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Linh Pham, Toan Luu Duc Huynh

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How does investor attention influence the green bond market?

Linh Pham[a,*], Toan Luu Duc Huynh[b]

[a] *Assistant Professor, Department of Economics, School of Business, University of Central Oklahoma, 100 N. University Dr, Box 103, Edmond, OK 73034.*

[b] *WHU - Otto Beisheim School of Management, Chair of Behavioral Finance & University of Economics Ho Chi Minh City, School of Banking*

Abstract

This paper is the first empirical study of the link between investor attention and the green bond market performance. Using daily data of investor attention and green bond indexes, we find that investor attention can influence green bond returns and volatility, however, this relationship is time varying. Our results are relevant for investors as they shed light into the newly developed and fast growing green bond market. Our findings also emphasize the importance of appropriate information and attention for directing financial flows towards sustainable investment.

Keywords: green bond; investor attention; sustainable finance; climate finance.
JEL Classification Codes: G40, Q50

*Corresponding author
Email addresses: lpham17@uco.edu (Linh Pham), toanhld@ueh.edu.vn (Toan Luu Duc Huynh)

Highlights

- Impact of investor attention on green bond market performance.
- Generalized forecast error decompositions are estimated to capture spillovers between investor attention and green bond market.
- Time-varying impact of investor attention on green bond returns and volatility.
- Feedback effect between the green bond market performance and investor attention.

1 Introduction

Clean energy finance is crucial to achieve sustainable development goals, yet it still represents a small share of the financial market [10, 7]. This highlights the relevance of informing investors about the behavior of clean energy investments. This paper aims at investigating the impact of investor attention on green bond, a growing market for sustainable investment.

Green bond is a new financial product whose proceeds directly benefit environmentally sustainable projects. Between 2012 and 2018, green bond sales grew substantially from $4.2 billion to $167.6 billion [2]. In the future, this market is expected to receive increasing investor attention for several reasons. First, available empirical evidence shows green bonds are weakly correlated with other markets, thus offering diversification benefits to investors.[1] Second, concerns over climate change motivate investors to search for environmentally friendly investments. Thus, understanding the interdependence between investor attention and green bond market performance can be useful for policy to promote environmentally friendly finance.

This paper is among the first empirical studies of the linkage between green bonds and investor attention. Our empirical results show interdependence between investor attention and green bond market returns and volatility, however, the relationship is time-varying and stronger in the short run. Thus, market attention provides relevant information for investors and policymakers on the dynamics of green bond markets.

Our paper proceeds as follows. Section 2 highlights previous literature; section 3 summarizes data characteristics and main methodology; section 4 presents the results and section 5 concludes with policy recommendations.

2 Related literature

Our paper contributes to two main branches of the literature. First, the paper adds to the limited empirical research on green bonds in the clean energy finance literature. Most previous studies focus on green equity markets, while research on green bonds only emerged recently. Several studies explore whether investors pay a premium for green bonds, while others investigate the relationship between green bonds and other financial assets [11, 8, 12].

[1] For example, Tang & Zhang [11], Reboredo & Ugolini [8].

Second, our paper contributes to the behavioral finance literature investigating the role of investor attention on financial asset performance, where significant influence of investor attention has been documented for other markets such as stock, oil, commodity and foreign currency [3, 5, 6].

In these literatures, the relationship between investor attention and green bonds has not been directly modeled. Analyzing the role of investor attention in green bond markets is important for several reasons. First, Climate Bonds Initiative [2] projects that retail investor attention is important for future green bond market evolution. Second, unlike conventional financial markets, green financial markets like green bonds are subject to unique risks [9], for example, those that stem from uncertainty in renewable energy policy or the lack of clear standards for green bonds. In addition, since green bonds are relatively new financial instruments, the limited empirical evidence on green bonds implies that investors may have to learn about this market through the internet. Thus, internet search data can both reveal investor attention towards green bonds and serve as an additional predictor of green bond performance. To our knowledge, only one study has indirectly incorporated market attention into green bond modeling by analyzing the role of attention in the green-black bond correlation [1]. Our paper differs from Broadstock & Cheng [1] in several aspects. First, our empirical approach relies on the generalized forecast error variance decomposition of a vector autoregressive model, thereby directly accommodating potential feedback effects between green bonds and investor attention. Second, we employ the Google search volume index to measure investor attention, thus capturing the impact of information demand on green bond performance. Third, rather than relying on one single green bond index, our data contain a diverse set of green bond indexes, thereby identifying additional dynamics within the green bond market.

