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RÉSUMÉ

Trois Essais Sur La Finance Climatique

La lutte contre le changement climatique nécessite des innovations technologiques et financières. Étant donné que les entreprises doivent réaliser d'importants investissements, deux problèmes fondamentaux en finance, à savoir les contraintes de financement et les conflits d'agence, se posent. La présente thèse examine comment le financement par obligations vertes et une bonne gouvernance peuvent aider les entreprises à lutter contre le changement climatique. Elle comprend trois essais.

Les obligations vertes, dont le produit d'émission sert à financer uniquement des projets respectueux de l'environnement, font partie des innovations financières liées au changement climatique. L'essai 1 examine la performance financière et environnementale à long terme des entreprises suite à l'émission d'obligations vertes. Il adopte une approche événementielle et effectue des tests de robustesse en utilisant la méthode calendaire. Contrairement aux études sur les obligations conventionnelles, les résultats révèlent que les entreprises qui ont émis à plusieurs reprises et les émettrices opérant dans des secteurs caractérisés par une forte matérialité environnementale, réalisent une performance boursière à long terme relativement aux firmes de contrôle. Ce qui indique la sous-réaction des cours des actions des émettrices à l'annonce des émissions d'obligations vertes. Les marchés financiers ne sont donc pas efficients compte tenu des possibilités de greenwashing. L'étude montre également que les émettrices réduisent leurs émissions de CO_2, améliorent leur efficacité en matière d'utilisation de ressources et leurs performances environnementales après l'émission, et sont les plus éco-innovantes. Les résultats invalident l'hypothèse du greenwashing et soutiennent que les entreprises signalent leur engagement envers l'environnement en émettant des obligations vertes. Dans l'ensemble, l'émission d'obligations vertes d'entreprises est bénéfique pour les investisseurs existants et pour la société.

L'adaptation des entreprises au changement climatique nécessite des innovations technologiques. L'essai 2 exploite le modèle d'investissement q de Tobin pour examiner la relation entre la gouvernance d'entreprise et l'innovation verte. L'étude postule qu'une bonne gouvernance crée des conditions favorables à l'innovation, telles que l'accès au financement externe et la réduction des problèmes d'aléa moral. En utilisant le GMM en système sur un échantillon de 3 896 entreprises de 45 pays sur 2002 à 2021, l'étude montre que plus la gouvernance d'une entreprise est bonne, plus elle investit dans la R&D verte. L'étude montre également qu'une augmentation du score de chaque dimension (management, stratégie et actionnariat) de la gouvernance d'entreprise entraîne une augmentation de la probabilité d'innovation de produits verts. Les résultats suggèrent que les mécanismes de gouvernance aident à résoudre les conflits d'agence associés à l'innovation verte.

Enfin, en prévision de réglementations environnementales très strictes et de risque carbone, les entreprises bien gouvernées peuvent investir dans des technologies peu polluantes ou opter pour une énergie propre. L'essai 3 examine la relation entre les mécanismes de gouvernance d'entreprise et la transition vers les énergies renouvelables (ER). Il a adopté un modèle de panel, suivi de tests de robustesse à l'aide de méthodes alternatives. Les modèles probit bivarié et probit bivarié récursif sont utilisés pour analyser l'interaction entre la décision d'utiliser et la décision de produire des ER. L'analyse est basée sur un échantillon de 3 896 entreprises couvrant 45 pays à travers le monde. Les résultats révèlent que les entreprises dotées de mécanismes de gouvernance appropriés sont les plus susceptibles de produire et d'utiliser des ER. Enfin, alors que l'utilisation des ER a un impact positif sur la valeur boursière et la performance environnementale des entreprises, elle n'a pas d'effet significatif sur la profitabilité actuelle. Ainsi, les investisseurs considèrent-ils l'utilisation des ER comme un avantage concurrentiel et anticipent la performance financière future de l'entreprise. Dans l'ensemble, les résultats suggèrent que la transition vers les énergies renouvelables nécessite avant tout la mise en place de mécanismes de gouvernance appropriés au sein des entreprises.

Mots clés : Risque de changement climatique, Finance durable, Investissement durable, Obligations vertes, Innovation verte, Transition énergétique, Conflits d'agence, Gouvernance d'entreprise.

ABSTRACT

Three Essays on Climate Finance

Technological and financial innovations are essential to address climate change. Since firms must implement considerable investments, two fundamental problems in finance, namely, financing constraints and agency conflicts, arise. The present thesis examines how green bond financing and stronger corporate governance may help firms address climate change. It includes three essays.

Green bonds, the proceeds of which finance climate-friendly projects only, are part of the financial innovations related to climate change. Essay 1 examines the long-run financial and environmental performance of corporations following green bond issuance. It adopts an event-time approach and conducts robustness tests using the calendar-time method. In contrast with the earlier studies on conventional bond offerings, the results reveal that multiple-time issuers and issuers operating in industries where the natural environment is financially material, perform financially in the long term relative to the control firms. The long-run excess return is consistent with issuer stock prices under-reacting to the green bond issuance announcement. Given the suspicions of greenwashing, the stock markets are not efficient. The study also documents that corporate green bond issuers reduce their CO_2 emissions and improve their resource use efficiency and environmental performance, post-issuance; and are the most eco-innovative. The findings invalidate the greenwashing hypothesis and support the signaling view that firms signal their commitment toward the environment by issuing green bonds. Overall, corporate green bond issuance is beneficial for existing investors and society.

Corporate adaptation to climate change requires technological innovations. Essay 2 exploits Tobin's q model of investment to examine the relationship between corporate governance and green innovation. It assumes stronger governance creates favorable conditions for innovation, such as access to external financing and reducing moral hazard problems. Using the system GMM on a sample of 3,896 firms from 2002-2021, covering 45 countries worldwide, we find that the better the corporate governance, the more the firm invests in green R&D. The study also documents that an increase in the score of each dimension (management, strategy, and shareholder) of corporate governance results in an increase in the probability of green product innovation. The findings suggest that governance mechanisms help resolve agency conflicts associated with green innovation.

Finally, in anticipation of stronger environmental regulations and carbon risks, well-governed firms may invest in low-polluting technologies or opt for clean energy. Essay 3 examines the relationship between corporate governance mechanisms and renewable energy (RE) transition. It employed an econometric framework of a panel model, followed by the robustness check using alternative methods, including logit regressions. The bivariate probit and recursive bivariate probit models are adopted to analyze the interaction between the decision to use and the decision to produce RE. The analysis is based on a sample of 3,896 firms covering 45 countries worldwide. The results reveal that firms with appropriate governance mechanisms are more likely to produce and use RE than others. Finally, while RE use positively impacts firms' market value and environmental performance, we find no significant effect on current profitability. Thus, investors view RE use as a competitive advantage and anticipate the firm's future financial performance. Overall, the findings suggest that RE transition requires, first of all, establishing appropriate governance mechanisms within companies.

Keywords: Climate change risk, Sustainable finance, Sustainable investing, Green bonds, Green innovation, Renewable energy transition, Agency conflicts, Corporate governance.

DEDICATION / DÉDICACE

To my family / À ma famille

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INTRODUCTION

Climate change, a costly negative externality imposed on society (Nordhaus, 2019; Shive and Forster, 2020), is gaining increasing attention worldwide. The finance literature considers it a risk factor (Baldauf *et al.*, 2020; Bansal *et al.*, 2017; Balvers *et al.*, 2017). Climate change is the change in the statistical distribution of future weather patterns with potentially devastating economic consequences and falls into the second category of long-run risks (Nordhaus, 1977; Baldauf *et al.*, 2020). The literature relies on the damage function to incorporate the effects of climate change on economic outcomes (Balvers *et al.*, 2017). Climate shocks act as a systematic negative productivity shock (Balvers *et al.*, 2017; Nordhaus, 1977, 2019). Specifically, low climate change risk in terms of percentage means significant losses in dollars (Painter, 2020). The financial consequences of climate change can be categorized into production, reputation, regulatory, physical, and technological climate risks (Krueger *et al.*, 2020; Painter, 2020). Climate change risk is related to decisions and decision-makers (Beck, 2015). Those who produce this risk are not necessarily the most affected.

Climate change risks have an uneven impact since all countries and industries are not equally affected by climate shocks (Andersson *et al.,* 2016). Some sectors and geographical areas are more vulnerable because they have high exposure to climate events (Balvers *et al.,* 2017). In Nordhaus (2019) analysis, the theory of public goods applies to climate change. Climate change is viewed as a global negative externality whose impacts are indivisibly spread worldwide. Nordhaus (2019) considers global externalities different from national public goods because they resist the control of markets and national governments. For global public goods like climate, the free-riding problem arises because individual nations enjoy only a small fraction of the benefits of their actions. Consequently, as Andersson *et al.* (2016) stated, introducing a new regulation gives rise to policy debates between the losers, who exaggerate the costs, and the winners, who emphasize the urgency of the new policy.

