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LETTER

Climate policy uncertainty and green bond markets

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Abstract

Using monthly data from July 2013 to April 2023, this study applies a time-varying causality approach to examine the relationship between climate policy uncertainty and the green bond market. During the episode December 2016 - December 2018, a negative bi-directional relationship is found, suggesting that higher green bond returns contributed to a reduction in policy uncertainty, fostering a more stable investment environment. However, during the COVID-19 pandemic, the relationship shifted, showing that increased green bond returns were associated with higher CPU, reflecting investor concerns about regulatory responses in times of crisis. Overall, the study emphasizes the importance of considering the time-varying nature of the CPU-green bond nexus while developing consistent and supportive climate policies to sustain the growth of green finance.

Introduction

Green bonds (GB) are a type of fixed-income financial instrument designed to generate capital for projects that deliver environmental benefits such as renewable energy development, climate adaptation or carbon emission reduction efforts. Green bonds have become crucial in allocating funds to sustainable projects that support the global shift to a low carbon economy. On the other hand, Climate Policy Uncertainty (CPU) emphasizes the unpredictability arising from the government's actions on climate policies. It comprises elements like regulatory adjustments, changes in environmental commitments, and swings in enforcement policies that may impact the investor confidence. High CPU may deter green finance investment as it raises risk perception; however, a stable and certain policy regime can strengthen market trust and therefore increase the capital flow towards green investments.

The impact of climate policy uncertainty (CPU) on green bonds emerges as a significant and concerning driver for society and especially policy makers in the processes of economic and environmental policy construction for many interrelated reasons. These concerns arise from the increasing recognition of green bonds as significant financial instruments that provide funding for the projects focused on environmental sustainability. Primarily, green bonds are essential financial instruments as they support sustainable projects supporting society. Therefore, if the CPU has an effect that hinders the performance of green bonds, it may lead to a decrease in interest in supporting projects such as renewable energy, climate adaptation and change, and biodiversity conservation. To achieve environmental and sustainable goals, green finance should be effectively adapted to policy changes where it benefits society and other interested parties. Secondly, it is crucial for those designing and implementing climate policy to comprehend the impact of CPU on green bonds. In order to finance the shift to a low-carbon economy, policymakers must consider the impact that their choices will have on investor confidence and the attractiveness of green bonds. Sound policies that reduce uncertainty will boost green bonds' efficiency, attract additional funding, and accelerate the delivery of climate-related projects. It is worth noting that vague or often changing policies can impact the market, potentially deterring investors and jeopardizing the funding of key environmental initiatives. Thirdly, a better comprehension of the relationship between the CPU and the efficiency of green bonds would be beneficial for the academic community. Also, it provides clear insights into the ways in which policy variables impact financial markets and contributes to the corpus of knowledge on environmental finance. This paper aims to help in the development of risk assessment and financial product development models. We believe this paper will assist scholars in developing frameworks that could potentially mitigate the negative impacts of these uncertainties. Overall, this subject lies at the nexus of politics, environmental sustainability, and finance, making it a complicated yet important field of research. It is important to consider the potential impact of CPU on green bonds beyond the immediate financial implications. There is a possibility that the effect of CPU on green bonds may influence the pace and efficacy of global attempts to address climate change.