3 Data and methodology

Since our goal is to identify the connectedness between investor attention and green bond market performance, our data set consists of two main variables: investor attention and green bond indexes.

To measure investor attention related to green bond, we use the Google Search Volume Index (GSVI) of the main keyword 'Green bond'. Our choice of the GSVI is motivated by its extensive use in the behavioral finance literature as a measure of investor attention (e.g.

Da et al. [3], Goddard et al. [5], Gupta & Banerjee [6]).[2] Figure 1 shows an increase in the green bond GSVI over time.

We use several green bond indexes to measure green bond performance, specifically the S&P Green Bond index (SPGB), Solactive Green Bond index (SOLACTIVE), and the Bloomberg Barclays MSCI Global, US, and European Green Bond indexes (BLOOMBERG GLOBAL, BLOOMBERG US, BLOOMBERG EU). Since these indexes were launched around 2014, our data set ranges from October 2014 to November 2019. We calculate daily returns by log-differencing the variables, and use the conditional variances from univariate GARCH models applied to each return series as proxies for volatilities. As seen in figure 2, the indexes exhibit an upward trend during the sampling period, however, they do not always co-move, because of differences in the index components.[3] Table 1 demonstrates the summary statistics of the log-differenced series. Overall, the SOLACTIVE index exhibits the highest average returns while the SPGB and BLOOMBERG EU indexes have the lowest average returns. All series exhibit stationarity, according to the ADF unit root test.

In addition to these variables, we also include other variables to control for the general market conditions. We use the Bloomberg Barclays Global Treasury and Investment Grade Corporate Bond Indexes, the MSCI World Index and the S&P GSCI Energy Commodity Index to measure the bond, stock and energy commodity markets. These indexes are available from Bloomberg.

We apply the Diebold & Yilmaz [4] connectedness framework to examine the green bond-investor attention nexus. Specifically, consider a covariance stationary VAR model:

$$y_t = \sum_{s=1}^{p} \Theta_s y_{t-s} + \epsilon_t \tag{1}$$

where y_t is a vector of n endogenous variables, which include the green bond index, the GSVI

[2] In a robustness check, we also include other keywords such as 'Green loan', 'Green debt' and 'Climate bond', however, the results on these keywords are insignificant.

[3] The SPGB index is a global index that include green bonds denominated in any currency issued from any country with no credit rating requirement. The BLOOMBERG GLOBAL, US and EU indexes include investment grade green bonds in the global, U.S. and European markets, with fixed minimum issue sizes similar to the Bloomberg Barclays Global Aggregate Index. The SOLACTIVE index includes green bonds with minimum amount outstanding of 100 million USD and minimum time to maturity of 6 months.

and other control variables as described above. Θ_s are parameter matrices and $\epsilon_t \sim (0, \Sigma)$ is the residual vector. The moving average (MA) representation of y_t is: $y_t = \sum_{k=0}^{\infty} A_k \epsilon_{t-k}$, where $A_k = \Theta_1 A_{k-1} + \Theta_2 A_{k-2} + ... + \Theta_l A_{k-l}$.

The H-step ahead GFEVD is:

$$\phi_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i^T A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i^T A_h \Sigma A_h^T e_i)} \tag{2}$$

where σ_{jj} is the standard deviation of variable j's residual and e_i is a vector with values 1 for the i-th element and 0 otherwise.The directional spillover from variable j to variable i is defined as the share of GFVED in variable i explained by variable j and given by $\tilde{\phi}_{ij}(H) = \frac{\phi_{ij}(H)}{\sum_{j=1}^{n} \phi_{ij}(H)}$.