In the financial literature, climate change risk is modeled in several ways. These include structural and non-structural approaches as well as continuous-time designs. Barnett *et al.* (2020) apply continuous-time decision theory and asset pricing tools to model the economic impacts of uncertainty induced by climate change. They show that ambiguity aversion and aversion to model misspecification increase the estimates of the social cost of carbon. Their model consists of an information structure and the evolution of endogenous state variables, including reserves, cumulative emissions, capital, and environmental damages, along with societal preferences. It provides important implications for asset pricing and climate risk management. Concerning asset pricing, the temperature-augmented long-run risk model of Bansal *et al.* (2017) implies that climate change risk is a bigger concern for long-term investors, who are more likely to suffer the consequences of adverse climate risk realizations. In the model, climate change risk acquires a positive premium, reflected in the prices of equities and real estate. Temperature risks affect aggregate wealth and asset valuations through the variation in expected growth rates and discount rates.

Climate change risk and real estate prices

Unsurprisingly, climate change risk negatively affects stock prices, real estate prices, and investment and financing decisions of corporations. Murfin and Spiegel (2020) noticed that sea level changes have dramatic consequences across many industries and should directly affect the value of coastal real estate since these risks are priced. Using a hedonic model, Baldauf *et al.* (2020) echo Bernstein *et al.* (2019), who previously documented that homes exposed to the sea level rise sell approximately for 7% less than observably equivalent unexposed properties equidistant from the beach. More interesting, they find that in the absence of flood risks and projected damage due to climate change, homes closer to the coast may be more valuable due to the amenity values of being close to the coast or having waterfront views. Giglio *et al.* (2021) report a 2% to 3% relative decrease in the prices of properties in the flood zone compared to similar properties in the same zip code when the climate attention index doubles. Consequently, house prices reflect heterogeneity in beliefs about long-run climate change risks.

Climate change risk and stock prices

Like real estate, climate risks impact stock prices and portfolio companies. Choi *et al.* (2020) consider three channels by which these effects arrive. First, climate-unfriendly firms may be fundamentally damaged. Second, people may update their valuation of firms when they revise their beliefs about climate change upward. For instance, investors may think that high-emission firms' future cash-flows are adversely affected because climate change can hurt firms' production functions, impose higher costs for future emissions, or induce tighter regulations on emissions. Third, on recognizing the risk of climate change, socially responsible investors may stay away from climate-unfriendly firms. Krueger *et al.* (2020) point out that climate risks can affect investors' portfolio firms in several ways. First, some firms face direct costs related to climate change, originating from extreme weather events or a sea level rise. For instance, insurance firms are exposed to higher losses from insured properties in coastal areas, and food producers are exposed to sustained drought spells. Second, certain firms can be negatively affected by policies and regulations implemented to combat climate change. Finally, technological innovations related to climate change also threaten the business models of portfolio firms that operate in traditional industries. On the other hand, the authors remark that climate change provides investment opportunities, for instance, in green innovation, renewable energy, or energy storage.

Empirical studies also show how climate change risk affects asset prices. Using a structural and non-structural approach, Balvers *et al.* (2017) find a significantly negative risk premium for the temperature shock factor (TSF) in the U.S equity markets. The coefficient estimated is -0.01% for CAPM+TSF and -0.02% for Fama-French+TSF. Hong *et al.* (2019) show that the long-run effect of climate change, as proxied by the drought trend, negatively affects stock prices in the food industry. In addition, the excess return predictability is consistent with food stock prices under-reacting to climate-change risks. Thus, the stock markets are inefficient with respect to information about drought trends. Concerning carbon risk, Choi *et al.* (2020) document that stocks of carbon-intensive firms underperform firms with low carbon emissions in the month in which the exchange city is warmer than usual. As a result, retail investors sell high-emission firms and buy low-emission firms when attention to climate change increases. Thus, unusually warm weather is a salient event that affects individual investors.

In Krueger *et al.* (2020) survey, investors worry about the financial costs of climate change risks and believe that equity valuations do not fully reflect the climate change risks. Regarding portfolio decisions, Alok *et al.* (2020) document that fund managers overreact to climatic disasters that happen close to them, underweighting disaster zone stocks greater than distant mutual fund managers. Especially, the funds close to the disaster zone reduce their portfolio weights on disaster zone stocks by approximately 0.09%, compared to the reduction in weight by funds far from the disaster zone. This translates into a 1.5% drop in the dollar value of each disaster stock. A portfolio that goes long on the disaster zone stocks that experience the sharpest reduction in weights in portfolios of close funds and goes short on the stocks that experience the least reduction generates statistically and economically significant positive risk-adjusted returns after the disaster. Thus, climate risk misestimation is costly to the fund investors. Bernile *et al.* (2021) use the differences-in-differences approach to examine the portfolio risk attitudes of U.S-based mutual funds that invest abroad. They find that these managers become more risk-averse after a catastrophic experience. The monthly fund return volatility decreases by 60 bps in year 1, and the effect disappears in year 3.

Climate change risk and financial decisions

Because of its negative impact on stock prices and portfolio companies, climate change risk also affects the cost of capital and financial decisions. In the analysis of Li *et al.* (2014), the emissions reduction plans of the governments generate extra carbon-related costs that affect firms' cost of capital. Indeed, debt holders will be reluctant to bear emission costs and may require higher interest rates or more stringent debt covenants to mitigate the extra risks related to emissions. The equity owners, to absorb carbon-related costs, need a higher required rate of return on their investments. In the APT model in which climate change risk is a systematic risk factor, Balvers *et al.* (2017) find that the annual weighted average increases in the cost of equity capital attributed to uncertainty about climate shocks are 0.22%, implying a present value loss of 7.92% of wealth. Kim *et al.* (2015) show that a 10% increase in carbon intensity results in a 0.79% increase in the cost of equity capital. Li *et al.* (2014) document that carbon risk is associated with an increase in the cost of capital, including the cost of debt and equity.

In the bond market, Painter (2020) finds that investors and underwriters require a premium to accept climate change risk, resulting in an average rise in total annualized issuance costs of $1.7 million for the average county in the municipal bond market. Zerbib (2019) uses green bonds as an instrument to identify the impact of pro-environmental preferences on bond prices and finds a significant negative bond premium, suggesting that the lower cost of debt for firms with good environmental performances should be more related to a lower level of risk than to non-pecuniary motives.

Consistent with salience theories of choice, Dessaint and Matray (2017) document that the managers of unaffected firms respond to hurricanes that occur in their proximity by increasing corporate cash holdings by 1.1 percentage points of total assets relative to firms farther away. This represents an average increase in cash of $15 million and accounts for 10% of the within-firm standard deviation of cash holdings. According to the authors, this cash holding is inefficient and costly for firms. Finally, Balachandran and Nguyen (2018) found a reduction in both the propensity to pay dividends and the level of dividend payouts after the Kyoto Protocol ratification (in Australia in December 2007) for polluters compared to non-polluters. They also show that the post-Kyoto reduction in the dividend payout of polluters is driven by the relative increase in earnings uncertainty. Thus, the authors conclude that carbon risk negatively impacts earnings stability, decreasing dividend payouts. Firms exposed to high carbon risk will attract fewer investors.

Hedging problem of climate change risk

One of the major financial challenges posed by climate change risks is hedging. Since uncertainty around the trajectory and the economic consequences of climate change are substantial, investors may desire products that hedge against climate risk (Engle *et al.*, 2020). However, climate change risk is hard to price and hedge (Andersson *et al.*, 2016; Engle *et al.*, 2020). As Engle *et al.* (2020) noticed, standard futures or insurance contracts are difficult to implement because of the long-run and non-diversifiable nature of climate risk. No counterparty could credibly guarantee to pay claims during a climatic disaster because a bad outcome would mandate all contracts to be paid simultaneously. Therefore, individual investors are constrained to self-insure (Engle *et al.*, 2020). Andersson *et al.* (2016) point out that one of the main challenges for long-term investors is the uncertainty concerning the timing of climate mitigation policies. For instance, an asset manager looking to hedge climate risk by divesting from stocks with high carbon footprints bears the risk of underperforming his benchmark for as long as climate mitigation policies are postponed, and market expectations about their introduction are low. In the model of Engle *et al.* (2020), news about physical damages from climate change and news about regulatory risks related to climate change are two risks that move independently from each other. Therefore, the first challenge is to construct a time series that captures news about long-run climate risk and which can help construct an appropriate hedge target.