The goal of this study is to investigate the nexus between CPU and the green bond market. We wish to contribute to the literature on two fronts. First, the causality from CPU to green bond market is well documented in the literature. However, the vice versa is frequently disregarded. Strong returns on green bonds can signal to policymakers and the market that climate-related initiatives are both profitable and effective, potentially reducing CPU by affirming the direction of current policies, suggesting that the market is likely to be more inclined to design and implement stable, long-term climate policies. Therefore, this study intends to incorporate this overlooked aspect in understanding the role of green finance in CPU. Second, the structure of the CPU-green bond causality is not necessarily static and can differ by the continuous evolution of climate policies and the maturation of the green bond market, alongside fluctuating economic conditions and changing investor sentiments. This dynamic interplay leads to varying degrees of impact on green bond valuation and investor confidence over time. There are a limited number of attempts to discover the time-varying relationship between CPU and the green bond market. Yu *et al* (2023) report that the impact of CPU on the volatility of the green bond market is time-varying in China. Ren *et al* (2023) find that the CPU is more inclined to act as a risk recipient than a sender in the market volatility spillover in traditional energy, clean energy, and green bond markets. By applying the recently developed recursive evolving window test to the time-varying causality approach, we wish to contribute to the existing by examining the causality from the green bond market to CPU over time, alongside vice versa.

The remainder of the study is organised as follows: first, the relevant literature is reviewed, followed by a description of the model and data. Next the empirical methodology and findings are presented. Finally, the study culminates in policy implications and concluding remarks.

Literature review

Although the literature looking into the impact that the CPU has on stock markets has recently developed, there are a bulk of studies on this issue. Lasisi *et al* (2022) find that the US and UK stock markets significantly respond to CPU. Lv and Li (2023) report that the CPU has significant predictive power for energy, materials, industrials, consumer discretionary, health care, and the utility sectors of the Chinese stock market. Treepongkaruna *et al* (2023) find that CPU and cross-section returns of individual stocks are negatively related in the US. Xu *et al* (2023) find significant differences between the nonlinear and lag impacts of the CPU indices on stock markets while comparing the Chinese and the US markets. Chen *et al* (2023) find that CPU has a significant effect on stock price volatility in China. Hoque *et al* (2023) find that carbon allowances serve as a safe haven and hedging mechanism against climate transition risks in the US when CPU increases. Wang *et al* (2023) investigate the impact of climate policies on investment funds in China and find that the fund adoption of losers follows a high-carbon investment strategy whereas that of winners follows a green investment strategy. He and Zhang (2022) find that CPU can predict oil industry stock returns in the US. From a global perspective, Bouri *et al* (2022) find that the CPU is a significant factor in the performance of green stocks relative to brown stocks.

Given the well-known differences between stocks and bonds, particularly due to the nature of these instruments (investor base reasons, maturity and duration impact, credit risk assessment, market depth and liquidity, regulatory implications, etc), the bond market is likely to exhibit a distinct sensitivity to CPU, reflecting policy changes that affect interest rates and, consequently, bond yields. Notice also that green bonds serve as a signal of commitment to sustainability. CPU could disrupt this signaling effect, as uncertainty might deter issuers from engaging in such signaling or investors from trusting the signal due to policy instability. Furthermore, green bonds are essential for financing the transition to a sustainable economy. CPU could affect the scope and pace at which this transition can be financed, with implications for achieving international climate goals. In contrast to a well-researched body of work regarding the impact of CPU stock markets, the number of studies in the case of green bonds is relatively limited. For instance, Wang *et al* (2022) find that climate risk concerns increase for most firms after the issuance of green bonds in Taiwan. Tian *et al* (2022) show that only China's green bond is asymmetrically affected by CPU in the short run, while the asymmetric effects exhibited by the European green bond market are more extensive and share similar characteristics to the US in the long run. Husain *et al* (2022) find that the CPU provides a better explanation for green stock and bond market responsiveness than other uncertainty indices in the US. Given the scarcity of research on this issue, our motivation for this study is to provide global evidence of the relationship between CPU and the green bond market.

Data and model

This study utilizes the monthly time series data of the green bond returns and climate policy uncertainty index over the period 2013:M7–2023:M4. Green bond returns are calculated using the S&P Green Bond Index designed to track the global green bond market. The data on the CPU are obtained from the widely known CPU index developed by Gavriilidis (2021). Note that Gavriilidis (2021) follows the methodology introduced by Baker *et al* (2016), which led to the development of the Economic Policy Uncertainty (EPU) index. All data are seasonally adjusted. Following the existing literature, this study uses a univariate model described in equation (1).

$$gb = f(cpu) \tag{1}$$

where green bond returns are denoted by gb and climate policy uncertainty index is denoted by cpu.