Our empirical procedure is as follows. First, we estimate the VAR model (1) for each green bond index, where the lag order is based on the Akaike Information Criteria. Next, we compute the spillovers among the green bond index, the GSVI and other control variables using the GFEVD in equation (2). Finally, we obtain the 99% confidence interval for the spillover parameters from 1000 bootstraps of the VAR model.

Figure 1: Green bond Google search volume index daily values

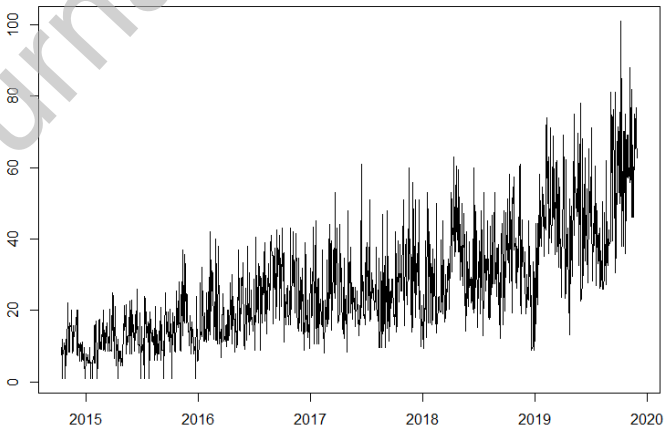

Figure 2: Green bond index daily closing prices

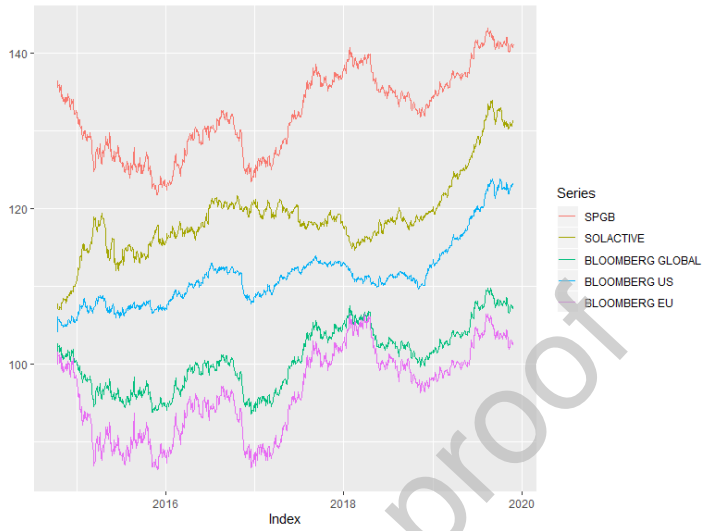

Table 1: Summary statistics of the log-differenced series

Variable	**Mean**	**Std. Dev.**	**Skewness**	**Kurtosis**	**JB**	**Stationary**
SPGB	0.003	0.301	-0.176 *	4.723 *	166.5 *	-10.938 *
SOLACTIVE	0.015	0.263	-0.407 *	7.137 *	957.1 *	-11.009 *
BLOOMBERG GLOBAL	0.004	0.338	-0.150 *	4.443 *	117.0 *	-11.099 *
BLOOMBERG US	0.012	0.192	-0.139 *	4.706 *	160.7 *	-10.119 *
BLOOMBERG EU	0.002	0.537	-0.099	4.825 *	181.4 *	-11.070 *
GSVI	0.128	57.559	0.140 *	8.099 *	1403.7 *	-16.475 *
Observations	1292					

Notes: * indicates 5% significance level. Column "JB" presents Jarque-Bera normality test statistic. Column "Stationary" presents the ADF test statistic, where a statistically significant statistic indicates stationarity.

4 Empirical results

Table 2 summarizes the connectedness of investor attention with green bond returns (Panel A) and volatility (Panel B) based on an estimation of the VAR model for the entire sampling period. Column (1) summarizes the percent of forecast error variance in green bond returns and volatility explained by investor attention while column (2) presents the percent of forecast error variance in investor attention that is explained by green bond returns and volatility.[4] Our results show that the static connectedness between green bond and investor attention is relatively small (less than 1%). Additionally, the spillover from investor attention to returns is larger than that in the reverse direction while the opposite is true for indexes with more selective eligibility criteria such as the SOLACTIVE, BLOOMBERG US and BLOOMBERG EU indexes. Regarding volatility connectedness, investor attention exhibits a larger influence on green bond volatility than the impact in the opposite direction. Altogether, our results suggest asymmetry in the spillovers between green bond returns and volatility and investor attention.

