] In Column (3), we do not find evidence of geographic clustering in green bond issuances as the Proximity variable that we control for is statistically insignificant. An increase in *GREEN INTERLOCK* continues to increase the predicted propensity of 12.27% of becoming a new green bond issuer.

[Insert Table 7 here]

5.2 Issuer stacking

Another explanation for our findings in terms of *GREEN INTERLOCK* may be that an issuer planning to issue green bonds may actively appoint employees who serve on the issuers that have previously issued green bonds. This issuer stacking effect could reflect a reverse causal process by which management teams that desire green bond issuances recruit employees with green bond issuance experiences to their organization. To address this concern, we follow Stuart & Yim (2010) to examine the impact of migrated directors. Consider the scenarios in Fig.2, Issuers A, B and C are connected through employee x, and Issuer A, is the first to issue green bonds. Green arrows refer to the tenure

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[12] The Proximity variable for firm j at year t is defined as $\sum_{i \neq j} 1/1 + d(i,j)$, where j is the issuer that starts to issue green bonds in a given year t and d(i,j) is the physical distance between issuers i and j. After weighting the contribution of each connected issuer i that has previously issued green bonds, we can then sum all weighted contributions across all issuers i, which produces a distance-weighted measure of the proximity of all green bond issuance activities to each focal issuer j.

[13] The haversine formula gives great-circle distances between two points on a sphere. The distance between locations j and i is calculated as $d_{ji} = R \times 2 \times \arcsin\left(\min\left(1, sqrt(a)\right)\right)$, where R is the earth's radius (approximately 6371 kilometres), $a = (\sin(dlat/2))^2 + \cos(lat_j) \times \cos(lat_i) \times (\sin(dlon/2))^2$. In this expression, $dlat = lat_i - lat_j$ and $dlon = lon_i - lon_j$. Lat_j and lon_j (Lat_i and lon_i) are the latitudes and longitudes of $location_j$ and $location_i$, respectively.

of employee service in each of three issuers, and green diamonds refer to the years for which issuers B and C have green interlocks because of the employee's green bond experience in Issuer A. Issuer B and C represent the cases of existing employees and migrated employees, respectively. For Issuer B, employee x serves on his/her position before Issuer A starts to issue green bonds. However, in Issuer C, employee x joins his/her position after Issuer A has issued green bonds through which employee x can obtain related experience. We refer to this type of employee in Issuer C as migrated employees. Issuers that desire for green bond issuances may intentionally recruit migrated employees who have specialized experience and knowledge in this field. To alleviate this reverse causality concern, we create a dummy variable, Migrated, which assigns the value of one if the issuer has at least one migrated director or executive who joins the issuer after the connected issuer has issued green bonds, and zero otherwise. We find that 1263 issuer-year observations, less than one quarter of our sample are associated with migrated employees. Column (4) of Panel A, Table 7 shows that migrated employees are not significantly less likely to issue green bonds, not supporting the notion that issuers stack up employees with previous green bond issuance experience to prepare for issuing green bonds. It is noted, moreover, the marginal effect of *GREEN INTERLOCK* remains positive and significant at the 1% level, and the magnitude of 20.22% is similar to that in the baseline regression in Column (5) of Panel B, Table 3, implying that the alternative explanation of issuer stacking alone cannot fully explain the positive effect of green interlock on the decision of green bond issuances.

[Insert Figure 2 here]

Second, we tend to believe that interlocking directors or executives with a short tenure in the previous issuers are more likely to be appointed for the sole purpose of issuing green bonds. Thus, we assume that the issuer stacking effect is likely to come from recently appointed employees. In Column (5) of Table 7, we include an interaction term of *GREEN INTERLOCK* with a dummy variable, Tenure less than three years, which assigns the value of one if any of interlocked employees has a tenure of less than three years, and zero otherwise. Employing 1182 issuer-year observations with such short-tenured employees, the findings suggest that although interlocked employees with a service of less than three years are less likely to issue green bonds, the effect is not statistically significant. More importantly, the marginal effect of *GREEN INTERLOCK* continues to be significantly positive, indicating that issuer stacking is not a serious concern in our study.

5.3 Size-adjusted firm network measures

It is commonly acknowledged in literature that board characteristics may not randomly selected variables. Some omitted variables may otherwise determine both board characteristics and the green bond issuance decision. For instance, greater network centrality exists with larger companies that may be related to the proclivity of green bond issuances. One problematic feature of our *GREENET*, *ALLNET* and other network centrality measures is that larger firms tend to have a larger group of top management team with a larger network. To separate the effects of firm size and board network on the likelihood of green bond issuances, we follow Larcker et al.'s (2013) approaches to take the residual from cross-sectional regressions of respective *GREENET*, *ALLNET*, *GREEN BETWEEN*, *ALL BETWEEN*, *GREEN EIGEN* and *ALL EIGEN* on the log of firm size (AT) and the square of AT. [14]

Panel B, Table 7 reports the coefficients of size-adjusted network measures for the public and private firm sample. We confirm our main findings are unchanged when using the *RESID GREENET* and *RESID ALLNET* in Columns (1) and (2). For instance, according to the marginal effect of *RESID GREENET,* a point increase is associated with an increase of 19.64% in the likelihood of green bond issuances, resembling to 19.67% reported in the baseline specification in Column (6), Table 3. Issuer green centrality measured by *RESID GREENBETWEEN* and *RESID GREENEIGEN* are consistently positive and statistically significant at the 1% level, and the magnitudes of the marginal effects (3.90% and 1.33) resemble those in the baseline regressions. Issuer full centrality measures - *RESID ALLNET*, *RESID ALLBETWEEN* and *RESID ALLEIGEN*, become insignificant after controlling for financial characteristics in the public and private firm sample, similar to the baseline findings (in Table 3 and 4).

[Insert Table 8 here]

5.4 IV-2SLS estimation

To further address endogeneity concerns in our study, we construct instrumental variables in direct relation to the decreases in connectedness due to director or executive retirements and sudden departures, which are not directly related to green bond issuance decisions. Following Cai et al. (2021)

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[14] We also follow Larcker et al.'s (2013) approaches to rank all firms each into quintiles based on AT and then sort firms within each AT quintile into quintiles based on *GREENET*, *ALLNET* and all green centrality and full centrality measures. In Section 3.2.3, we construct two composite network measures (*GREEN SCORE* and *ALL NSCORE*) based on this quintile approach and report the results in Columns 1-2 and 7-8 of Table 4. Moreover, in the Appendix, Table IA.3 shows consistent results for each of quintile centrality measures.

and Fracassi (2017), we consider retirements (*RETIRE*) as a departure at the age of seventy or older and sudden departures (*SUDDEN*) as a departure followed by departures from all other positions within two years.[15] As exogenous shocks, the retirements and sudden departure may allow us to estimate how firm network changes influence the likelihood of green bond issuances.

We define *RETIRE* as an indicator variable taking on a value of one if a director or top executive connected with previous green bond issuers retire at the age of seventy or older, and *SUDDEN* as an indicator variable taking on a value of one if a director or top executive connected with previous green bond issuers depart from their positions followed by departures from all other positions. We assume these two variables would lower green network. In our sample, we collect 301 retirements and 42 sudden departures of directors and executives.

Table 8 reports the regression results of the two-stage-least-squares instrumental estimator (2SLS-IV). Panel A presents the first-stage regression results for the public and private firm sample with each interlock and network centrality measure as dependent variables and *RETIRE* and *SUDDEN* as main independent variables. The coefficients of *RETIRE* and *SUDDEN* are negative and significant at the 10% level, suggesting that the unexpected departure of directors or executives due to their retirement or other unexpected reasons lowers the connections for the focal issuer. Panel B displays the second-stage regression results, where we regress *GREEN ISSUE* on fitted values of each interlock and centrality measure estimated from the first-stage regressions. All the columns indicate a positive and significant effect of interlock or centrality on the likelihood of green bond issuances at the 10% level or above. Therefore, our results are consistent when employing the 2SLS-IV estimator. We also provide evidence on the Wald F-test statistics, Wu-Hausman test and Sargan test to be indicative of the validity of our instruments. Specifically, the statistically insignificant p-values of Wu-Hausman test indicate that we cannot reject the instrumental variable estimator is consistent and we cannot reject the over-identifying restrictions of our second-stage models because p-values of the Sargan test are statistically insignificant, implying that our instruments are distributed independently of each of our independent variables.

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[15] The data on directors' or executives' departure from their current companies is collected from BoardEx Announcement profiles.

[Insert Table 9 here]

5.5 Green network split by independent directors and top key executives

In our main analysis, we aggregate the director- or executive-level connections to the firm-level. For example, the unique number of links to other distinctive previous green bond issuers are counted for *GREENET* instead of calculating how many connections are available for a single pair of issuer links. Nevertheless, it remains a question whether connections through independent non-executive directors and executives play a different role in the facilitation of green bond issuances because their roles and responsibilities are considered to be different - Independent non-executive directors carry out monitoring and advisory responsibilities while executives are in charge of day-to-day operations and management.

To analyse their separate roles in the decision of green bond issuances, two subsets of network samples are constructed connected through independent non-executive directors and through executives, respectively, in examining the effect of green interlock and network centrality on the propensity of green bond issuances. Panel A reports the results for *GREEN INTERLOCK* and *GREENET*, where a higher marginal effect of executive *GREEN INTERLOCK* (21.25%) is identified than that of independent directors (20.65%), but once firms have established green connections with previous green bond issuers, the accumulative effect of *GREENET* appears to be larger for independent directors' connections (21.31%) on the likelihood of green bond issuances, compared to executives (18.89%). This implies that establishing green connections through executives is more effective in improving the likelihood of green bond issuances, and adding one more green connection to pre-existing ones is more valuable for independent directors. For the sake of brevity, we do not report *ALLNET* and *FULL INTERLOCK*, which are statistically insignificant after controlling for financial characteristics, as in baseline specifications.