Policies and governance mechanisms against climate change

Given the irreversible nature and devastating consequences of climate change, there is an urgent need to act by tackling its fundamental causes. Since greenhouse gas (GHG) emissions are the primary cause of climate change (Yu *et al.*, 2022; Flammer, 2021), the urgency of limiting global warming has encouraged countries worldwide to transition toward low-carbon economies (Zhu *et al.*, 2022). In that regard, technological innovations related to climate change (Krueger *et al.*, 2020; Amore and Bennedsen, 2016), developing clean energy (Wang, 2022; Yu *et al.*, 2022), governance mechanisms (Shive and Forster, 2020; Amore and Bennedsen, 2016), and green bond funding (Flammer, 2021; Fatica and Panzica, 2021), play an essential role in climate action. Regulatory policies, international commitments, and stakeholder awareness regarding climate issues also conduct firms to limit their emissions (Dogan *et al.*, 2022). Indeed, the United Nations Framework Convention on Climate Change (UNFCC), signed at the Earth Summit in Rio de Janeiro in 1992, is the primary international, intergovernmental forum for negotiating the global response to climate change. The United Nations' Sustainable Development Goals (SDGs) -Goal 13- recommends integrating climate change measures into national policies, strategies, and planning. The Paris Agreement plans to contain global warming by 2100. In line with the 26th United Nations (U.N) Climate Change Conference in Glasgow (COP26), countries reaffirmed the Paris Agreement goal of limiting the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit it to 1.5 °C. In addition, financial institutions announced moves to realign trillions of dollars towards achieving global net zero emissions[1].

Given that firms must make important investments to address climate change, two well-known problems in finance arise: financing constraints and agency problems associated with corporate short-termism (Hong *et al.*, 2020). With emissions-reducing legislation, as well as increasing pressure from stakeholders, firms will be required to measure, disclose, monitor, and reduce their CO_2 emissions (Li *et al.*, 2014). However, localized policies aimed at mitigating climate change risk can have unintended consequences due to regulatory arbitrage by firms. For instance, Bartram *et al.* (2022) find that the 2013 California cap-and-trade rule has spillover effects across the U.S.A due to firm financial constraints. Specifically, the authors document that financially constrained firms shift emissions and plant ownership from California to other states. So, while financially constrained firms reduce greenhouse gas emissions from plants in California by 35%, they significantly increase emissions from plants in other states by 29% more than those owned by firms without a presence in California. Overall, neither constrained nor unconstrained firms reduce significantly their total emissions in response to the new regulation (Bartram *et al.*, 2022). This suggests that internal factors

[1] Climate action- COP26: Together for our planet. United Nations https://www.un.org/en/climatechange/cop26

within firms can constitute an obstacle to climate strategies and the necessity to consider factors specific to the firms.

As corporations and managers are utility maximizers (Ferrell *et al.*, 2016), investing in climate protection must combine both financial and environmental performance to be worth achieving (Schoenmaker and Schramade, 2018). Firms will be incited to invest in environmental protection if they are not financially constrained and if these investments do not negatively impact profitability. Along this line, empirical studies report that environmental degradation is driven by lower investment in green technologies due to financial constraints (Akey and Appel, 2021; Xu and Kim, 2022), and inadequate governance mechanisms (Hong *et al.,* 2016; Shive and Forster, 2020). For instance, Xu and Kim (2022) point out the externalities of financial constraints in the form of environmental pollution. Specifically, the authors document that firms reduce emission abatement expenditures when facing financial constraints because their environmental protection costs increase. In addition, they find evidence that relaxing financial constraints reduces U.S public firms' emissions while the effects of financial constraints on pollution are amplified when regulatory enforcement and external monitoring weaken. Akey and Appel (2021) report that the moral hazard problem associated with limited liability generally results in lower investment in emission abatement technologies and, hence, the increase in pollution, suggesting the importance of effective corporate governance mechanisms.

Appropriate governance mechanisms help firms reduce environmental pollution. Using data on U.S firms, Atif *et al.* (2020) show that gender-diverse boards are beneficial in terms of greater renewable energy (RE) consumption, and the interaction between RE consumption and board gender diversity has a positive effect on firm financial performance. Hart and Zingales (2017) modeled prosocial behavior by focusing on non-separable activities, where profit and damage are connected. The model integrates the dimensions of corporate social responsibility related to climate change, and how corporate governance can reduce firm-level externalities. In the model, the externality is not separable from firm money-making activities. Consequently, one way to maximize shareholder welfare is to let shareholders vote on the broad outlines of corporate policy. An investor may vote for a company to adopt a "clean" rather than a "dirty" technology even if this reduces profit, but will be willing to hold shares in a "dirty" company if he/she is not responsible for the decision. This governance mechanism implies that firms and asset managers should pursue policies consistent with the preferences of their investors.

Regarding firm ownership, Shive and Forster (2020) show that independent private firms pollute less and are less likely to incur environmental penalties than public firms. Within public firms, they find a negative association between emissions and mutual fund ownership and board size. The authors conclude that the increased oversight could drive reduced emissions. As remarked by Hong *et al.* (2020), these results suggest that agency and horizon considerations may affect corporations' climate change strategies. This implies considering governance mechanisms and financing methods when examining firm environmental policies.

Research question and objective

Climate change mitigation involves investing in green technologies, and financing environmental innovation and projects. Hong *et al.* (2020) consider that agency conflicts and financial constraint considerations can result in less-than-required investment to address climate change. Agency costs and financial market frictions affect corporate investment and are fundamental factors in innovation activities (O'Connor and Rafferty, 2012). In general, innovation and research and development (R&D) activities face a severe problem of asymmetric information and uncertainty, making investments in innovative projects hard to value by the financial markets (Howell, 2017). Hence, the nature of the innovative activity itself poses a specific problem of financing.

Gompers *et al.* (2003) point out the role of corporate governance in firm investment. They argue that without monitoring and incentive-based mechanisms, managers tend to undertake inefficient projects for their private interest. Ferrell *et al.* (2016) find well-governed firms more likely to promote efforts to help protect the environment. Hong *et al.* (2016) provide evidence identifying corporate governance as a determinant of managerial incentives for environmental performance. In addition, innovation that is beneficial for the environment depends on the quality of firm internal governance and the availability of financial resources (Amore and Bennedsen, 2016). By limiting agency conflicts, effective corporate governance favors efficiency, facilitates access to external financing, including green bond funding, and may encourage environmental innovation and the transition toward a low-carbon economy. ***Therefore, this thesis aims to show how effective corporate governance and green bond financing can favor the low-carbon economic transition***. Specifically, it tends to answer the following questions: *Do the firms' financial and environmental performance increase in the* *years following green bond issuances? How does corporate governance affect green innovation? How do corporate governance mechanisms affect renewable energy transition?*

The present thesis focuses on corporate and financial innovation related to climate change. It consists of three essays on climate finance. According to Hong *et al.* (2020), climate finance is about investments that governments, corporations, and households must undertake to transition the economy to a low-carbon path, reduce greenhouse gas emissions, and build the resilience of countries to climate change. It covers various topics, including, among others, the risks of stranded assets for energy and carbon-intensive firms and industries; the building of hedge portfolios of climate state variables; understanding a firm's climate risk exposures based on sparse corporate disclosures or environmental ratings by agencies; agency, governance, and general incentive problems that might affect corporate climate action and climate risk management (Hong *et al.,* 2020). The latter is the central topic of this thesis.

Financial innovations are necessary to fund corporate environmental innovations and projects (Hong *et al.,* 2020). One of these financial innovations, green bonds, already exists (Zerbib, 2019; Tang and Zhang, 2020). Green bonds are similar to conventional ones, except that their proceeds finance only climate-friendly projects (Flammer. 2021). Essay 1 of the present thesis examines the long-run financial and environmental performance of corporations following green bond issuance. It assumes that well-governed firms are less exposed to agency conflicts, less financially constrained, and may easily finance their environmental innovation and projects by issuing green bonds. Corporate green bond financing may help them reduce their emissions in the long term while improving their financial performance, compared to similar firms that do not issue green bonds. The data analyzed includes 259 corporate green bond issuers from 2013 to 2020. The event-time approach is used to examine corporate green bond issuers' long-run stock market performance, and robustness tests are conducted using the calendar-time method. The difference-in-differences approach is used to explore the issuers' environmental performance, CO_2 emissions, and resource use.