One drawback of the VAR model using the entire sample is that it assumes the coefficients of the VAR model does not change over time. Such a static model may not be able to capture the evolution of the green bond market in the short run. To capture the time-varying green bond-investor attention dependence, we re-estimate equations (1)-(2) using a 200-day rolling window (about a trading year) and a 10-step ahead forecast horizon. This allows us to identify the evolution in the green bond-investor attention relationship, as the coefficients of the VAR model are allowed to change among the time windows. Figures 3-4 summarize the results of our rolling connectedness estimates, where the shaded areas represent the bootstrapped confidence intervals. The figures suggest that the relationship between green bond and investor attention is changing over time. Additionally, there exists a feedback channel between green bond returns and investor attention. Periods where green bond return is a net receiver of shocks from investor attention tend to be followed by periods where it is a net transmitter of shocks.[5] Similar results can be obtained when considering volatility connectedness between green bond and investor attention (figure 4), however, the magnitude

[4] Each row in the table corresponds to a separate estimation of the spillover network described in section 3, which includes one green bond index, the GSVI and other control variables. However, since our focus is on the nexus between green bond and GSVI and due to limited space, we omit the spillover results of the control variables. These results are available from the corresponding author upon request.

[5] Green bond return is a net receiver (transmitter) of shocks from investor attention if the impact of green bond return on investor attention is smaller (larger) than the impact in the opposite direction.

of the connectedness is smaller in the volatility network than in the return network. As our empirical approach identifies the percent of forecast error variance in green bond returns and volatility explained by investor attention and other control variables, our results imply that other factors play a more important role in explaining the variance of green bond volatility than investor attention. Finally, on average, our dynamic rolling-window model suggests a stronger connectedness between green bond performance and investor attention than the static model. The static model relies on the full sample data, therefore, it captures the long-run dependence between the variables. On the other hand, the dynamic model captures the short-run dynamics among the variables. Thus, our results imply that investor attention and green bond market performance significantly influence each other in the short run, however, the relationship weakens in the long run. This reflects the quick adjustments of investor decisions in financial markets.[6]

In summary, we find the interdependence between green bond market performance and investor attention varies over time and is stronger in the short run than in the long run. Thus, investor attention can be a useful tool to predict green bond market performance. To test the robustness of our results, we select different time horizons to calculate the GFEVD, specifically, we consider 20-, 40- and 60-steps ahead GFEVD. We also choose different rolling windows for the rolling connectedness analysis, specifically, we use a 50- 100-, and 400-day rolling window. Finally, we include alternative search terms in our calculation of the Google attention index, such as "Green loan" and "Climate bond". We find that our conclusions are qualitatively similar under these robustness tests.

[6]In unreported results, we find that the magnitudes of the connectedness measures are larger (smaller) when we shorten (lengthen) the rolling windows. An alternative to capture the time-varying connectedness is to compute the GFEVD based on a time-varying-parameter (TVP) VAR model, however, such an approach is computationally challenging.

Table 2: Static connectedness between green bond and investor attention

	(1)	(2)
Panel A: Return connectedness		
	Attention → Bond	Bond → Attention
SPGB	0.377 [0.135, 1.440]	0.178 [0.082, 1.991]
SOLACTIVE	0.411 [0.086, 2.293]	0.561 [0.139, 2.611]
BLOOMBERG GLOBAL	0.188 [0.047, 0.941]	0.158 [0.059, 1.742]
BLOOMBERG US	0.135 [0.035, 0.977]	0.496 [0.076, 2.806]
BLOOMBERG EU	0.201 [0.049, 1.077]	0.202 [0.067, 1.970]
Panel B: Volatility connectedness		
	Attention → Bond	Bond → Attention
SPGB	0.042 [0.008, 0.725]	0.057 [0.013, 1.030]
SOLACTIVE	0.060 [0.009, 1.012]	0.026 [0.005, 0.957]
BLOOMBERG GLOBAL	0.154 [0.016, 0.889]	0.083 [0.010, 1.065]
BLOOMBERG US	0.181 [0.021, 1.253]	0.015 [0.006, 1.272]
BLOOMBERG EU	0.335 [0.047, 1.495]	0.065 [0.011, 1.054]

Notes: The numbers in brackets are the 99% confidence intervals of the connectedness measures.