With respect to green centrality and full centrality measures, we find that issuers with a higher quintile rank in both green centrality and full centrality connected through independent directors are respectively 6.68% and 2.95% more likely to issue green bonds, relative to 6.2% and 2.09% for the centrality network connected through executives. Other specific green centrality measures comparing independent directors and executives are similar in the magnitude of the effect, for example, an increase in *GREEN BETWEEN* both displays an increase of 3.9% in the likelihood of green bond issuances. Only *ALL BETWEEN* measured within independent directors among break-down firm full centrality measures displays significance at the 5% level.

6 Issuer Network, Green Bond Issuances, and Firm Value

6.1 Cumulative abnormal returns (CARs)

In this section, we report results from an event study analysis that tests whether green interlock, centrality and full network centrality measures boosts the firm value created by the issuance of green bonds. That is, we examine the stock market reaction towards announcements of green bonds and how the stock reactions vary based on the type of interlocked connection and the degree of various network measures. As stock data is only available for public firms, this analysis is limited to public firms.

Following Tang & Zhang (2020), we restrict bond issuers that have at least 300 trading days of returns data prior to announcement dates and 50 trading days after the announcement. [16] We employ the capital asset pricing model (CAPM) and standard event study methodology using an estimation window of 250 trading days, daily abnormal returns (ARs) in Eq. [9] are obtained by subtracting estimated returns on day t for issuer j with parameters estimated in Eq. [8] from the actual stock return on day t for issuer j.

$$R_{j,t} - r_f = \mu_j + \beta_j \left(R_{m,j,t} - r_f\right) + \varepsilon_{j,t} \quad \text{Eq. [8]}$$

$$AR_{j,t} = R_{j,t} - \hat{R}_{j,t} \quad \text{Eq. [9]}$$

Where $\left(R_{m,j,t} - r_f\right)$, as the market premium, is the difference between market return ($R_{m,t}$) and 10-year Treasury bond yield (r_f) for stock j in date t, and ($R_{j,t} - r_f$) is the stock return premium. $R_{m,j,t}$ is the market return, proxied by the market return data on which the firm's stock is listed, collected from Datastream. $\hat{R}_{j,t}$ is the estimated stock return in Eq. [8] for issuer j on day t.

[Insert Table 10 here]

We report results for the [-3,+3] event window, relative to actual dates of green bond issuance announcements (in days), where t=0 on the day of the announcement. [17] We investigate the drivers of the green bond issuance effect on firm wealth from the perspective of network, by reporting results

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[16] The announcement dates for green bonds are collected from Bloomberg, and we search on Thomson Eikon and the issuer company's websites to fill the gap in any missing announcement dates, followed by Tang & Zhang (2020).
[17] Unreported results using alternative event windows such as [-5,+5] produce similar results.

by various measures of the degree of green interlock, network and full centrality measures. The first four measures we consider include *GREEN INTERLOCK*, *GREENET* and *FULL INTERLOCK*. When we split the sample based on whether the issuer has *GREEN INTERLOCK* (*FULL INTERLOCK*), we find an average market reaction of 0.1387% (0.1355%) for issuers with a green (full) interlock, and -0.2333% (-0.3644%) for firms without green (full) interlocks. The difference in average CARs across the two subsamples is 0.372 % (t=-2.6), which is statistically significant at the 1% level. Similarly, by splitting the sample based on the top versus bottom quintiles of *GREENET*, we find that the mean CAR is 0.1308% for firms with larger green network, compared to -0.3221% for firms with smaller green network. Such average CAR difference is again significant at the 5% level. The second set of network measures includes green and full centrality measures. The results show a higher average CAR for issuers with higher green centrality rank (0.152%) and measures (0.314% for *GREEN BETWEEN* and 0.1149% for *GREEN EIGEN*) than those for issuers with lower green centrality, which are statistically significant at the 10% level or above. However, we do not find a statistically significant difference in mean CARs across the subsamples split by four measures of issuer full network and centrality (*ALLNET, ALLNSCORE, ALL BETWEEN* and *ALL EIGEN*).

6.2 Issuer network, Green Bond Issuances, and Firm Value

In this section, we investigate whether the univariate results in Panel A of Table 10 are robust to a multivariate regression analysis where we control for firm financials and year, industry and region fixed effects. We estimate regressions of CARs for the public firm sample following the OLS specification below:

$$CARs_{j,t} = \beta_0 + \beta_1\ Interlock\ and\ network\ measures_{jt} + \beta_3\ Issuer\ Controls_{jt} + Country\ Dummies + Industry\ Dummies + Year\ Dummies + \varepsilon_{jt} \qquad \text{Eq.[10]}$$

Where the dependent variable $CARs_{it}$ is the cumulative abnormal returns for issue j in year t, calculated using CAPM market-adjusted models over the estimation windows of [-3,+3]. $Interlock\ and\ network\ measures_{jt}$ indicates the respective interlock and network centrality measures for issuer j in year t and ε_{jt} is a random error term.

The results from these regressions are reported in Panel B, Table 10. Consistent with univariate analysis, we find that *GREEN INTERLOCK* and *GREENET* are positively and significantly associated with the firm value (measured by CARs) generated by the green bond issuances. Furthermore, *GREEN SCORE* and *ALL NSCORE* both have a significantly positive effect on the firm value at the 1% and 10% level, respectively.

7 Green Network, Green Bond Issuances, and Issuance Costs

In this section, we test whether green and full network measures influence the issuance costs associated with green bonds, in other words, whether green bond investors consider network characteristics as a mechanism to lower information asymmetry during the issuance process. We examine this effect in the formula below by investigating two types of issuance costs: yield spreads and gross spreads.

$$YIELDSPREAD_{jt}\ or\ GROSS\ SPREAD_{jt} = \beta_0 + \beta_1\ Interlock\ and\ network\ measures_{jt} + \beta_3 Bond\ Controls_{jt} + Country\ Dummies + Industry\ Dummies + Year\ Dummies + Company\ Type\ Dummies + \varepsilon_{jt} \qquad \text{Eq.[11]}$$

Where $YIELDSPREAD_{it}$ is measured as the yield spread in percentage calculated as the difference between the yield on issue for green bond j issued at year t and the comparable Treasury yield on the closest date with similarity. $GROSS\ SPREAD_{jt}$ is measured as the fees paid to underwriter as a fraction of the offering price, collected from Thomson Eikon. ε_{jt} is a random error term.

[Insert Table 11 here]

7.1 Yield spreads

Following Flammer (2021), we collect the yield on the issue date from Bloomberg, which reflects the price that the bond is offered on the pricing date, indicative of the financing burden on the issuers. Yield spread, calculated as the difference between the yield on issue for green bond j issued at year t and the comparable Treasury yield on the closest date with similarity, is a proxy for the cost of green bond financing (see e.g., Anderson et al., 2004; Ge & Liu, 2015). We utilize two subsamples of green bond issues: first-time issues and all issues from unique bond issuers. Table 11 reports the OLS results of the effect of issuer interlock and network (Panel A) and green and full centrality measures (Panel B) on the yield spreads. Controlling for bond characteristics, such as *RATING*, *MATURITY* and *AMTISSUED*, we find that firms with a *GREEN INTERLOCK* can lower their costs of green bond financing, and firms with a larger *GREENET* and *ALLNET* are also associated with lower yield spreads of green bonds. The magnitude of the effects for first-time issues is larger than those for all unique issues, which is consistent with the notion that the effect on first-time green bond issues tends to be more significant (Flammer, 2021).

In terms of issuer's centrality measures, the findings in Panel B of Table 11 suggest that a higher quintile rank in both green and full centrality, measured by *GREEN SCORE* and *ALL NSCORE,* as well as higher centralities measured by *GREEN BETWEEN* and *ALL BETWEEN* contribute to a lower cost of green bond financing, captured by yield spreads. We do not find a negative effect of centralities measured by eigenvector.

[Insert Table 12 here]

7.2 Gross Spread

We also proxy the cost of green bond issuances for Gross Spread, defined as the fees paid to underwriter as a fraction of the offering price. Table 12 presents the regression results of the effect of interlock and centrality measures on the gross spreads of green bond issues. A statistically significant (at the 1% level) and positive coefficient (-0.2318) of *GREEN INTERLOCK* on the gross spreads is documented in Column (1), as well as of *GREENET* at the 10% level (-0.0064). Despite that the effect of *ALLNET* is not statistically significant, there is a 5% significantly positive association between *FULL INTERLOCK* and the cost of green bonds with the coefficient of -0.1717. Quintile ranks of centralities and betweenness centralities also have a significant and positive impact on the gross spreads of green bond financing. Overall, our findings suggest that firms with a green (full) interlock and higher centrality positions can have a lower cost of green bond financing.

8 Conclusion

The empirical findings in this paper show that past experiences that can be transmitted across the connections via shared directors or executives or officials (government institutions only) in the firm network contribute to the spread of green bond issuances. Utilizing a sample of all Northern American and European green bond issuers between 2012 and 2021, we find that issuers that have interlocks with previous green bond issuers are approximately 20% more likely to issue green bonds. The quintile ranks of issuer green centrality and specific centrality positions measured by degree, betweenness and eigenvector are positively associated with the propensity of green bond issuances. We also find statistically significant evidence that better-connected issuers with other issuers in our entire sample (measured by the quintile rank of full network connectedness) are more inclined to issue green bonds. To address the concerns of endogeneity and reverse causality, we test alternative hypotheses of the employee-firm matching and issuer stacking, employ size-adjusted network and centrality measures, conduct subsample analysis split by independent non-executive directors and top executive directors, and estimate a 2SLS model with the instruments as deaths and sudden departure of employees. These robustness checks confirm our baseline findings.