In contrast with the earlier long-run event studies, the results reveal that multiple-time issuers and issuers operating in industries where the natural environment is financially material, perform well financially in the long term relative to the control firms. The continuation of positive abnormal returns from the announcement period into the post-event period suggests that the stock markets underreacted to the information in the announcement of corporate green bond issuances. Markets are not efficient given the suspicions of greenwashing. The study also documents that corporate green bond issuers reduce their CO_2 emissions and improve their resource use efficiency and environmental performance, post-issuance. Green bond issuers are also the most eco-innovative. To the best of our knowledge, this is the first study examining the long-run effect of green bond issuance on firms' stock market performance. It has the particularity to document that corporate green bond issuance is beneficial for investors and society. The findings help us understand that firms do not issue green bonds for greenwashing.

Corporate adaptation to climate change requires investment, particularly in technological innovations related to climate change and renewable energy. Essay 2 exploits the rich literature in corporate finance on innovation to examine how corporate governance can affect green innovation. Green innovation is the primary tool for reducing firms' negative environmental externalities through developing green technologies, services, processes, and eco-friendly products (Chen *et al.*, 2018; Zhang and Zhu, 2019). These include innovation in energy-saving technologies, pollution prevention, waste recycling, green product design, and corporate environmental management (Albort-Morant *et al.*, 2016; Zhang and Zhu, 2019). Essay 2 exploits Tobin's q model of investment to examine the relationship between corporate governance and green innovation. It assumes that stronger governance creates favorable conditions for innovation, such as access to external financing and the reduction of moral hazard problems.

The study is based on a sample of 3,896 firms from 2002-2021, covering 45 countries worldwide. It employs the system-GMM to analyze the causal effect. The results reveal that the better the corporate governance, the more the firm invests in green R&D. In addition, an increase in the score of each dimension (strategy, management, and shareholder) of corporate governance results in an increase in the probability of green product innovation. Finally, green innovation is positively related to firm environmental performance, including emission reduction and resource use efficiency. The findings provide implications to support managers and policy-makers on how to improve sustainability through corporate governance. Governance mechanisms will help resolve agency problems and, in turn, encourage green innovation. The present study helps achieve one of the precious U.N's SDGs: Goal 13 on climate action. Overall, the results suggest that stronger corporate governance is necessary for environmental efficiency.

Finally, as the energy sector is responsible for most global emissions, developing clean energy is crucial to combat climate change. High-emission companies may face divestment campaigns in conjunction with environmental regulations that may negatively affect their financial stability (Hong *et al.,* 2020). In addition, investors who anticipate the negative impact of future CO_2 emission regulations on firms' financial performance can divest from traditionally polluting sectors or polluting firms. The regulatory risk associated with a potential divestment campaign by environmentalists can result in the financial instability of polluting companies. In anticipation of these risks, well-governed firms can invest in low-polluting technologies or opt for green energy sources.

Essay 3 of the current thesis examines the relationship between corporate governance mechanisms and renewable energy transition. The study adopts an econometric framework of a panel model, followed by the robustness check using alternative methods, including logit regressions. The bivariate probit and recursive bivariate probit models are used to analyze the interaction between the decision to use and the decision to produce RE. The analysis is based on a sample of 3,896 firms covering 45 countries worldwide. The results reveal that firms with appropriate governance mechanisms are more likely to produce and use RE than others. Finally, while RE use positively impacts firm value and environmental performance, we find no significant effect on current profitability. Overall, the findings suggest that RE transition requires, first of all, establishing appropriate governance mechanisms within companies.

CHAPTER -I

Long-run Performance Following Corporate Green Bond Issuance

Abstract

Green bonds, the proceeds of which finance climate-friendly projects only, have become more prevalent as a new instrument in climate finance. This study examines the long-run financial and environmental performance of corporate green bond issuers, from 2013 to 2020. It adopts an event-time approach, and conducts robustness tests using the calendar-time method. In contrast with the earlier studies on conventional bond offerings, the results reveal that green bond issuance is followed by the stock market performance of issuers, over 1-year and 3-year, post-issuance. However, this performance is not due to the higher profitability of the issuers. In addition, the long-run stock market performance is limited to multiple-time issuers and issuers operating in industries where the natural environment is financially material. The long-run excess return is consistent with issuer stock prices under-reacting to the green bond issuance announcement. The stock markets are not efficient given the suspicions of greenwashing. Using the difference-in-differences method, the study documents that the issuers reduce their CO_2 emissions, improve their resource use efficiency and environmental performance, post-issuance; and are the most eco-innovative. The findings invalidate the greenwashing hypothesis and support the signaling view that firms signal their commitment toward the environment by issuing green bonds. Overall, corporate green bond issuance is beneficial for existing investors and society.

Keywords: Climate change risk, Sustainable investing, Sustainable finance, Green bonds

JEL classification: G14 - G32 - M14 - Q56

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1. Introduction

Climate change is one of the most crucial issues faced by people and governments worldwide (Beck, 2015). For firms and investors, it was considered a long-run risk (Baldauf et *al.,* 2020). Greenhouse gas emissions are a major cause of climate change (Atif et *al.,* 2020). Since the 2015 United Nations Climate Change Conference, the low-carbon transition has become the objective of global environmental governance (Cui et *al*., 2021). Environmental impact is considered an essential factor that determines new business opportunities and portfolio decisions for institutional investors (Baulkaran, 2019). This development could explain the growth of green bonds in recent years as a new instrument of sustainable finance.

Green bonds are similar to standard bonds, except that their proceeds are used to finance environmental and climate-friendly projects, such as renewable energy, green buildings, resource conservation, and so on (Baulkaran, 2019; Flammer, 2021). The literature focuses first on the pricing and the cost of green bond financing. Some studies find no green premium, indicating that investors view green and non-green securities by the same issuer as almost exact substitutes (Larcker and Watts, 2020; Tang and Zhang, 2020; Flammer, 2021). Others point out the existence of a negative yield differential in favor of green bonds compared with conventional bonds of the same firm (Gianfrate and Peri, 2019; Zerbib, 2019; MacAskill et *al*., 2021). As determining factors of green bond premium, empirical research identified the pro-environmental preferences (Zerbib, 2019; MacAskill et *al.,* 2021) and external reviews (Bachelet et *al.,* 2019). This suggests that second-party opinion is essential to reduce informational asymmetries by signaling the quality to investors for financing the transition toward a low-carbon economy and avoiding suspicion of greenwashing (Fatica and Panzica, 2021). Other factors, such as liquidity risk (Febi et *al*., 2018) and shades of green (Dorfleitner et *al.,* 2021), are also determinants of yield spread for green bonds.

Furthermore, other studies examine the effects of green bond issuance on firms' outcomes. Indeed, in the short run, corporate green bond issuance announcements are followed by positive stock market reactions, and this effect is not due to the potentially lower cost of green bond funding (Baulkaran, 2019; Tang and Zhang, 2020; Flammer, 2021). Additionally, green bonds serve as a credible signal of firms' commitment toward the environment (Flammer, 2021), as issuers reduce their carbon dioxide (CO_2) emissions, achieve a higher environmental rating, following the funding, and become more attractive for long-term and green investors (Tang and Zhang, 2020; Flammer, 2021; Fatica and Panzica, 2021). However, despite the relevance of this literature, studying green bonds is still in its beginning, and many factors remain unexplored. A fundamental issue that remains unclear is the long-run performance of green bond issuers. To date, no study has been conducted on the long-term effects of corporate green bonds. Our study completes the previous empirical research. It aims to examine the long-run firm-level outcomes following corporate green bond issuance. Specifically, we try to answer the following question: Do the firms' financial and environmental performance increase in the years following green bond issuances?

We explore two potential long-run effects of corporate green bonds for issuing firms: the long-run stock market performance and the long-run environmental performance. We based our study on the assumption that the effectiveness of corporate green bond financing depends on the long-term financial and environmental performance of the issuers. Both profitability and environmental performance are necessary to achieve the objectives of sustainable finance. Although social preferences play an important role for investors in socially responsible investment funds, financial viability is a condition for sustainable investment; otherwise, projects might need to be aborted because of financial shortfalls (Schoenmaker and Schramade, 2018). As a corporate strategy, if corporate green bond financing aims to achieve the goals of sustainable finance, it must combine both long-run economic and environmental concerns. On the other hand, because of the greenwashing phenomenon, firms can issue green bonds to forge an eco-responsible image among the public without taking any concrete action (Flammer, 2021). Thus, if the greenwashing hypothesis holds, one can expect no significant increase in the environmental rating and any decrease in CO_2 emissions, in the long run, following the issuance. Since projects financed by green bonds can take any time before producing positive impacts in terms of financial and environmental performance, we consider 1-year, 3-year, and 5-year periods, to capture the short and long-run effects.