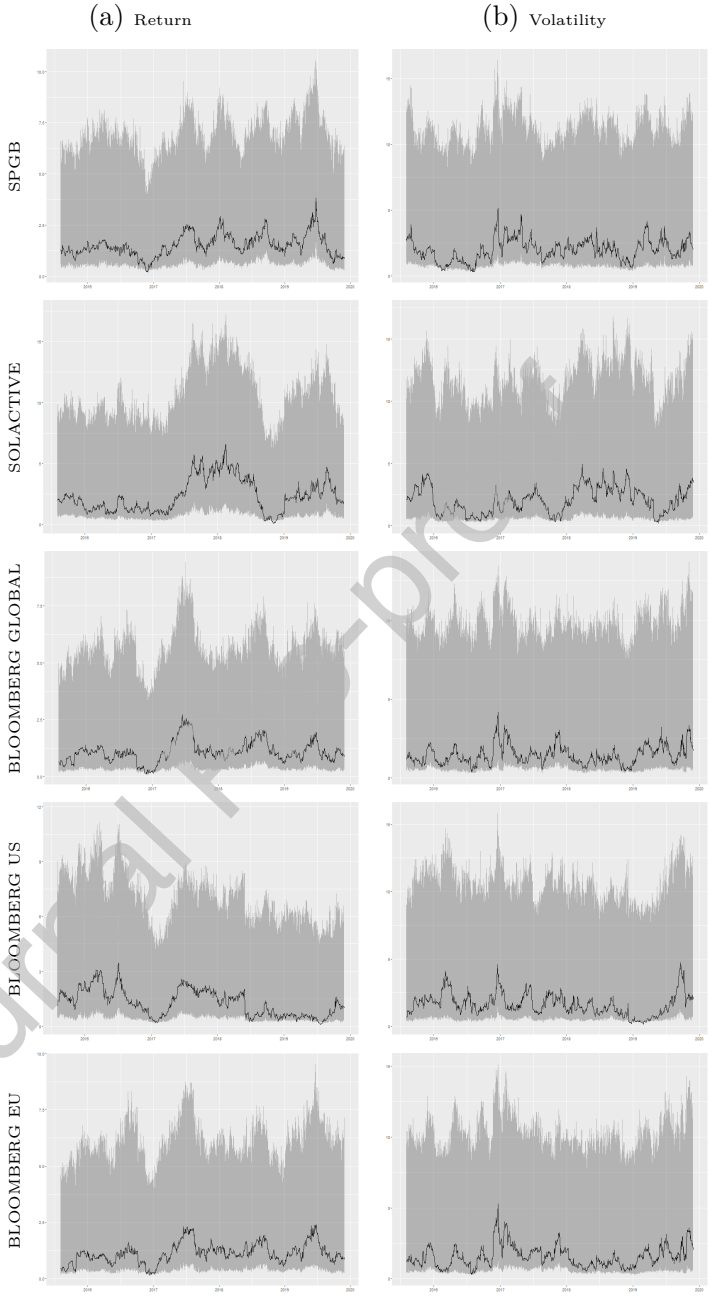

Figure 3: Return connectedness between investor attention and green bond
The shadow area represents 99% confidence interval for the time-varying connectedness.