Furthermore, we explore possible channels through which green network and centrality benefit issuers. Additional analysis on the CARs and issuance costs captured by yield spreads and gross spreads shows that issuer green interlocks and centrality positions are positively associated with firm value (measured by CARs) and adversely related to issuance costs, demonstrating that the issuance of green bonds can be a value-enhancing and cost-efficient practice for issuers with green networks. Future research can be conducted into the conduits of firm network in developing financial policies and value implications of social imitations for organizations.

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Table 1: Summary statistics comparing issuer links of green bond issuers and non-green-issuers

Table 1, Panel A and B presents the average number of firm links that firms have to other firms in our sample and the percentage and number of firm links to previously green bond issuers. Panel A presents the number of green bond issuers by government institutions, private firms and public firms each year (N), the number of new issuers starting to issue green bonds by government institutions, private firms and public firms each year (New green issuers), the percentage (%Links) and average number of links (Avg links) to other firms in our sample, and the percentage (%Green links) and average number of links to other firms in our sample that have issued green bonds in previous years (Avg green links). Panel B presents the statistics for firms that are in the sample in a given year, but have not issued green bonds. Panel C presents the summary statistics of network and financial characteristics for different types of organizations.

		Panel A: Green bond issuers						Panel B: Non-green-bond issuers				
Year		N	New green issuers	%Link	Avg links	%Green links	Avg green links	Non-green issuers	%Link	Avg links	%Green links	Avg green links
2012	GOV	6	3	33.33	2.00	33.33	1.00	244	15.16	0.47	2.05	0.03
2012	PRIVATE	9	2	0.00	0.00	0.00	0.00	582	47.42	4.36	3.44	0.04
2012	PUBLIC							293	65.53	6.15	5.12	0.05
2013	GOV	8	2	0.00	0.00	0.00	0.00	242	14.88	0.49	2.48	0.03
2013	PRIVATE	16	7	100.00	17.43	100.00	1.29	575	48.87	4.29	9.22	0.14
2013	PUBLIC	2	2	100.00	20.00	100.00	1.50	291	69.42	6.49	14.43	0.20
2014	GOV	23	15	13.33	0.80	13.33	0.53	227	14.98	0.52	3.96	0.05
2014	PRIVATE	39	23	60.87	5.13	60.87	2.39	552	50.72	4.43	12.14	0.24
2014	PUBLIC	11	9	88.89	9.78	88.89	3.44	282	70.21	6.48	25.89	0.38
2015	GOV	49	26	15.38	0.62	15.38	0.38	201	14.43	0.49	4.98	0.07
2015	PRIVATE	66	27	51.85	5.56	70.37	3.70	525	51.62	4.59	18.67	0.38
2015	PUBLIC	20	9	55.56	9.78	66.67	3.89	273	73.26	6.61	32.97	0.56
2016	GOV	71	22	13.64	0.36	13.64	0.18	179	16.20	0.59	6.15	0.08
2016	PRIVATE	97	31	45.16	4.06	61.29	2.55	494	54.25	5.31	26.92	0.56
2016	PUBLIC	31	11	81.82	10.91	90.91	3.18	262	74.05	7.04	41.60	0.80
2017	GOV	96	25	16.00	0.88	16.00	0.64	154	15.58	0.53	7.79	0.10
2017	PRIVATE	152	55	63.64	5.24	69.09	3.45	439	54.44	5.52	32.35	0.90
2017	PUBLIC	53	22	90.91	8.55	90.91	6.36	240	72.50	7.04	45.83	1.03
2018	GOV	121	25	16.00	0.48	16.00	0.28	129	13.95	0.56	7.75	0.11
2018	PRIVATE	207	55	69.09	8.00	74.55	5.15	384	53.13	5.24	34.38	1.14
2018	PUBLIC	77	24	75.00	10.50	75.00	4.00	216	72.69	6.91	51.39	1.38
2019	GOV	149	28	3.57	0.07	3.57	0.04	101	16.83	0.69	10.89	0.19
2019	PRIVATE	309	102	57.84	6.51	60.78	4.22	282	53.19	5.34	43.62	1.62
2019	PUBLIC	125	48	91.67	10.79	91.67	4.54	168	69.05	6.01	55.95	1.77
2020	GOV	194	45	17.78	0.58	17.78	0.29	56	17.86	0.61	16.07	0.25
2020	PRIVATE	415	106	52.83	4.60	53.77	2.93	176	53.98	6.07	44.32	2.12
2020	PUBLIC	191	66	71.21	7.12	81.82	4.98	102	72.55	6.25	67.65	2.29
2021	GOV	250	56	16.07	0.61	16.07	0.38					
2021	PRIVATE	591	176	54.55	6.52	54.55	4.41					
2021	PUBLIC	293	102	73.53	6.82	73.53	4.46					
Total			1124					7669				

Panel C: Network and financial characteristics

All organizations									Government institutions							
Variable	**N**	**Mean**	**SD**	**Median**	**Min**	**Q1**	**Q3**	**Max**	**N**	**Mean**	**SD**	**Median**	**Min**	**Q1**	**Q3**	**Max**
GREEN ISSUE	8793	0.128	0.334	0	0	0	0	1	1995	0.123	0.328	0	0	0	0	1
GREEN INTERLOCK	8793	0.258	0.438	0	0	0	1	1	1995	0.063	0.242	0	0	0	0	1
GREENET	8793	0.933	161.624	1	0	0	2	111	1995	0.105	2.092	0	0	0	0	7
ALLNET	8793	4.6	901.866	2	0	0	6	166	1995	0.533	13.097	0	0	0	0	14
FULL INTERLOCK	8793	0.501	0.5	1	0	0	1	1	1995	0.153	0.36	0	0	0	0	1
GREEN SCORE	8793	2.998	8.645	3	1	2	4	5	1995	2.988	8.637	3	1	2	4	5
ALL NSCORE	8793	2.998	8.645	3	1	2	4	5	1995	2.988	8.637	3	1	2	4	5
GREEN BETWEEN	8793	57.24	491640.234	0	0	0	0	2976.55	1995	3.564	59494.441	0	0	0	0	1382.313
ALL BETWEEN	8793	160.311	894972.271	0	0	0	15.801	2999.737	1995	9.501	225898.032	0	0	0	0	2847.106
GREEN EIGEN	8793	0.016	0.039	0	0	0	0	1	1995	0.003	0.006	0	0	0	0	0.397
ALL EIGEN	8793	0.027	0.053	0	0	0	0.006	1	1995	0.002	0.001	0	0	0	0	0.157

Public firms									Private firms							
Variable	**N**	**Mean**	**SD**	**Median**	**Min**	**Q1**	**Q3**	**Max**	**N**	**Mean**	**SD**	**Median**	**Min**	**Q1**	**Q3**	**Max**
GREEN ISSUE	1916	0.098	0.297	0	0	0	0	1	3376	0.107	0.309	0	0	0	0	1
GREEN INTERLOCK	1916	0.43	0.495	0	0	0	1	1	3376	0.272	0.445	0	0	0	1	1
GREENET	1916	1.406	86.729	0	0	0	2	56	3376	0.967	131.518	1	0	0	1	61
ALLNET	1916	6.884	416.245	4	0	0	10	88	3376	4.741	1297.936	2	0	0	6	166
FULL INTERLOCK	1916	0.733	0.442	1	0	0	1	1	3376	0.517	0.5	1	0	0	1	1
GREEN BETWEEN	1916	132.257	786308.549	0	0	0	0	2908.577	3376	47.733	403958.969	0	0	0	0	2976.55
ALL BETWEEN	1916	340.28	1377613.159	1.633	0	0	443	2939.355	3376	130.537	702709.333	0	0	0	6.723	2999.737
GREEN EIGEN	1916	0.024	0.043	0	0	0	0.01	1	3376	0.018	0.044	0	0	0	0	1
ALL EIGEN	1916	0.04	0.038	0.002	0	0	0.033	0.86	3376	0.027	0.068	0	0	0	0.004	1
AT (in log)	1845	9.256	46.766	9.202	2.206	7.717	10.772	14.65	2379	8.264	41.962	8.413	0.019	6.863	9.896	13.93
ROA	1844	0.033	0.011	0.033	-0.374	0.009	0.055	0.219	2161	0.029	0.01	0.023	-0.24	0.003	0.048	0.346
MTB	1841	1.633	26.264	1.085	-0.112	0.815	1.774	22.28								
LEV	1836	0.344	0.135	0.339	0	0.207	0.47	0.822	2218	0.485	0.321	0.451	0	0.268	0.711	1.073
DEBT MAT	1798	0.739	0.294	0.809	0	0.627	0.924	1	1936	0.778	0.294	0.857	0	0.688	0.953	1
TANGIBILITY	1793	0.258	0.26	0.096	0	0.005	0.48	0.982	1685	0.416	0.339	0.427	0	0.004	0.794	0.989
FIRM AGE	1816	73.371	12327.158	51	0	18	124	247.86	2701	44.546	8016.879	19	0	7	73	198.11
BOARD SIZE	1839	13.891	4484.548	12	2	8	16	293	2809	23.766	14447.38	10	0	5	19	465
%INDEP	1818	0.528	0.33	0.6	0	0.222	0.818	1	2435	0.155	0.249	0	0	0	0.157	1
CEOTENURE	1569	6.107	87.572	5.7	0.2	2.2	9.005	25.9	1250	6.729	63.133	7.003	0.4	3.3	9.7	28.3
%INST	1185	0.303	0.224	0.241	0	0.132	0.419	1								

Table 2: Summary statistics for private and public firms

This table presents the number of non-green-bond issuer-year observations and green-bond issuer-year observations by country and one-digit SIC industrial classification.