Following Flammer (2021) and the previous studies on conventional bond issuance (Dichev and Piotroski, 1999; Spiess and Affleck-Graves, 1999), we use the matching approach. In the years preceding the issuance, we match the corporate green bond issuers with non-green bond issuers using the environmental score, the same country, the same industry, and the firms' characteristics. We follow the financial literature (Fu and Huang, 2016; Dutta and Jog, 2009; Renneboog and Vansteenkiste, 2019; McLaughlin et *al.,* 1998) and use the buy-and-hold abnormal returns (BHAR) method to analyze the long-run stock market performance of green bond issuers. We employ the calendar-time approach (CT) for the robustness tests. We estimate a difference-in-differences (DiD) model using the treated and control firms to examine how firms' outcomes (firm value, operating performance, environmental rating, CO_2 emissions, resource use, and green innovation scores) evolve following green bond issuance.

We first examine the stock market performance of corporate green bond issuers over 1-year, 3-year, and 5-year, post-issuance. We compute both equal-weighted and value-weighted BHAR. Concerning the equal-weighted BHAR, for the entire sample, our results indicate the 1-year and 3-year period stock market performance of green bond issuers compared to the matched control firms. However, only multiple-time issuers perform well over three years when we consider the subsamples. Green bond issuers realized no significant abnormal return over five years. That is, corporate green bond issuers perform only over three years compared to the control firms. After a 3-year period, their stock market performance is similar to that of the control firms. Concerning the value-weighted BHAR, we obtain similar results for the entire sample over the 12-month period: the BHAR is positive and significant. However, the BHAR of the 3-year and the 5-year periods are insignificant. For the subsamples, only multiple-time issuers realize positive and significant abnormal returns over three years and five years. Finally, we distinguish between green bond issuers operating in industries with high versus low SASB scores of environment materiality and find that only issuers operating in industries where the natural environment is financially material are more likely to perform well in the long run. Thus, we conclude that only multiple-time issuers, and issuers operating in industries where the natural environment is financially material, perform well in the long term relative to the control firms.

Next, to validate our BHAR results, we examine the long-run firm value and operating performance using the DiD estimation. Our results confirm that green bond issuers achieve an increase in their market value three years after the issuance, compared to non-issuers. However, we find no significant increase in firm value for the 5-year period. Furthermore, we find no significant results when we analyze the operating performance. Corporate green bond issuers and the control firms exhibit similar returns on assets over 1-year, 3-year, and 5-year periods, post-issuance. That is, the increase in firm value for the 3-year period, and the positive BHAR obtained are not necessary due to the increase in profitability of green bond issuers, relative to non-issuers, after the issuance. These findings support the investor attention view of Flammer (2021) that green bond issuers attract long-term and green investors, post-issuance. In consequence, they contrast the earlier studies, which reveal that debt issuers have significant declines in operating and stock market performance in 1-year, 3-year, and 5-year periods after the offering (McLaughlin et *al.,*1998; Lee and Loughran, 1998; Spiess and Affleck-Graves, 1999; Dichev and Piotroski, 1999). In sum, issuing green bonds appears to be financially beneficial for the existing shareholders in the short term confirming some previous studies (Tang and Zhang, 2020; Flammer, 2021) and, in the long term.

Furthermore, we examine the long-run environmental performance of corporate green bond issuers. First, we confirm the results of Flammer (2021) and Fatica and Panzica (2021) that green bond issuance does not produce any significant effect in the short term. Corporate green bond issuers reduce significantly their CO_2 emissions and improve their environmental rating three years after the issuance. The emission reduction and the environmental rating improvement are more important in five years or more. That is, issuing green bonds contributes to pollution reduction and improves firm-level environmental performance only in the long term. This seems justified since projects financed by green bonds may take time to produce any output. Thus, our results invalidate the greenwashing hypothesis and support the signaling view that firms signal their commitment toward the environment by issuing green bonds. Finally, we complete the previous studies by exploring if corporate green bond funding is associated with resource use efficiency and green innovation. Using Refinitiv ESG data, we find that the resource use score of the issuers goes up by 6.61% one year after the issuance and 7.75% three years after. That is, corporate green bond issuers become more efficient in terms of the use of natural resources in comparison with non-green bond issuers, post-issuance. Concerning the Refinitiv innovation score, our findings indicate that green innovation is a characteristic of green bond issuers rather than an effect resulting from green bond funding. Compared with non-issuers, corporate green bond issuers have higher green innovation scores before and after the issuance.

This research completes the previous studies of the announcement period returns, which reveal that issuing corporate green bonds improve firm value in the short run (Baulkaran, 2019; Tang and Zhang, 2020; Flammer, 2021). The first novelty of our study is that we consider the long-run stock market performance. Furthermore, our study goes beyond the stock market performance and examines the fundamental channel, specifically, the long-run firm operating performance following the issuance. Indeed, it makes it possible to understand that the stock market performance obtained is due to the investors' attention rather than the profitability of projects financed by green bonds. We also complete the earlier studies on the long-run performance following conventional bonds and private debt issuances, which reveal that the announcement period returns tell an incomplete story (McLaughlin et *al.,* 1998; Lee and Loughran, 1998; Dichev and Piotroski, 1999). In contradiction with these studies, our results reveal that green bond issuance is beneficial for the existing shareholders, in the long term. The main contribution is that our study examines corporate green bonds instead of standard bonds or private debt. Our findings contribute to the literature analyzing the effects of corporate social responsibility (CSR) on firm value.

Flammer (2021) and Fatica and Panzica (2021) show that, following green bond issuance, environmental ratings go up and the CO_2 emissions are reduced for the issuers, corroborating the signaling argument. Our research completes their studies. In our analysis, we consider separately, 1-year, 3-year, and 5-year periods, to capture the short and long-run effects. Our study provides evidence of the long-run impact of green bond issuances on corporate CO_2 emissions and environmental performance. In addition, we examine if corporate green bond issuance is associated with resource use efficiency and green innovation. This constitutes a key contribution since the previous studies did not consider these environmental variables. Our findings help us understand that firms do not issue green bonds for greenwashing. Given that corporate green bond issuance is beneficial for investors, and has a positive effect on the environment, policymakers aiming at taking action to combat climate change should put in place mechanisms to support the development of the green bond market. For their part, firms have an interest in financing their environmental projects by issuing green bonds.

The rest of the chapter is organized as follows. Section 2 presents the conceptual framework. Section 3 presents the data. Section 4 discusses the methodology and the empirical strategy. Section 5 examines the long-run stock market performance. Section 6 analyzes the financial and environmental performance. Section 7 discusses the results, and section 8 concludes.

2. Conceptual framework

To understand the impact of corporate green bonds on firms' outcomes, we follow previous studies (Tang and Zhang, 2020; and Flammer, 2021) and explore three potential sources: the "investor attention" channel, the "fundamental" channel, and the "greenwashing" channel.

2.1. Investor attention

While insiders are well informed about firms' activities and corporate decisions, it is hard for outsiders to have such relevant information. This information asymmetry is a market imperfection that generally results in the opportunism of insiders who favor their personal interests over that of other stakeholders (Jensen and Meckling, 1976). According to economic theory, signaling is the relevant solution to deal with information asymmetries. Since Akerlof (1970) and Spence (1973) publications, it has been widely admitted that it is in the interest of insiders to reduce the information asymmetry by sending credible signals. Firms must take actions that market participants can interpret correctly. To be credible, the signal must be costly to mimic (Spence, 1973). In financial theory, managers can issue debt to credibly signal the quality of their projects to the market. Debt issuance represents a signal of confidence emitted by managers on the profitability of their firm (Ross, 1977). Accordingly, bond issuance is often followed by a positive stock market reaction.

Corporate green bonds are similar to standard bonds, except that their proceeds are used to finance environmental and climate-friendly projects (Baulkaran, 2019). Given their environmental benefits, green bonds are expected to send a strong positive signal to the market compared to traditional bonds. The green bond issuance will draw people's attention and attract more investors (Cheong and Choi, 2020; Tang and Zhang, 2020; Flammer, 2021), and this can imply a big difference concerning firms' outcomes and stock market reaction in the long run as well as in the short run. According to Tang and Zhang (2020), when a firm announces green bond issuance, media exposure increases compared with conventional bond issuance. Green bond issuance is also followed by press releases, which send a good signal to the market. Media exposure attracts attention, and the issuing firms' visibility may increase. More investor attention expands the investor base for issuers and more demand for their shares. Flammer (2021) argues that firms can signal their commitment to the environment by issuing green bonds. This signal is likely credible since firms commit substantial amounts of money to green projects by issuing green bonds. Also, independent third parties often certify green bonds to guarantee that the proceeds are used to finance the green projects outlined in the bond prospectus. Therefore, green bond financing is expensive compared to conventional bonds (Cheong and Choi, 2020). As firms signal their commitment to the environment, they would become attractive for green investors (Flammer, 2021). Investors who consider sustainable development goals and environmentally friendly projects will appear to the financial market and push up the stock price (Tang and Zhang, 2020). Thus, one can expect a positive stock market reaction after green bond issuance.