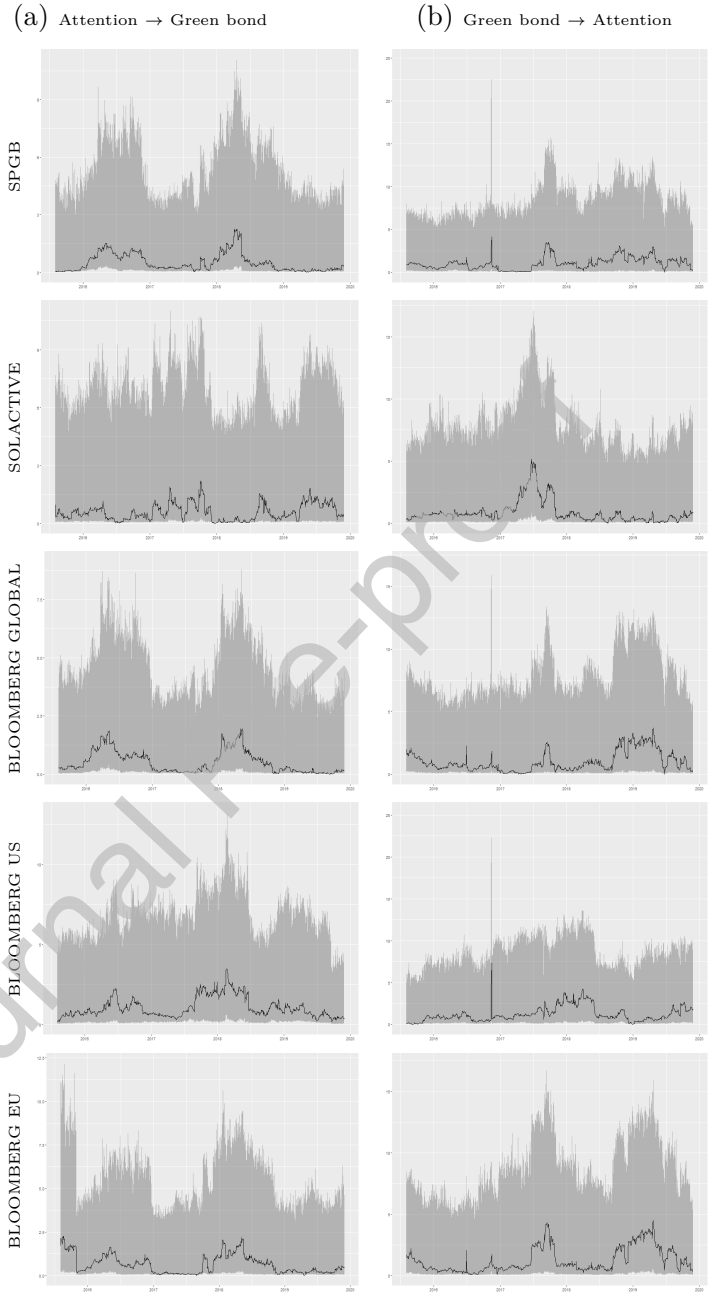

Figure 4: Volatility connectedness between investor attention and green bond
The shadow area represents 99% confidence interval for the time-varying connectedness.

5 Conclusions and policy implications

Concerns over climate change have intensified the need to direct financing towards environmentally friendly activity. This paper provides the first empirical investigation of the interaction between investor attention and green bond markets' performance. Using daily Google Search Volume Index and five green bond indexes, we find a time-varying feedback effect between green bond performance and investor attention. Our paper has several implications. First, investors with interests in green bonds can rely on market attention as a useful tool to predict green bond performance. Second, our paper provides new insights into the green bond market, which is helpful in the promotion of climate friendly financial instruments. As there exist feedback effects between green bond and investor attention, policy that informs investors about green bonds can influence incentives to invest in this market, thereby offering an additional channel to fulfill the financing requirements for transitioning to a low-carbon economy. Additionally, creating universal standards for green bond certifications will allow investors to identify green bonds from conventional investments, which further draws attention and demand in the green bond market. Future research could facilitate the growth of the green bond market by investigating other aspects of this market, for example, its relationship with other financial assets and its impact on carbon emission and energy transition.

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This document details the contribution of each author to the manuscript.

Linh Pham (Corresponding Author):

1. Supervision and project administration
2. Conceptualization
3. Data curation
4. Methodology, software, formal analysis and validation
5. Writing – Original draft, review and editing

Toan Luu Duc Huynh (Co-author):

1. Conceptualization
2. Data curation
3. Methodology, formal analysis and validation
4. Writing – Review and editing