	PRIVATE		PUBLIC	
	Non-Green	Green	Non-Green	Green
Austria	42	7	55	9
Belgium	38	6	49	7
Bermuda	15	2	35	7
Canada	109	18	87	14
Denmark	59	10	28	5
Estonia	2	1		
Finland	62	10	57	8
France	210	40	105	22
Germany	227	40	159	24
Greece	10	2	31	4
Guernsey			7	1
Hungary	88	12	24	3
Iceland	19	3	22	3
Ireland	25	4	15	2
Italy	91	16	76	14
Jersey	8	1		
Latvia	14	3		
Lithuania	8	1	10	2
Luxembourg	104	16	22	3
Netherlands	245	44	42	7
Norway	300	48	124	18
Poland	20	3	35	5
Portugal	34	5	13	2
Russia	27	4	15	2
Slovenia	9	2		
Spain	139	23	107	16
Sweden	290	56	239	40
Switzerland	120	18	59	9
Ukraine	15	2		
United Kingdom	211	33	89	15
United States	417	74	303	47
Total	2958	504	1808	289

One-digit SIC		Non-Green	Green
Agriculture, Forestry and Fishing	PRIVATE	23	3
	PUBLIC	8	1
Mining and Construction	PRIVATE	73	13
	PUBLIC	85	12
Manufacturing	PRIVATE	115	18
	PUBLIC	329	53
Transportation and Communications	PRIVATE	726	126
	PUBLIC	332	60
Trade	PRIVATE	52	8
	PUBLIC	30	4
Finance, Insurance and Real Estate	PRIVATE	1743	296
	PUBLIC	958	150
Services	PRIVATE	195	34
	PUBLIC	45	6
Public Administration	PRIVATE	31	6
	PUBLIC	21	3
Total		4766	793

Table 3: Firm interlocks and the propensity of green bond issuances

This table presents the multiperiod logit regression estimations in examining the effect of green interlock (*GREEN INTERLOCK*), network (*GREENET*), full network (*ALLNET*) and interlock (*FULL INTERLOCK*) on the propensity of green bond issuances. Dependent variable (*GREEN ISSUE*) takes on a value of one if the firm initially issues green bonds in a given year, and zero otherwise. Detailed descriptions of independent and control variables are provided in the Appendix. Robust standard errors of coefficients are reported in parentheses and marginal effects are reported in square brackets. We drop firms from the sample in future years after the year they issue green bonds at the first time. For the sake of brevity, we do not report marginal effects for control variables. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

	Panel A: All organizations				**Panel B: Public and private firms**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GREEN INTERLOCK	1.2920***				1.5130***			
	(0.0937)				(0.1526)			
	[0.1393]				[0.2024]			
GREENET		1.1350***				1.7400***		
		(0.0609)				(0.1090)		
		[0.0906]				[0.1967]		
ALLNET			0.1336***				0.0853	
			(0.0404)				(0.0714)	
			[0.0119]				[0.0115]	
FULL INTERLOCK				0.1896**				-0.1075
				(0.0896)				(0.1519)
				[0.0170]				[-0.0147]
AT					0.1078***	-0.0635	0.1774***	0.2059***
					(0.0384)	(0.0427)	(0.0408)	(0.0387)
ROA					-2.6310*	-1.7500	-2.2390	-2.2510
					(1.5000)	(1.5580)	(1.4690)	(1.4760)
LEV					1.0300***	1.2000***	1.1130***	1.1330***
					(0.3171)	(0.3469)	(0.3065)	(0.3062)
DEBT MAT					0.1298	0.3160	0.1378	0.1550
					(0.2891)	(0.3100)	(0.2837)	(0.2845)
TANGIBILITY					0.2613	0.3301	0.2928	0.2891
					(0.2248)	(0.2366)	(0.2208)	(0.2215)
FIRM AGE					-0.0031**	-0.0027*	-0.0027**	-0.0026**
					(0.0013)	(0.0014)	(0.0013)	(0.0013)
Constant	-5.8380***	-5.5720***	-6.1890***	-6.2070***	-7.1760***	-5.2060***	-7.9630***	-8.1000***
	(0.5397)	(0.5425)	(0.5385)	(0.5383)	(1.3260)	(1.2990)	(1.2760)	(1.2710)
Year	YES	YES	YES	YES	YES	YES	YES	YES
Company Type	YES	YES	YES	YES	YES	YES	YES	YES
Industry	NO	NO	NO	NO	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES
N	8,793	8,793	8,793	8,793	3,413	3,413	3,413	3,413
Pseudo R-squared	38.94%	41.53%	36.16%	36.07%	39.97%	47.01%	36.30%	36.27%

Table 4: Network centrality and the propensity of green bond issuances

This table presents the multiperiod regression estimations for all organizations (Columns 1-6) and private and public firm sample (Columns 7-12) in examining the effect of green and full network centrality measures on the propensity of green bond issuances. Dependent variable (*GREEN ISSUE*) takes on a value of one if the firm initially issues green bonds in a given year, and zero otherwise. Detailed descriptions of other variables are provided in the Appendix. Robust standard errors of coefficients are reported in parentheses and marginal effects are reported in square brackets. For the sake of brevity, we do not report marginal effects for control variables. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
GREEN SCORE	0.0727**						0.1929***					
	(0.0311)						(0.0484)					
	[0.0065]						[0.0257]					
ALL NSCORE		0.2833**						0.1223*				
		(0.0332)						(0.0528)				
		[0.0245]						[0.0164]				
GREEN BETWEEN			0.2846***						0.3229***			
			(0.0183)						(0.0256)			
			[0.0238]						[0.0395]			
ALL BETWEEN				0.0470***						0.0288		
				(0.0168)						(0.0238)		
				[0.0042]						[0.0039]		
GREEN EIGEN					6.5760***						10.5900***	
					(0.6876)						(1.1060)	
					[0.5767]						[1.3429]	
ALL EIGEN						0.7173						1.5210
						(0.6767)						(1.1950)
						[0.0644]						[0.2042]
AT							0.1639***	0.2307***	0.0459	0.1815***	0.0973**	0.1843***
							(0.0381)	(0.0399)	(0.0405)	(0.0394)	(0.0392)	(0.0386)
ROA							-2.3670	-2.2650	-2.7250*	-2.3560	-1.3600	-2.1510
							(1.4610)	(1.4870)	(1.5010)	(1.4680)	(1.4810)	(1.4730)
LEV							1.1270***	1.1390***	1.0930***	1.1140***	1.1840***	1.1510***
							(0.3076)	(0.3066)	(0.3244)	(0.3062)	(0.3193)	(0.3071)
DEBT MAT							0.1730	0.1627	0.2903	0.1328	0.4904*	0.1650
							(0.2842)	(0.2845)	(0.2962)	(0.2837)	(0.2955)	(0.2844)
TANGIBILITY							0.2960	0.2756	0.2701	0.2884	0.3279	0.2846
							(0.2213)	(0.2226)	(0.2286)	(0.2209)	(0.2237)	(0.2210)
FIRM AGE							-0.0030**	-0.0025*	-0.0028**	-0.0026**	-0.0028**	-0.0027**
							(0.0013)	(0.0013)	(0.0014)	(0.0013)	(0.0013)	(0.0013)
Constant	-6.5070***	-7.4730***	-5.8570***	-6.2030***	-6.0910***	-6.2060***	-8.2810***	-8.7960***	-6.1550***	-7.9330***	-7.6570***	-8.0440***
	(0.5539)	(0.5614)	(0.5409)	(0.5386)	(0.5385)	(0.5384)	(1.2680)	(1.3130)	(1.2680)	(1.2770)	(1.2770)	(1.2720)
Year & Region & Company Type	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES
N	8,793	8,793	8,793	8,793	8,793	8,793	3,413	3,413	3,413	3,413	3,413	3,413
Pseudo R-squared	36.08%	37.11%	39.53%	36.12%	37.28%	36.02%	36.80%	36.43%	41.87%	36.30%	39.49%	36.30%

Table 5: Interlock and the propensity of green bond issuances for respective public and private firms

This table presents the multiperiod regression estimations for respective public firms and private firms in examining the effect of interlock on the propensity of green bond issuances. Dependent variable (*GREEN ISSUE*) takes on a value of one if the firm initially issues green bonds in a given year, and zero otherwise. Detailed descriptions of independent and control variables are provided in the Appendix. Robust standard errors of coefficients are reported in parentheses and marginal effects are reported in square brackets. For the sake of brevity, we do not report marginal effects for control variables. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