Methodology and findings

Prior to causality, we conduct a unit root test to figure out whether the series contains a unit root. Note that all series are I(1) and stationary series are employed in the analysis[5]. Traditional Granger causality tests assume that causal relationships remain constant over the entire sample period, which can be problematic in dynamic environments where structural changes and varying external conditions may affect these relationships. The time-varying approach proposed by Shi *et al* (2018) and Shi *et al* (2020) specifically incorporates the recursive evolving window (REW) method, which offers flexibility in detecting changes in causality over time. In the REW approach, the starting and ending points of the regression window evolve recursively, allowing for the identification of time-specific causal relationships. This methodology is particularly advantageous in capturing causal shifts caused by events such as policy changes, economic crises, or technological advancements.

While the time-varying Granger causality approach provides valuable insights into the evolving relationship between climate policy uncertainty (CPU) and green bond returns, it is important to acknowledge its inherent limitations. Granger causality primarily assesses predictive relationships rather than establishing strict causal mechanisms. This means that the analysis identifies periods where predictive linkages are statistically significant.

The core of the approach involves calculating a sequence of Wald statistics over evolving sub-samples of data. The test statistic is then derived as the supremum of these calculated Wald statistics, enabling the detection of periods when causality emerges or dissipates. This framework is implemented using a lag-augmented VAR (LA-VAR) model, an extension of the traditional VAR model, to accommodate the presence of non-stationary processes, thereby ensuring robust and reliable hypothesis testing. The basic features of the recursive evolving window algorithm are shown in figure 1.

The MWald statistic, $W_{f_1}^{f_2}$, is obtained for each subsample regression with a sample size fraction of $f_w = f_2 - f_1 \geqslant f_0$. Then, the supremum of the MWald statistic sequence is defined as follows:

$$SW_f(f_0) = \sup_{f_2 = f, f_1 \in [0, f_2 - f_0]} W_{f_1}^{f_2} \tag{2}$$

The results obtained from the time-varying causality are illustrated in figure 2 and 3. For the minimum window size, 29 observations are considered. In estimating the LA-VAR model, the lag orders are assumed to be constant and selected using the Bayesian Information Criterion (BIC) with a maximum length of 8. The 5% bootstrapped critical values are obtained with 1000 repetitions and controlled over a five-day period[6].

The findings displayed in figure 2 suggest a negative causality from green bond returns to the CPU from December 2016 to December 2018. In addition, the findings illustrated in figure 3 display a negative causality relationship from the CPU to the green bond returns from December 2016 to November 2018. Overall, a bi-directional negative causal relationship between green bond returns and the CPU from December 2016 to

[5] The unit root results are not reported and they are available upon request.

[6] To ensure the robustness of our findings, we conducted additional analyses using alternative model specifications. Specifically, we tested scenarios where the window size was set to 23 and the lag length was determined using the Akaike Information Criterion (AIC). The results remained consistent with our primary findings, confirming the stability of the observed relationships. These additional results are provided in the appendix.

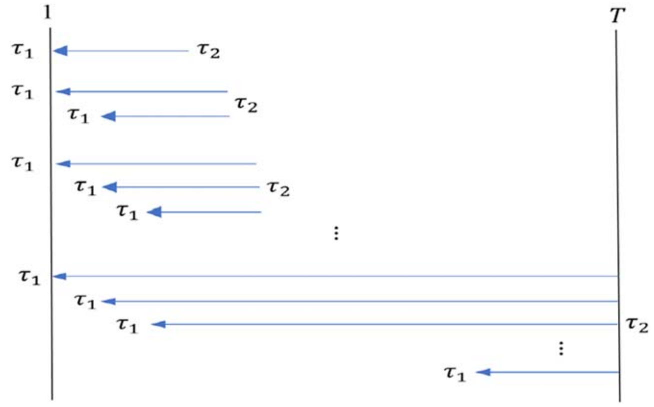

Figure 1. The recursive evolving window algorithmSource: Emirmahmutoglu *et al* (2021); Topcu *et al* (2021).