Short-run event studies confirm investor attention view that the stock market responds positively to the green bond issuance announcement. Tang and Zhang (2020) present empirical evidence that the stock prices of issuers react positively to green bond issuance announcements. Specifically, there is a 1.4% cumulative abnormal return (CAR) for the 21-day event window around green bond issuance announcements. Flammer (2021) confirms these results and shows that in a short-time event window of [-5, 10], around the announcement of green bond issuance, the CAR is 0.49% for issuers. However, the earlier studies in the debt market reveal that, while short-term event studies show a positive stock market reaction following conventional bond issuances, long-run event studies reveal that debt issuances are often followed by poor stock and operating performance in the years following the offering (Barry, Mihov, 2015; Lee and Loughran, 1998; Spiess and Affleck-Graves, 1999). This suggests that debt offerings, like equity offerings, are signals that a firm is overvalued, contradicting the prediction of signaling theory. Similar results are also found for corporate events such as mergers and acquisitions (Malmendier et *al*., 2018; Cui and Leung, 2020), seasoned equity offerings (SEOs), stock repurchases (Fu and Huang, 2016), and initial public offerings (Barry and Mihov, 2015), among others. This contradiction among the results of short-run and long-run event studies makes it necessary to examine the long-run returns of green bond issuers by exploring the fundamental channel.

2.2. Fundamental channel: Green bonds, operating performance, and firm value

The fundamental channel implies that CSR activities create value for firms not only in the short run but also in the long term. Based on the fundamental channel, Tang and Zhang (2020) reveal that green bond issuance contains relevant information about firms' CSR activities and valuable investment opportunities. In particular, green bond issuers explicitly indicate their use of proceeds in the prospectus. This reveals valuable investment opportunities and illustrates the firm's dedication to sustainable development, which may help the issuing firm survive in the long run. Therefore, green bond issuance sends a costly signal that informs the market that a firm has long-term sustainable investing at heart, and the market could take that as a positive sign (Cheong and Choi, 2020). Investors also interpret corporate green bond issuance as a reputation-building strategy to accumulate valuable social capital (Gilchrist et *al.,* 2021). Then, going green may increase the firm value since investing in green projects is profitable in the long run, as they bring a higher positive net present value (NPV) (Cheong and Choi, 2020). Because the investors believe in the firm's long-term high valuation, they will hold the stock rather than realize the gain in the short run (Tang and Zhang, 2020). A costly commitment to greenness signals managerial engagement in sustainability, which in turn signals long-term firm value for shareholders (Cheong and Choi, 2020).

In sum, green bonds demonstrate the firm's dedication to sustainable development. Investing in such projects can be valuable for firms in the long run, including helping them survive adverse situations (Tang and Zhang, 2020). Under the fundamental channel, one can expect an increase in firm value and profitability, in the long run, following green bond issuance.

2.3. Greenwashing channel: Green bonds and firm environmental performance

Since corporate green bonds act as a credible signal, one can argue that some companies can use them to practice greenwashing (Cheong and Choi, 2020). Greenwashing consists of putting forward environmental commitment arguments to forge an environmentally friendly image among the public. It implies that firms issue corporate green bonds to depict themselves as environmentally responsible without taking any concrete action (Flammer, 2021). Thus, if the greenwashing hypothesis holds, one can expect no significant increase in environmental rating, following corporate green bond issuance. However, green bond financing is an expensive source of capital compared with conventional bonds (Cheong and Choi, 2020). While there exist benefits from green bond financing, there are also potential costs, one of which is the fees paid to third-party certifiers and auditors to perform annual reviews (Tang and Zhang, 2020). Indirect costs also arise from the limited usage of green bond proceeds (Cheong and Choi, 2020). These considerations may discourage firms from issuing green bonds to greenwash.

Corporate green bond issuance signals a credible commitment toward the environment since this signal is costly, and cannot be mimicked for greenwashing purposes. The signaling argument implies that, following the issuance, issuers would improve their environmental performance (Flammer, 2021). This means the environmental rating will rise, and the CO_2 emissions will drop, in the years following the issuance year. On the other hand, as part of the issuance of green bonds, the signal is credible because, if later, the public discovers that a firm has issued to greenwash, this information will also be publicized, and media exposure will increase. Thus, the environmental rating of the firm can drop, investors can divest, and customers can boycott the company's products. This would have a negative impact on both the operational performance and the stock market valuation. In addition, studies have shown that green bonds are not less costly than conventional bonds (Larcker and Watts, 2020; Tang and Zhang, 2020; Flammer, 2021). So the gain resulting from greenwashing by issuing green bonds can be minimal compared to the risk of being detected. Given these risks, companies will not be encouraged to issue green bonds for greenwashing.

Furthermore, Paranque and Revelli (2019) propose a framework in which green bonds can perform as a tool that facilitates the transition to a sustainable economy. In their analysis, green bond financing allows investors to know the specific project in which they invest and generates a context that puts pressure on firms to meet the investor's impact request. It also ensures a more direct dialogue between investors and issuers than through equity funding, where investment projects are not consistently identified. Finally, empirical studies confirm that firms improve their environmental performance following green bond issuances. Flammer (2021) finds a significant increase in the firm environmental performance, following the issuance year. Specifically, the environmental rating increases by 8.7%, and the CO_2 emissions are reduced by 12.9%. These findings are confirmed by Fatica and Panzica (2021), who show that green bond issuers present a reduction in total and direct emissions. In sum, after corporate green bond issuance, one can expect an increase in the environmental rating and a decrease in the CO_2 emissions of the issuers, in the long run.

3. Corporate green bond and firm-level data

This section presents the green bonds, firm-level data, and sample construction.

3.1. Evolution of the green bond market

The world's first green bond was issued in 2007 by the European Investment Bank (Tang and Zhang, 2020). In 2013, Vasakronan, Sweden's largest property company, issued the world's first corporate green bonds[2]. According to Climate Bonds Initiative (CBI)[3], since 2011, the annual issuance of green debt instruments has steadily increased, with an upswing from 2015. Green bond issuance rebounded in the second half of 2020 to reach a record-breaking USD 269.5 billion by the end of December, just above the 2019 final total of USD 266.5 billion (2018: USD 171.4 billion). The 2020 figure is the highest since the market inception. The cumulative market size in 2020 reflects an average annual growth rate of 60% since 2015.

Concerning the use of the proceeds, CBI reveals that investment in the energy sector comprised the largest share of 2020 issuance (USD 93.6 billion). Low-carbon buildings

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[2] Green Bonds on the Rise, PUBLISHED JUL 2, 2021 on NASDAQ by Prableen Bajpai
[3] Posted: Jan 24, 2021by Climate Bonds Initiative

represented the second-highest investment (70.6 billion), followed by low-carbon transport (63.7 billion), water infrastructure (17.5 billion), and land use (13.6 billion). The 2020 top five countries for annual green bond issuance are, respectively, the United States (51.1 billion), Germany (40.2 billion), France (32.1 billion), China (17.2 billion), and the Netherlands (17.0 billion). The top five largest green bond issuers in 2020 are Fannie Mae (13 billion), Federal Republic of Germany (12.8 billion), Société du Grand Paris (12.2 billion), KfW (9.4 billion), and Republic of France (6.9 billion). Germany's domestic green bond market is already one of the biggest in the world. The Republic of France remains a sovereign and European market leader.

3.2. Corporate green bonds by country and industry

We started our data construction by exploring all green bonds referenced in Bloomberg since 2007. This dataset covers green bonds issued across the world. In total, we collected 4,739 labeled green bonds from January 2007 to May 2021. From these green bonds, we excluded those issued by governments, supranational institutions, and development banks (a total of 1,168 green bonds). We obtained 3,571 corporate green bonds issued by listed and private firms: 1,849 by financial firms, and 1,722 by non-financial firms.