	Panel A: Public firms				Panel B: Private firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GREEN INTERLOCK	3.2850***				1.9010***			
	(0.6937)				(0.4524)			
	[0.0342]				[0.0336]			
GREENET		4.6890***				2.4190***		
		(0.5377)				(0.3298)		
		[0.0078]				[0.0269]		
ALLNET			0.6520***				0.0552	
			(0.2265)				(0.1758)	
			[0.0097]				[0.0010]	
FULL INTERLOCK				0.8903				-0.1754
				(0.5860)				(0.4538)
				[0.0107]				[-0.003]
AT	0.5617***	0.2911	0.5215***	0.6051***	0.3805***	0.0217	0.4807***	0.5035***
	(0.1520)	(0.1955)	(0.1477)	(0.1439)	(0.1315)	(0.1473)	(0.1365)	(0.1308)
ROA	-9.3640**	-9.7610*	-4.6970	-5.2940	-5.6540	-2.1910	-8.9280	-9.3470
	(4.2680)	(5.2680)	(4.2030)	(4.2450)	(7.2230)	(7.8670)	(7.3720)	(7.3390)
MTB	0.1314	0.1705*	0.0596	0.0783				
	(0.0847)	(0.0978)	(0.0836)	(0.0831)				
LEV	1.0440	2.7450*	1.1290	1.1330	1.8340***	1.7360**	1.8880***	1.9160***
	(1.0330)	(1.5860)	(1.0080)	(0.9938)	(0.7019)	(0.7904)	(0.7059)	(0.7059)
DEBT MAT	0.4629	2.7120**	0.1809	0.1092	0.2245	-0.1278	0.4736	0.5265
	(0.8465)	(1.2300)	(0.8208)	(0.8137)	(0.6528)	(0.7063)	(0.6415)	(0.6443)
TANGIBILITY	1.6660*	2.1550	1.1210	1.0310	1.0940*	1.2390*	0.9962*	0.9828
	(0.9716)	(1.5350)	(0.9486)	(0.9377)	(0.5969)	(0.6725)	(0.5976)	(0.6010)
FIRM AGE	-0.0066*	-0.0035	-0.0059	-0.0055	-0.0031	-0.0009	-0.0027	-0.0027
	(0.0040)	(0.0050)	(0.0038)	(0.0037)	(0.0033)	(0.0035)	(0.0033)	(0.0033)
BOARD SIZE	-0.5726	-0.3270	-0.6333	-0.6691	-0.6912**	-0.6475**	-0.5060*	-0.4691
	(0.5860)	(0.8001)	(0.5299)	(0.5233)	(0.2883)	(0.3124)	(0.2817)	(0.2883)
%INDEP	-0.7759	-1.9990	-0.4015	-0.1155	-1.1790	-2.2160	-0.6570	-0.5540
	(0.7344)	(0.9843)	(0.7079)	(0.6871)	(0.7071)	(0.8238)	(0.6531)	(0.6406)
CEO TENURE	-0.0502	0.3782	-0.0090	-0.0432	0.1527	0.2346	0.1084	0.0949
	(0.2073)	(0.2931)	(0.1994)	(0.1978)	(0.2559)	(0.2855)	(0.2441)	(0.2435)
%INST	-2.1880	-2.7390	-2.2180**	-2.4010*				
	(1.3750)	(1.8360)	(1.3430)	(1.3320)				
Constant	-12.1000***	-14.2800***	-10.7500***	-10.8200***	-8.3830***	-5.9600**	-8.9060***	-8.9190***
	(2.7110)	(3.7800)	(2.5380)	(2.5140)	(2.3880)	(2.5100)	(2.3640)	(2.3600)
Year	YES	YES	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES
N	955	955	955	955	721	721	721	721
Pseudo R-squared	32.74%	60.89%	26.08%	24.89%	32.60%	43.17%	32.60%	32.60%

Table 6: Network Centrality and the propensity of green bond issuances for respective public and private firms

This table presents the multiperiod regression estimations for respective public firms and private firms in examining the effect of green and full network centrality measures on the propensity of green bond issuances. Dependent variable (*GREEN ISSUE*) takes on a value of one if the firm initially issues green bonds in a given year, and zero otherwise. Detailed descriptions of independent and control variables are provided in the Appendix. Robust standard errors of coefficients are reported in parentheses and marginal effects are reported in square brackets. For the sake of brevity, we do not report marginal effects for control variables. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

	Panel A: Public firms						**Panel B: Private firms**					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
GREEN SCORE	1.1710***						0.2849**					
	(0.1809)						(0.1217)					
	[0.0100]						[0.0054]					
ALL NSCORE		-0.0683						0.1531				
		(0.1638)						(0.1298)				
		[-0.0011]						[0.0028]				
GREEN BETWEEN			0.4579***						0.2913***			
			(0.0640)						(0.0621)			
			[0.0049]						[0.0051]			
ALL BETWEEN				0.1201*						-0.0629		
				(0.0616)						(0.0596)		
				[0.0019]						[-0.0012]		
GREEN EIGEN					21.3100***						9.2400***	
					(3.3050)						(2.0600)	
					[0.2354]						[0.1523]	
ALL EIGEN						7.0150**						4.7220
						(3.0500)						(2.9160)
						[0.1091]						[0.0872]
Constant	-15.1300***	-10.5600***	-11.1500***	-10.6500***	-10.2900***	-10.9900***	-9.3910***	-9.5740***	-7.9150***	-8.9380***	-8.2420***	-8.4600***
	(2.9130)	(2.5030)	(2.8410)	(2.5070)	(2.6730)	(2.5300)	(2.3700)	(2.4300)	(2.3660)	(2.3640)	(2.4260)	(2.3680)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	955	955	955	955	955	955	721	721	721	721	721	721
Pseudo R-squared	36.90%	24.44%	36.52%	25.15%	35.36%	25.41%	29.60%	28.77%	32.82%	28.72%	32.53%	29.03%

Table 7: Robustness checks

This table presents the multiperiod regression estimations for public and private firm sample testing the employee-firm matching and board stacking alternative explanations (Panel A) and employing size-adjusted network measures using residual approach (Panel B). The dependent variable (*GREEN ISSUE*) takes on a value of one if the firm initially issues green bonds in a given year, and zero otherwise. Detailed descriptions of independent and control variables are provided in the Appendix. Robust standard errors of coefficients are reported in parentheses and marginal effects are reported in square brackets. Industry, year, region and company type effects are included. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Panel A: Employee-firm matching and board stacking	(1)	(2)	(3)	(4)	(5)
GREEN INTERLOCK (Dif industry)	0.8917***				
	(0.1289)				
	[0.1283]				
GREEN INTERLOCK (Dif industry and country)		0.9763***			
		(0.1317)			
		[0.1385]			
GREEN INTERLOCK			1.9611***	1.5107***	1.3490***
			(0.4564)	(0.1603)	(0.1613)
			[0.1227]	[0.2022]	[0.1803]
Proximity			0.0998		
			(0.1742)		
GREEN INTERLOCK × Migrated				0.7836	
				(0.7766)	
GREEN INTERLOCK × Tenure less than three years					1.2777
					(0.7860)
Migrated				-0.8935	
				(0.7638)	
Tenure less than 3 years					-0.7580
					(0.7744)
Constant	-7.9000***	-7.7500***	-9.4749	-7.2886***	-6.9319***
	(1.3048)	(1.3068)	(10.8600)	(1.3327)	(1.3166)
Controls	YES	YES	YES	YES	YES
N	3,413	3,413	1,076	3,413	3,413
Pseudo R-squared	37.88%	38.15%	17.35%	40.04%	40.36%

Panel B: Size-adjusted network	(1)	(2)	(3)	(4)	(5)	(6)
RESID GREENET	1.7220***					
	(0.1090)					
	[0.1964]					
RESID ALLNET		0.0514				
		(0.0718)				
		[0.0069]				
RESID GREENBETWEEN			0.3169***			
			(0.0256)			
			[0.0390]			
RESID ALLBETWEEN				0.0230		
				(0.0241)		
				[0.0031]		
RESID GREENEIGEN					10.4700***	
					(1.1310)	
					[1.3322]	
RESID ALLEIGEN						0.6781
						(1.2490)
						[0.0912]
Constant	-7.1830***	-8.0730***	-7.1130***	-8.0430***	-8.3120***	-8.1020***
	(1.2970)	(1.2730)	(1.2640)	(1.2720)	(1.2810)	(1.2730)
Controls	YES	YES	YES	YES	YES	YES
N	3,413	3,413	3,413	3,413	3,413	3,413
Pseudo R-squared	46.66%	36.27%	41.62%	36.28%	39.28%	36.26%

Table 8: IV-2SLS estimations

This table reports regression results of network centrality measures on the likelihood of green bond issuances employing two instrumental variables: retirement and sudden departure of directors or executives. Panel A presents the first-stage regression results while Panel B reports the second-stage regression results. Detailed descriptions of variables are provided in the Appendix. Robust standard errors of coefficients are reported in parentheses. Industry, year, region, and company type effects are included. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Panel A: First-stage estimations

Dependent variable	GREENET	ALLNET	GREEN BETWEEN	ALL BETWEEN	GREEN EIGEN	ALL EIGEN
	(1)	(2)	(5)	(6)	(7)	(8)
RETIRE	-0.0716	-0.1025*	-0.4881**	-0.2468	-0.0114**	-0.0179***
	(0.0495)	(0.0616)	(0.1965)	(0.2000)	(0.0057)	(0.0067)
SUDDEN	-0.3148*	0.5710	1.2149	-0.5691*	0.0307	0.0490
	(0.2039)	(0.4295)	(1.2512)	(1.1307)	(0.0198)	(0.0462)
Constant	-0.6978***	-0.8452***	-3.0446***	-3.1657***	-0.0094**	-0.0077*
	(0.0751)	(0.1327)	(0.3324)	(0.2884)	(0.0043)	(0.0044)
Controls	YES	YES	YES	YES	YES	YES
N	3413	3413	3413	3413	3413	3413
R2	0.35	0.43	0.23	0.29	0.27	0.40
Wald F statistics	12.22	21.03	9.0	16.65	18.61	22.77
P values of Wu-Hausman test	0.52	0.27	0.73	0.26	0.58	0.21