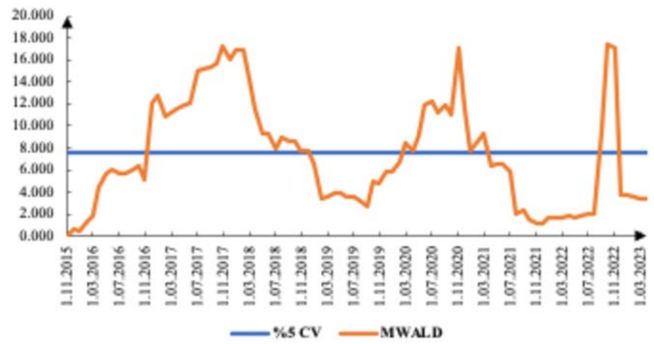

Figure 2. Time-varying Granger causality from gb to CPU.

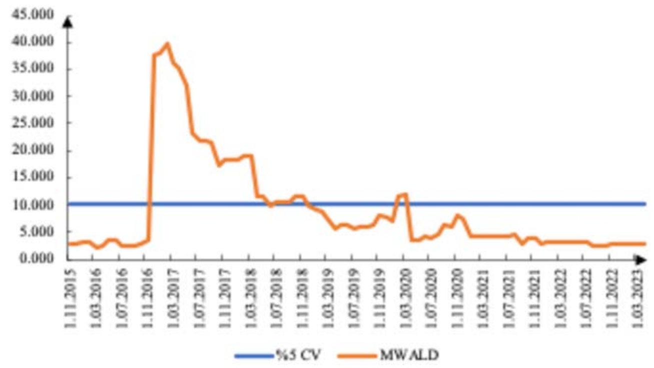

Figure 3. Time-varying Granger causality from CPU to gb.

December 2018 suggests that an increase in green bond returns may lead to a decrease in uncertainty in climate policies, whereas the reduction in policy uncertainty might have boosted investor confidence, enhancing green bond market performance. This reflects a synergy where financial market success in green initiatives contributes to clearer policy environments, which in turn support the financial markets. This interplay indicates that the positive financial performance of green bonds could have been seen as a successful indicator of sustainable investment, leading to more stability and predictability in climate policies.

The findings suggest that during the COVID-19 era, specifically from March 2020 to March 2021, increases in green bond returns are associated with an increase in the CPU. This period was also differentiates by high financial market volatility, as well as, uncertainty regarding the stimulus driven climate policies, and a change in investor sentiment toward sustainable assets. This increase in CPU may reflect investor concerns over the evolving regulatory responses and the long term policy commitments results of the crisis. Note that the positive causality could imply that as investors saw better returns from green bonds—perhaps due to increased interest in sustainable investments and the anxiety in financial markets during the pandemic (Apergis 2023)—this may have heightened uncertainty about climate policies[7]. This could be due to policymakers reacting to the financial market's shifts, potential speculations about future regulations, or increased attention on sustainability issues that could lead to new or amended policies. This period was marked by significant global disruptions, and these findings highlight how financial markets can influence policy landscapes, particularly in environmentally sensitive areas.

Policy implications

The negative sign of causality between green bond returns and the CPU during December 2016 to December 2018 could be interpreted in the context of significant global and environmental policy developments at that time. Notably, this period was marked by the initial years following the Paris Agreement on climate change (adopted in December 2015), which may have led to increased investor confidence and a surge in green bond investments. As these investments performed well, they likely contributed to a clearer and more stable policy environment, reducing uncertainty around climate policies. This scenario suggests that successful green finance initiatives can play a role in stabilizing policy landscapes by reinforcing the economic viability and benefits of adhering to environmental agreements.