For our study, we limit the sample period from 2013 to 2019, since the world's first corporate green bonds were issued in 2013. We only include listed non-financial issuers as our analysis requires stock market data. As a listed firm, we consider any firm referenced in Compustat or Datastream databases. Indeed, to build our sample, we first checked whether each issuer is referenced in Compustat. If the issuer is represented, we consider it a listed firm. If it is not, we check its presence in Datastream. If the issuer is not represented in any of these databases, we check on the Internet whether it is a subsidiary of a listed firm. If it is not, we consider it a private firm. If it is, we attribute the green bonds to its parent firm, just as if the parent firm is the direct issuer. After this process, we obtained 616 green bonds issued by 200 listed financial firms during 2013-2019. For the subsample of the listed non-financial firms, we obtained 811 green bonds issued by 312 firms. In sum, we have 1,427 corporate green bonds issued by 512 listed firms (financial and non-financial), over 2013-2019. Table I-1 presents the number of corporate green bonds issued and the corresponding amounts (in millions of USD). Figures I-1, and I-2 illustrate the evolution of corporate green bond issuance since 2013.

FIG 1. CORPORATE GREEN BONDS ISSUED (IN MILLIONS USD)

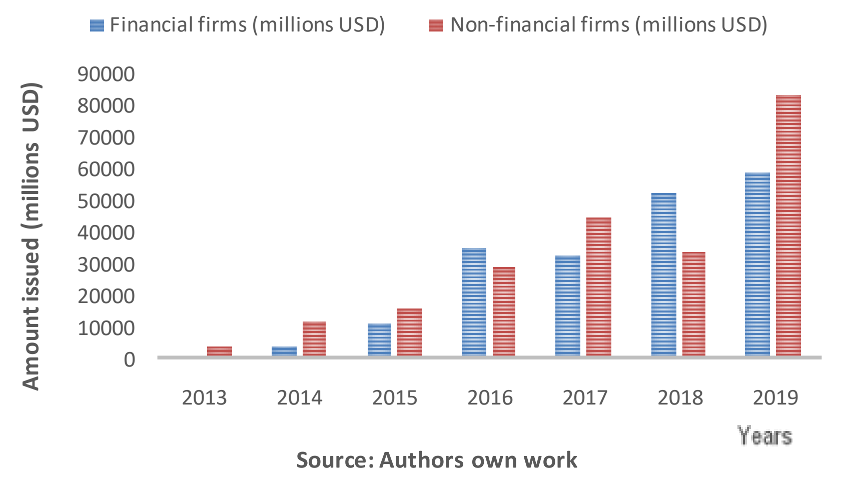


FIG 2. CORPORATE GREEN BOND ISSUANCE OVER TIME

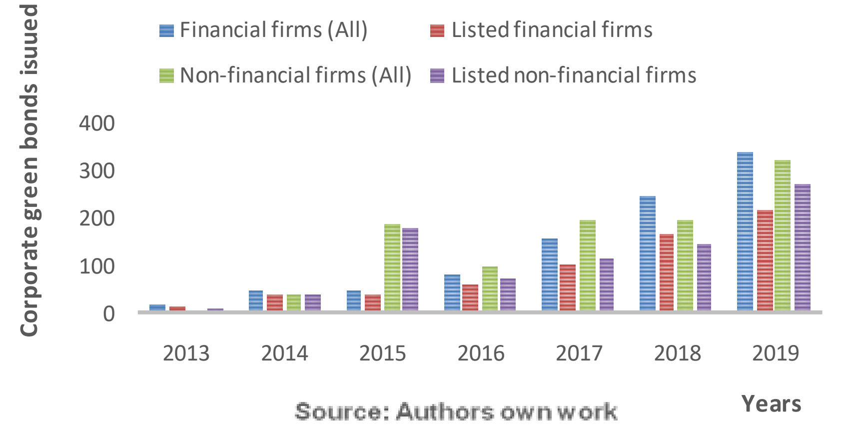
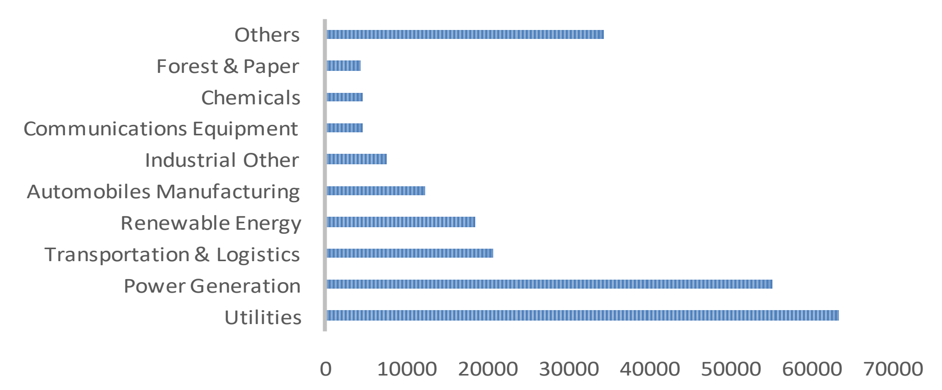


FIG 3. ISSUANCE BY NON-FINANCIAL FIRMS BY INDUSTRY (MILLIONS USD)



Source: Authors' own work

Table I-1. Corporate green bonds by year

	Financial firms			Non-financial firms		
IssueYear	All	Listed	Amount (millions USD)	All	Listed	Amount (millions USD)
2019	338	215	59099.448	319	270	83488.762
2018	242	163	52433.249	192	143	33902.135
2017	154	98	32538.924	191	113	44720.49
2016	79	59	35030.779	96	68	29266.784
2015	46	35	11099.199	183	177	15711.129
2014	44	35	3935.093	36	34	11422.138
2013	13	11	1218.444	4	6	3947.157
Total (2013-2019)	916	616	195355.136	1021	811	222458.595

Note (s): "All" represents all Bloomberg-labeled corporate green bonds. "Listed" corresponds to green bonds issued by listed firms, i.e., firms referenced in Computat, and or in Datastream databases. The amounts issued are in millions of USD.

Source: Authors' own work

3.2.1. Corporate green bonds by industry

First, we use Bloomberg's BICS (Bloomberg Industry Classification System) Level 2 codes for the industry classification of corporate green bond issuers in Table I-2. As can be seen, in the non-financial industry, corporate green bonds are more commonly issued by the energy sector (renewable energy, power generation, and utilities). Banks and real estate firms are the biggest issuers in the financial industry. Figure I-3 illustrates the repartition of corporate green bonds by industry, since 2013.

3.2.2. Corporate green bond issuers by country and industry two-digit SIC code

We limit our sample to 312 non-financial issuer-firms over 2013-2019. Of these firms, 270 are referenced in the Compustat and Refinitiv ESG databases, so they have the financial, and environmental, social and governance (ESG) data we need in the analysis. However, as we will see later, after matching, we ended up with 259 issuer-firms since we do not have a match for all issuers. Table I-3 presents the repartition of non-financial issuers by country and industry over 2013-2019. The top three countries for corporate green bond issuance in our sample are respectively China (24.07%), the USA (10.74%), and Japan (10.37%). Corporate green bonds are more commonly issued by the energy sector (SIC codes 49 (38.89%)).

3.3. Firm-level data

3.3.1. Accounting and stock market data

We collect firm information, accounting data, and stock prices using Compustat (Compustat North America and Compustat Global). These include firms' industry SIC code, country of location, total assets and liabilities, long-term debt, total equity, earnings before interest and taxes (EBIT), monthly stock prices, book-to-market ratio, and so on. Following the previous studies (e.g., Bardos et *al.,* 2020, among others), we define the firm size (log_assets) as the logarithm of the book value of the total assets. The debt ratio is the ratio of the book value of the long-term debt to the book value of total equity. Return on assets (ROA) is the ratio of the EBIT to the book value of total assets. Tobin's Q (firm value) is the ratio of the firm's market capitalization (the number of shares outstanding times the adjusted closing price) to the book value of total equity. We compute the monthly log returns using the monthly stock prices.

3.3.2. ESG data and CO_2 emissions

ESG data and CO_2 emissions are obtained from the Refinitiv ESG database. We collect environmental ratings, social ratings, corporate governance ratings, and CO_2 emissions. Environmental data collected from Refinitiv also includes resource use score, and innovation score. Refinitiv ESG ratings are in decimal (not in percentage), and the CO_2 emissions are expressed in tons. We do not have ESG data for all green bond issuers since Refinitiv does not cover all public firms. Following the previous studies (Flammer, 2021), we compute CO_2 emissions as the ratio of CO_2 emissions divided by the book value of total assets.