Panel B: Second-stage estimations

	(1)	(2)	(3)	(4)	(5)	(6)
FITTED GREENET	2.6900**					
	(1.4770)					
	[0.3612]					
FITTED ALLNET		1.4950*				
		(0.8211)				
		[0.2008]				
FITTED GREENBETWEEN			0.7782**			
			(0.4154)			
			[0.1045]			
FITTED ALLBETWEEN				0.6118*		
				(0.3255)		
				[0.0822]		
FITTED GREENEIGEN					23.8600*	
					(12.7500)	
					[3.2045]	
FITTED ALLEIGEN						29.9600*
						(16.6500)
						[4.0230]
AT	-0.0997	-0.1622	-0.0457	-0.1579	-0.0036	-0.0177
	(0.1680)	(0.2017)	(0.1357)	(0.1933)	(0.1143)	(0.1259)
ROA	-1.2880	-1.7980	-2.3760	-3.6460**	-0.4161	-0.6760
	(1.5690)	(1.4950)	(1.4720)	(1.6420)	(1.7760)	(1.7210)
LEV	1.0340***	1.0750***	1.0700***	1.1290***	1.5450***	1.2170***
	(0.3096)	(0.3069)	(0.3072)	(0.3061)	(0.3808)	(0.3105)
DEBT MAT	0.4855	0.0899	0.5634	0.1088	0.4043	0.7715*
	(0.3414)	(0.2849)	(0.3627)	(0.2841)	(0.3169)	(0.4514)
TANGIBILITY	0.2868	0.2678	0.2126	0.2597	0.2790	0.3916*
	(0.2213)	(0.2217)	(0.2253)	(0.2220)	(0.2214)	(0.2281)
FIRM AGE	-0.0022*	-0.0024*	-0.0023*	-0.0013	-0.0023*	-0.0024*
	(0.0013)	(0.0013)	(0.0013)	(0.0015)	(0.0013)	(0.0013)
Constant	-4.6690**	-5.8790***	-5.3920***	-5.1540**	-7.4340***	-6.9110***
	(2.2620)	(1.7530)	(1.9160)	(2.0090)	(1.3170)	(1.4270)
Controls	YES	YES	YES	YES	YES	YES
N	3,413	3,413	3,413	3,413	3,413	3,413
Pseudo R-squared	36.35%	36.35%	36.36%	36.36%	36.36%	36.35%
P-value of Sargan test	0.52	0.46	0.66	0.44	0.78	0.83

Table 9: Board and executive interlocks and network

This table presents the multiperiod regression estimations for the network sample connected through independent non-executive directors and the sample connected through executives in examining the effect of green interlock (Panel A) and network centrality (Panel B) on the propensity of green bond issuances. Dependent variable (*GREEN ISSUE*) takes on a value of one if the firm initially issues green bonds in a given year, and zero otherwise. Detailed descriptions of independent and control variables are provided in the Appendix. Industry, year, region, and company type effects are included. Robust standard errors of coefficients are reported in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Panel A: Green interlock and network	**Independent non-executive directors**		**Executives**	
	(1)	(2)	(3)	(4)
GREEN INTERLOCK	1.3910***		1.3840***	
	(0.1398)		(0.1414)	
	[0.2065]		[0.2125]	
GREENET		1.8100***		1.5610***
		(0.1167)		(0.1142)
		[0.2131]		[0.1889]
Constant	-7.0000***	-5.9380***	-7.3210***	-6.5370***
	(1.3060)	(1.2960)	(1.3060)	(1.2930)
Controls	YES	YES	YES	YES
N	3,413	3,413	3,413	3,413
Pseudo R-squared	0.40	0.46	0.40	0.43

Panel B: Network centrality	**Independent non-executive director centrality measures**						**Executive centrality measures**					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
GREEN SCORE	0.5491***						0.5005***					
	(0.0573)						(0.0559)					
	[0.0668]						[0.0620]					
ALL NSCORE		0.2208***						0.1551**				
		(0.0551)						(0.0552)				
		[0.0295]						[0.0209]				
GREEN BETWEEN			0.3145***						0.3169***			
			(0.0258)						(0.0258)			
			[0.0392]						[0.0393]			
ALL BETWEEN				0.0605**						0.0127		
				(0.0239)						(0.0261)		
				[0.0082]						[0.0017]		
GREEN EIGEN					7.3740***						7.9950***	
					(1.1340)						(1.2850)	
					[0.9819]						[1.0555]	
ALL EIGEN						-0.0655						1.9400
						(0.9162)						(1.3130)
						[-0.009]						[0.2626]
Constant	-8.7260***	-8.3800***	-6.3510***	-7.9530***	-7.7230***	-8.0770***	-8.8980***	-8.2270***	-6.2870***	-8.0320***	-7.9690***	-8.0660***
	(1.2810)	(1.2750)	(1.2570)	(1.2710)	(1.2610)	(1.2610)	(1.2930)	(1.2660)	(1.2570)	(1.2640)	(1.2640)	(1.2610)
N	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413	3,413
Pseudo R-squared	0.40	0.37	0.41	0.37	0.38	0.36	0.39	0.37	0.42	0.36	0.38	0.36

Table 10: Cumulative abnormal returns (CARs) at the event window of [-3,+3]

This table reports the difference in average CARs across subsamples split by the presence of *GREEN INTERLOCK*, *FULL INTERLOCK* and based on the top versus bottom quintiles of *GREENET*, *ALLNET* and all centrality measures (Panel A) and multivariate regression results of the impact of interlocks and network centrality measures on firm value measured by CARs (Panel B). Detailed descriptions of variables are provided in the Appendix. Robust standard errors of coefficients are reported in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Panel A: CARs (%) by the presence of interlocks and quintile of network characteristics

Variables	**CAR (%) by quintile of X (except dummy variables)**		
	Top	Bottom	t-test
X=GREEN INTERLOCK	0.1387	-0.2333	-2.6***
X=GREENET	0.1308	-0.3221	-1.8**
X=ALLNET	0.1322	-0.2142	-1.6
X=FULL INTERLOCK	0.1355	-0.3644	-2.1**
X=GREENSCORE	0.1520	-0.0736	-1.7*
X=ALLNSCORE	0.1481	-0.0602	-1.5
X=GREEN BETWEEN	0.3140	-0.0219	-2**
X=ALL BETWEEN	0.1130	-0.0552	-0.7
X=GREEN EIGEN	0.1149	-0.0284	-2.4***
X=ALL EIGEN	0.1028	-0.5324	-2.1*

Panel B: Interlock, network centrality and firm value

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
GREEN INTERLOCK	0.0027**									
	(0.0015)									
GREENET		0.0017**								
		(0.0007)								
ALLNET			0.0016***							
			(0.0006)							
FULL INTERLOCK				0.0025						
				(0.0016)						
GREEN SCORE					0.0011***					
					(0.0004)					
ALL NSCORE						0.0007*				
						(0.0004)				
GREEN BETWEEN							0.0003*			
							(0.0002)			
ALL BETWEEN								0.0003		
								(0.0002)		
GREEN EIGEN									0.0036	
									(0.0039)	
ALL EIGEN										0.0039
										(0.0062)
ROA	-0.0030	-0.0031	-0.0029	-0.0037	-0.0012	-0.0017	-0.0012	-0.0018	-0.0044	-0.0040
	(0.0170)	(0.0168)	(0.0169)	(0.0171)	(0.0168)	(0.0169)	(0.0167)	(0.0169)	(0.0170)	(0.0168)
LEV	0.0024	0.0036	0.0037	0.0026	0.0043	0.0038	0.0031	0.0029	0.0029	0.0030
	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0033)	(0.0032)	(0.0032)	(0.0032)	(0.0033)	(0.0033)
DEBTMAT	-0.0042*	-0.0032	-0.0034	-0.0042*	-0.0031	-0.0034	-0.0038	-0.0038	-0.0035	-0.0035
	(0.0024)	(0.0023)	(0.0023)	(0.0024)	(0.0023)	(0.0023)	(0.0024)	(0.0024)	(0.0023)	(0.0023)
TANGIBILITY	-0.0049***	-0.0048***	-0.0045***	-0.0047***	-0.0050***	-0.0051***	-0.0051***	-0.0049***	-0.0051***	-0.0052***
	(0.0013)	(0.0013)	(0.0014)	(0.0014)	(0.0013)	(0.0014)	(0.0013)	(0.0013)	(0.0014)	(0.0013)
VOL	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Year	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	1191	1191	1191	1191	1191	1191	1191	1191	1191	1191
Adj R2	0.09	0.09	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09

Table 11: Green network and yield spreads

This table examines the effect of interlock measures (Panel A) and network centrality measures (Panel B) on the yield spreads of green bonds utilizing the public and private firm sample. Each panel employs two subsets of green bond issues: first-time issues and all unique issues. Detailed descriptions of independent and control variables are provided in the Appendix. Industry, year, region, and company type effects are included. Robust standard errors of coefficients are reported in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

Panel A: Interlock and yield spreads

	First-time issues				**All unique issues**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GREEN INTERLOCK	-0.8385**				-0.5819**			
	(0.4390)				(0.3123)			
GREENET		-0.2688***				-0.0878		
		(0.1016)				(0.0728)		
ALLNET			-0.2502***				-0.1082*	
			(0.0878)				(0.0623)	
FULL INTERLOCK				-0.4962				-0.2955
				(0.3257)				(0.2323)
RATING	0.1852	0.2033	0.1965	0.1720	-0.1625	-0.1714	-0.1723	-0.1768
	(0.1702)	(0.1686)	(0.1657)	(0.1699)	(0.1429)	(0.1443)	(0.1433)	(0.1431)
MATURITY	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
AMTISSUED (in log)	0.2196***	0.2464***	0.2432***	0.2255***	0.1098***	0.1085***	0.1072***	0.1104***
	(0.0613)	(0.0619)	(0.0616)	(0.0623)	(0.0264)	(0.0266)	(0.0264)	(0.0268)
N	297	297	297	297	679	679	679	679
R2	0.68	0.68	0.68	0.67	0.65	0.65	0.65	0.65