A demonstrated influence of green bond returns on reducing CPU could incentivize more sustainable investment by illustrating that such investments contribute to a more stable policy landscape, thus fostering a virtuous cycle of investment and policy clarity.

Exploring this causal direction is also important for the development of the green bond market itself. If green bond returns are found to influence CPU, it could encourage a more proactive role for green finance in shaping climate policy discourse and development.

Conclusion

This study investigates the dynamic relationship between CPU and the performance of green bond markets. The findings reveal a bi-directional negative causality over the episode December 2016 - December 2018, indicating the reinforcing effect of stable and profitable green investments on policy environments, leading to more predictable and supportive climate policies. Moreover, the episode during the COVID-19 period identified a shift to a positive causality, where heightened returns from green bonds were associated with increased policy uncertainty, suggesting that during periods of market disruptions, successful green bond investments may raise questions about future regulatory responses, thereby increasing uncertainty.

Overall, the study underscores the importance of considering the evolving and time-varying nature of the CPU-green bond nexus. Policymakers should take note of how market signals from green investments can either stabilize or destabilize the policy environment. The findings suggest that fostering consistent and supportive policies for green finance is essential to harness the full potential of green bonds as drivers of environmental sustainability and economic growth.

Our approach delivers important findings about these shifting relationships but presents several key limitations. First, Granger causality shows predictive relationships instead of definitive causal mechanisms so interpretations require careful consideration of these limitations. Second, the presence of confounding factors including broader economic shocks, investor risk perceptions, and policy intervention suggests that other models (e.g., structural models or instrumental variable techniques) could further refine our findings to understand these relationships more precisely. Lastly, the directionality of the relationship, particularly during the COVID-19 era, remains complex. Our results reveal that green bond returns may affect CPU but we need to investigate whether the opposite relationship also exists to understand the underlying causes of this link.

This study calls for future research which should apply alternative methodologies for stronger causal analysis and evaluate the impact of external shocks on green finance markets across different periods. Policymakers need to understand these dynamic insights to create stable and sustainable financial systems that minimize market risks while effectively supporting environment-focused climate initiatives and promoting sustainable finance. In addition, future research should also continue to explore these dynamic relationships, especially in the context of global transitions towards low-carbon economies and the impact of unforeseen events like pandemics.

[7] The heightened uncertainty about climate policies, in response to better returns from green bonds during the pandemic, could be due to several factors. First, the surge in green bond performance might lead to anticipations of more stringent future environmental regulations, as policymakers see financial markets responding positively to green investments. Additionally, increased returns might foster speculation about shifts in policy direction or the introduction of new regulations aimed at further promoting sustainable practices, thereby creating uncertainty about the exact nature of these potential changes.

Data availability statement

The data cannot be made publicly available upon publication because the cost of preparing, depositing and hosting the data would be prohibitive within the terms of this research project. The data that support the findings of this study are available upon reasonable request from the authors.

Appendix

Window size	Lag criteria	from gb to CPU	from CPU to gb
29	BIC	December 2016—December 2018 (−) March 2020—March 2021 (+) September 2022—November 2022 (−)	December 2016—December 2018 (−) February 2020—March 2020 (−)
23		December 2016—May 2018 (−) May 2020—December 2020 (+) April 2022 - November 2022 (−)	December 2016—March 2018 (−) October 2019—Janaury 2020 (−)
29	AIC	June 2016—October 2016 (−) March 2017—March 2018 (−) October 2020—December 2020 (+) September 2022—November 2022 (−)	December 2016—June 2017 (−) January 2020—March 2020 (−)
23		August 2017—March 2018 (−) June 2020—December 2020 (+)	December 2016—February 2017 (−) October 2019—January 2020 (−)

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