Panel B: Centrality and yield spreads

	First-time issues						**All unique issues**					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
GREEN SCORE	-0.2009**						-0.1514**					
	(0.0912)						(0.0701)					
ALL NSCORE		-0.2321***						-0.1590***				
		(0.0824)						(0.0600)				
GREEN BETWEEN			-0.0812***						-0.0327*			
			(0.0263)						(0.0193)			
ALL BETWEEN				-0.0844***						-0.0535***		
				(0.0229)						(0.0172)		
GREEN EIGEN					-0.4667						0.5748	
					(0.7937)						(0.4739)	
ALL EIGEN						-2.3065*						-0.4884
						(1.2208)						(0.6626)
RATING	0.1918	0.1582	0.2312	0.1903	0.1980	0.1939	0.0511	0.0368	0.0721	0.0520	0.0592	0.0606
	(0.1663)	(0.1650)	(0.1654)	(0.1649)	(0.1660)	(0.1654)	(0.1311)	(0.1301)	(0.1305)	(0.1304)	(0.1299)	(0.1311)
MATURITY	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
AMTISSUED (in log)	0.1101*	0.1146*	0.1186*	0.1220*	0.1082	0.1232*	0.0735***	0.0738***	0.0707***	0.0701***	0.0726***	0.0752***
	(0.0662)	(0.0646)	(0.0666)	(0.0622)	(0.0681)	(0.0712)	(0.0190)	(0.0191)	(0.0191)	(0.0189)	(0.0192)	(0.0190)
N	297	297	297	297	297	297	679	679	679	679	679	679
R2	0.74	0.74	0.74	0.75	0.73	0.74	0.71	0.71	0.71	0.71	0.71	0.71

Table 12: Interlock, network centrality and gross spreads

This table examines the effect of interlock measures and network centrality measures on the gross spreads of green bonds utilizing the public and private firm sample. Detailed descriptions of independent and control variables are provided in the Appendix. Industry, year, region, and company type effects are included. Robust standard errors of coefficients are reported in parentheses. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
GREEN INTERLOCK	-0.2318***									
	(0.0883)									
GREENET		-0.0064*								
		(0.0099)								
ALLNET			0.0052							
			(0.0051)							
FULL INTERLOCK				-0.1717**						
				(0.0822)						
GREEN SCORE					-0.0966**					
					(0.0385)					
ALL NSCORE						-0.0692*				
						(0.0345)				
GREEN BETWEEN							-0.0292**			
							(0.0146)			
ALL BETWEEN								-0.0373**		
								(0.0156)		
GREEN EIGEN									0.8261	
									(0.6661)	
ALL EIGEN										0.7398
										(0.7292)
RATING	-0.0864	-0.0799	-0.0785	-0.0870	-0.0936	-0.0905	-0.0758	-0.0778	-0.0766	-0.0818
	(0.0729)	(0.0737)	(0.0736)	(0.0731)	(0.0714)	(0.0729)	(0.0716)	(0.0714)	(0.0730)	(0.0736)
MATURITY	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
AMTISSUED (in log)	-0.2700***	-0.2877***	-0.2945***	-0.2676***	-0.2441**	-0.2521**	-0.2646***	-0.2621***	-0.2644***	-0.2979***
	(0.0937)	(0.0957)	(0.0958)	(0.0953)	(0.0960)	(0.0976)	(0.0960)	(0.0952)	(0.0939)	(0.0996)
N	189	189	189	189	189	189	189	189	189	189
R2	0.66	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.65

Appendix

Table A1: Variable descriptions

Variables	**Description**	**Source**
Network and interlock measures		
$GREENINTERLOCK_{j,t}$	An indicator variable taking the value of one if issuer j shares a director or executive or official with a previous green bond issuer i at year t, t-1, t-2, t-3, t-4, and zero otherwise.	
$GREENET_{j,t}$	Natural logarithm of 1 plus the total number of organizational links over a 5-year incubation window to other firms already issuing green bonds in prior years.	Self-calculation based on BoardEx and BvD Orbis
$ALLNET_{j,t}$	Natural logarithm of 1 plus the total number of organizational links between organizations in a given year t in our full sample.	
$FULLINTERLOCK_{j,t}$	An indicator variable takes on a value of one if the issuer has any links to any other organization(s) in our full sample in a given year t, not just to firms already issuing green bonds in previous year, and zero otherwise.	
$GREEN\ BETWEEN_{j,t}$	Betweenness centrality of issuer j is the sum of its betweenness ratios that defined as the number of geodesic paths from issuer s to issuer i passing through issuer j, divided by the number of geodesic paths from s to i. It evaluates the positioning advantage of the focal issuer in the network of green bond issuers who have previously issued green bonds in the preceding years. $\text{Betweenness}_j = \sum_{\substack{s\neq i\neq j\in I \\ s\neq i}} \frac{\sigma_{si}(j)}{\sigma_{si}}$.	
$ALL\ BETWEEN_{j,t}$	$ALL\ BETWEEN_{j,t}$ evaluates the positioning advantage of the issuer in the focal year in the entire network of all issuers included in our sample.	
$GREEN\ EIGEN_{j,t}$	Eigenvector centrality that developed by Bonacich (1987) evaluates the quality and importance of organizations' network of organizations who have already issued green bonds before, in which λ is associated maximum eigenvalue while A_{ij} is the adjacency matrix with the value of 1 when firm j and i are connected. $Eigenvector_j = \frac{1}{\lambda}\sum_i A_{ji}e_i$.	
$ALL\ EIGEN_{j,t}$	In a similar manner, $ALL\ EIGEN_{j,t}$ evaluates the quality and importance of organizations' network of all issuers included in our sample.	
$GREEN\ SCORE_{j,t}$	Follow Larcker et al.'s (2013) approaches to rank all firms each year into quintiles based on AT and sort firms within each AT quintile into quintiles based on $GREEN\ DEGREE_{j,t}$, $GREEN\ BETWEEN_{j,t}$, and $GREEN\ EIGEN_{j,t}$, respectively. $\text{GREEN SCORE}_{j,t} = \text{Quint}\ [\frac{1}{3}\{\text{Quint}\left(\text{GREEN DEGREE}_{j,t}\right) + \text{Quint}\left(\text{GREEN BETWEEN}_{j,t}\right) + \text{Quint}\left(\text{GREEN EIGEN}_{j,t}\right)\}]$	
$ALL\ NSCORE_{j,t}$	$\text{ALL NSCORE}_{j,t} = \text{Quint}\ [\frac{1}{3}\{\text{Quint}\left(\text{ALLNET}_{j,t}\right) + \text{Quint}\left(\text{ALL BETWEEN}_{j,t}\right) + \text{Quint}\left(\text{ALL EIGEN}_{j,t}\right)\}]$	
Other governance measures		
BOARD SIZE	The number of directors on board.	Thomson Eikon,BoardEx and BvD Orbis
%INDEP	The number of independent directors divided by the number of directors on board.	
CEO TENURE	Number of years that CEO serves in this position.	
%INST	The percentage of institutional ownership.	
Financial characteristics		
AT	The natural logarithm of total assets.	Capital I&Q and BvD Orbis
ROA	Net income divided by total assets.	
LEV	Interest-bearing debt divided by total assets.	
MTB	Market value of equity over book value of equity.	
TANGIBILITY	Net Property, Plant and Equipment (PP&E) scaled by total assets.	
FIRM AGE	The number of years since the firm is founded.	
DEBT MAT	The ratio of long-term debt over total debt.	
VOL	Stock price volatility is computed as standard deviation of monthly returns in the fiscal year.	
Bond characteristics		
RATING	An indicator variable taking on a value of 1 if the bond S&P (Moody's) rating is at or over BBB- (Baa3), and zero otherwise.	Bloomberg and CBI
MATURITY	The number of years that a bond takes to mature.	
AMTISSUED (in log)	The total amount of bond issued in dollars (in log).	

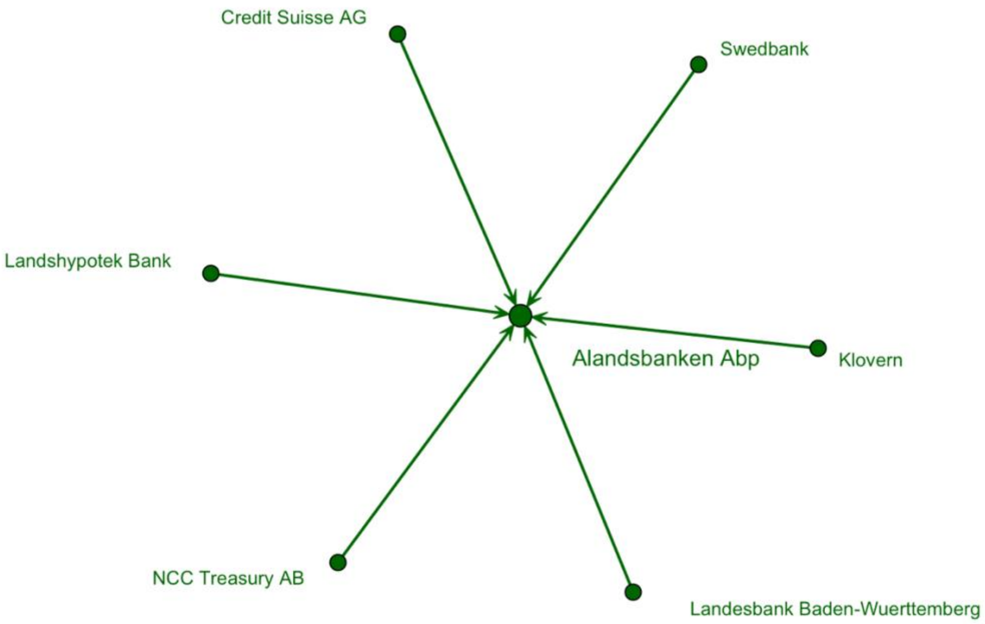

Fig.1. An illustrated example of the calculation of firm green networks for Alandsbanken Abp in 2021

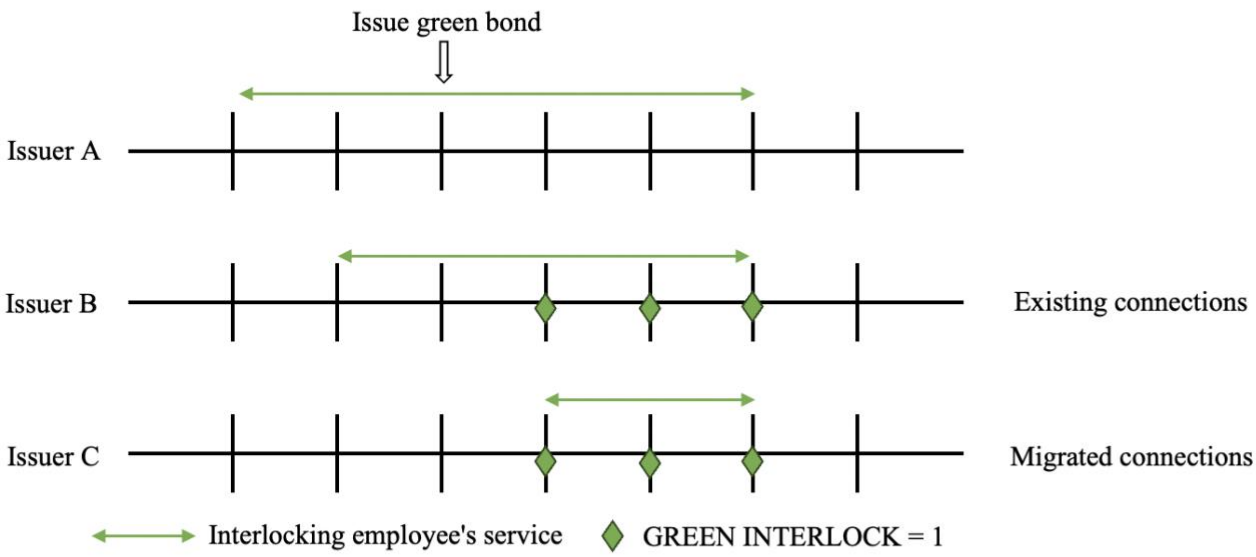

Fig.2. Migrated employees

Internet Appendix

Table IA.1: Correlation matrix for public and private firms

This table presents the Pearson correlation matrix. Detailed descriptions of independent and control variables are provided in the Table A1. * indicates significance at the 1 percent level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) GREEN ISSUE	1																
(2) GREEN INTERLOCK	0.28*	1															
(3) GREENET	0.40*	0.86*	1														
(4) ALLNET	0.05*	0.64*	0.67*	1													
(5) FULL INTERLOCK	0.03	0.56*	0.49*	0.86*	1												
(6) GREEN SCORE	0.03	0.62*	0.63*	0.52*	0.41*	1											
(7) ALL NSCORE	0.01	-0.59*	-0.59*	-0.91*	-0.81*	-0.64*	1										
(8) GREEN BETWEEN	0.32*	0.58*	0.80*	0.52*	0.34*	0.54*	-0.47*	1									
(9) ALL BETWEEN	0.05*	0.51*	0.54*	0.79*	0.57*	0.43*	-0.78*	0.51*	1								
(10) GREEN EIGEN	0.15*	0.48*	0.68*	0.53*	0.28*	0.44*	-0.43*	0.55*	0.39*	1							
(11) ALL EIGEN	0.01	0.39*	0.50*	0.65*	0.37*	0.36*	-0.56*	0.39*	0.48*	0.64*	1						
(12) AT	0.03	0.25*	0.29*	0.27*	0.23*	0.31*	-0.32*	0.33*	0.38*	0.29*	0.24*	1					
(13) ROA	-0.04	-0.03	-0.05*	-0.03	0.01	0.02	-0.01	-0.02	0.02	-0.09*	-0.09*	-0.04	1				
(14) LEV	0.06*	-0.03	-0.06*	-0.08*	-0.02	-0.12*	0.13*	-0.07*	-0.10*	-0.07*	-0.14*	-0.08*	-0.15*	1			
(15) DEBT MAT	0.04	-0.07*	-0.10*	-0.08*	0.03	-0.11*	0.07*	-0.10*	-0.07*	-0.17*	-0.15*	-0.11*	0.06*	0.19*	1		
(16) TANGIBILITY	0.00	-0.15*	-0.18*	-0.23*	-0.14*	-0.20*	0.25*	-0.14*	-0.18*	-0.20*	-0.24*	-0.24*	0.19*	0.13*	0.27*	1	
(17) FIRM AGE	0.02	0.24*	0.25*	0.35*	0.28*	0.24*	-0.35*	0.22*	0.29*	0.20*	0.26*	0.48*	-0.04	-0.29*	-0.19*	-0.29*	1

Table IA.2: Interlock, network centrality and the propensity of green bond issuances for government institutions

This table presents the multiperiod regression estimations for government institutions in examining the effect of interlock, network and centrality measures on the propensity of green bond issuances. Dependent variable takes on a value of one if the firm initially issues green bonds in a given year, and zero otherwise. Detailed descriptions of independent and control variables are provided in the Appendix Table A1. Robust standard errors of coefficients are reported in parentheses and marginal effects are reported in square brackets. We drop firms from the sample in future years after the year they issue green bonds at the first time. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
GREEN INTERLOCK	0.4783*									
	(0.2588)									
	[0.0408]									
GREENET		0.6208**								
		(0.2741)								
		[0.0443]								
ALLNET			-0.1397							
			(0.1585)							
			[-0.0100]							
FULL INTERLOCK				-0.2322						
				(0.2362)						
				[-0.0155]						
GREEN SCORE					1.4510***					
					(0.1164)					
					[0.0334]					
ALL NSCORE						1.6692				
						(0.1332)				
						[0.0294]				
GREEN BETWEEN							-0.0963			
							(0.2901)			
							[-0.0069]			
ALL BETWEEN								-0.2033		
								(0.1778)		
								[-0.0145]		
GREEN EIGEN									5.7482	
									(5.4196)	
									[0.4108]	
ALL EIGEN										-15.3547
										(10.5415)
										[-1.0931]
Constant	-5.2292***	-5.2164***	-5.2693***	-5.2675***	-11.9411***	-12.8919***	-5.2687***	-5.2592***	-5.2624***	-5.2732***
	(1.2960)	(1.2956)	(1.2978)	(1.2978)	(1.5624)	(1.6306)	(1.2979)	(1.2977)	(1.2976)	(1.2981)
Year	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Region	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995
Pseudo R-squared	0.30	0.31	0.29	0.28	0.30	0.28	0.31	0.29	0.29	0.29

Table IA.3: Size-adjusted network measures using quintile approach

This table presents the regression estimations employing size-adjusted network measures using quintile approach. Robust standard errors of coefficients are reported in parentheses and marginal effects are reported in square brackets. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
GREENQUINTD	0.3922***					
	(0.0515)					
	[0.0500]					
ALLQUINTD		0.1876***				
		(0.0528)				
		[0.0250]				
GREENQUINTB			0.0587*			
			(0.0442)			
			[0.0079]			
ALLQUINTB				0.3380***		
				(0.0492)		
				[0.0435]		
GREENQUINTE					0.1901***	
					(0.0513)	
					[0.0254]	
ALLQUINTE						0.0947*
						(0.0546)
						[0.0127]
AT	0.1246***	0.2485***	0.1904***	0.2802***	0.1610***	0.2200***
	(0.0387)	(0.0401)	(0.0375)	(0.0400)	(0.0383)	(0.0393)
ROA	-2.4030	-2.2440	-2.3330	-1.8090	-2.2680	-2.2930
	(1.4760)	(1.4980)	(1.4690)	(1.5340)	(1.4600)	(1.4820)
LEV	1.1190***	1.1560***	1.1390***	1.1030***	1.0900***	1.1380***
	(0.3129)	(0.3074)	(0.3063)	(0.3104)	(0.3074)	(0.3064)
DEBT MAT	0.1845	0.1781	0.1543	0.0854	0.1505	0.1556
	(0.2872)	(0.2852)	(0.2839)	(0.2871)	(0.2831)	(0.2844)
TANGIBILITY	0.3204	0.2679	0.2909	0.2832	0.3023	0.2744
	(0.2229)	(0.2235)	(0.2212)	(0.2252)	(0.2209)	(0.2225)
FIRM AGE	-0.0032**	-0.0024*	-0.0028**	-0.0022*	-0.0029**	-0.0025**
	(0.0013)	(0.0013)	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Constant	-8.3890***	-8.0590***	-8.1310***	-8.0490***	-8.2350***	-8.0250***
	(1.2660)	(1.2740)	(1.2680)	(1.2950)	(1.2750)	(1.2740)
Year & Region & Company Type & Industry	YES	YES	YES	YES	YES	YES
N	3,413	3,413	3,413	3,413	3,413	3,413
Pseudo R-squared	38.40%	36.68%	36.31%	37.90%	36.73%	36.35%