Table I-2. Corporate green bonds by industry

Industries (BICS Level 2)	# Green bonds	Amount (in millions USD)
NON-FINANCIALS	**811**	**222458.5945**
Renewable Energy	215	18591.067
Power Generation	165	55393.518
Utilities	140	63730.787
Industrial Other	53	7763.886
Transportation & Logistics	36	20955.07
Automobiles Manufacturing	26	12478.476
Travel & Lodging	20	2713.654
Waste & Environment Services & Equipment	18	3381.472
Metals & Mining	17	700.81
Forest & Paper Products Manufacturing	16	4533.972
Refining & Marketing	16	1039.257
Chemicals	13	4638.999
Electrical Equipment Manufacturing	9	906.367
Containers & Packaging	8	4076.705
Semiconductors	7	2000
Others	46	24432.302
FINANCIALS	**616**	**195355.136**
Banks	348	123542.090
Real Estate	167	32190.690
Diversified Banks	41	23858.419
Commercial Finance	20	3057.134
Consumer Finance	19	8481.414
Financial Services	16	1443.802
Life Insurance, Property & Casualty Insurance	5	2781.586
TOTAL	**1,427**	**417813.7245**

Note (s): Table I-2 presents the number of corporate green bonds issued by industry, using green bonds by listed firms from 2013-2019. Industries are partitioned according to Bloomberg's BICS (Bloomberg Industry Classification System) codes.

Source: Authors' own work

Table I-3. Green bond issuers by country and industry

Green bond issuers by industry (1)			Green bond issuers by country (2)		
Two-digit industry SIC code	Number of issuers	Percent	Country code	Number of issuers	Percent
10	4	1.48%	AUS	1	0.37%
12	3	1.11%	AUT	2	0.74%
15	5	1.85%	BRA	11	4.07%
16	7	2.59%	CAN	5	1.85%
17	3	1.11%	CHE	2	0.74%
20	7	2.59%	CHL	2	0.74%
22	2	0.74%	CHN	65	24.07%
23	1	0.37%	DEU	8	2.96%
24	1	0.37%	DNK	1	0.37%
26	7	2.59%	ESP	7	2.59%
27	1	0.37%	FIN	2	0.74%
28	14	5.19%	FRA	6	2.22%
29	5	1.85%	GBR	12	4.44%
32	3	1.11%	GRC	2	0.74%
33	6	2.22%	HKG	12	4.44%
34	1	0.37%	IND	4	1.48%
35	15	5.56%	ITA	12	4.44%
36	18	6.67%	JPN	28	10.37%
37	14	5.19%	KOR	13	4.81%
38	1	0.37%	LTU	1	0.37%
40	1	0.37%	LUX	1	0.37%
41	2	0.74%	MEX	2	0.74%
42	2	0.74%	MYS	2	0.74%
44	3	1.11%	NLD	2	0.74%
45	3	1.11%	NOR	5	1.85%
47	2	0.74%	NZL	2	0.74%
48	5	1.85%	PHL	3	1.11%
49	105	38.89%	POL	1	0.37%
50	3	1.11%	PRT	1	0.37%
51	1	0.37%	RUS	1	0.37%
53	2	0.74%	SAU	1	0.37%
54	2	0.74%	SWE	12	4.44%
55	1	0.37%	THA	6	2.22%
56	1	0.37%	TUR	1	0.37%
59	1	0.37%	TWN	5	1.85%
70	1	0.37%	USA	29	10.74%
73	4	1.48%			
80	2	0.74%			
87	5	1.85%			
99	6	2.22%			
TOTAL	**270**	**100 %**	**Total**	**270**	**100%**

Note (s): Table I-3 presents the repartition of non-financial corporate green bond issuers by country (Part 2) and industry (Part 1), over 2013-2019. The two-digit industry SIC codes are from Compustat, and the country codes are from Bloomberg.

Source: Authors' own work

4- Methodology

Firms are generally exposed to two types of events: economy-wide events and firm-specific events. Economy-wide events affect all firms and are often considered exogenous shocks if they meet certain conditions. Thus, shock-based event studies approaches are generally appropriate to examine such events. On the other hand, firm-specific events indicate a change in the company's policy (Dutta and Dutta, 2015) and cannot be exogenous. Corporate green bond issuance, for instance, corresponds to a firm-specific event, as are managerial decisions such as debt issuances. In the context of these events, the methodology varies depending on whether it is short-term or long-term event studies. Two main methods are widely used for analyzing long-run stock returns following corporate events: the BHAR and the CT approach (Kothari and Warner, 2007). We follow the financial literature (Fu and Huang, 2016; Cui and Leung, 2020; Dutta and Jog, 2009; Dichev and Piotroski, 1999) and use the BHAR method (event-time approach) to analyze the long-run stock market performance of green bond issuers. For the robustness tests, we employ the CT approach.

4.1. Event-time approach using the buy-and-hold abnormal returns (BHAR)

The BHAR is the reference method for measuring long-term abnormal returns, and most of the long-run event studies were based on it (Renneboog and Vansteenkiste, 2019; Mitchell and Stafford, 2000). As an event-time approach, it assumes independently distributed abnormal returns across firms. Barber and Lyon (1997) show that CARs are a biased predictor of long-run BHAR. The BHAR differs from the CARs in that it aggregates the abnormal returns geometrically rather than arithmetically over the event period, and includes the effect of compounding, whereas the CARs do not (Renneboog and Vansteenkiste, 2019; Barber and Lyon, 1997). Barber and Lyon (1997); and Lyon et *al.* (1999) argue that the BHAR measure is the appropriate estimator of long-run performance since it accurately represents the investor experience.

An appealing feature of using BHAR is that it better resembles investors' actual investment experience (Kothari and Warner, 1997; Lyon et *al.,* 1999). The BHAR refers to the difference between the long-run holding period return of the sample firms and that of the control firms (Kothari and Warner, 2007). Mitchell and Stafford (2000) describe BHAR as "the average multiyear return from a strategy of investing in all firms that complete an event and selling at the end of a pre-specified holding period versus a comparable strategy using otherwise similar non-event firms". Following Fu and Huang (2016), among others, we adopt Barber and Lyon (1997) method and use the post-issuance long-run BHAR to capture the stock market performance. We calculate the monthly BHAR as the buy-and-hold returns of a sample issuer minus the buy-and-hold return of the matched firm as follows:

$$(I-1): \qquad BHAR_{iH} = \prod_{t=1}^{H}(1+R_{it}) - \prod_{t=1}^{H}(1+R_{Bt}),$$

where R_{it} is the return on the event firm *i* at time *t* and R_{Bt} indicates the return on a control firm. The mean BHAR is the weighted average of the individual BHAR:

$$(I-2): \qquad \overline{BHAR} = \sum_{t=1}^{N} w_i \,. BHAR_i$$

Equal-weighted and value-weighted averages are computed, where the value-weights are based on market capitalization at event completion, divided by the implicit value-weight stock market deflator (Mitchell and Stafford, 2000). The t-statistic is t_{BHAR}:

$$(I-3): \qquad t_{BHAR} = \frac{\overline{BHAR}}{\sigma(BHAR_H)/\sqrt{n}} \quad ; \quad t_{aj} = \sqrt{n\left(S + \frac{1}{3}\hat{\gamma}S^2 + \frac{1}{6n}\hat{\gamma}\right)}$$

where $\overline{BHAR}$ is the sample mean, and $\sigma(BHAR_H)$ is the cross-sectional sample standard deviation of abnormal returns for the sample of n firms (Dutta and Dutta, 2015). It is also recommended to correct the t-statistic, taking into account the skewness (Lyon et *al.,* 1999). The skewness-adjusted t-statistic is t_{aj}, where $\hat{\gamma}$ is an estimate of the coefficient of skewness and $S\sqrt{n}$ corresponds to the conventional t-statistic (t_{BHAR}).

Barber and Lyon (1997) document that BHAR are subject to a new listing bias, a skewness bias, and a rebalancing bias. The new listing bias arises because, in long-run event studies, sampled firms generally have a long post-event history of returns, while firms that constitute the index (reference portfolio) typically include new firms that begin trading subsequent to the event month. Rebalancing bias arises because the compound returns of a reference portfolio are typically calculated assuming periodic rebalancing, while the returns of sample firms are compounded without rebalancing. Finally, skewness bias arises because long-run abnormal returns are positively skewed, leading to negatively biased t-statistics. To eliminate these biases, Lyon et *al.* (1999) document that matching sample firms to control firms based on similar sizes and book-to-market ratios yields well-specified test statistics. The control firm approach alleviates new listing, rebalancing, and skewness biases. We follow Fu and Huang (2016) and calculate the monthly BHAR as the buy-and-hold returns of a sample issuer minus the buy-and-hold returns of the matched firm.

4.2. Calendar-time approach

While Lyon et *al.* (1999) and Barber and Lyon (1997) defended that BHAR captures the investor's experience, one of the criticisms against this method is that it assumes independence of multiyear abnormal returns across firms (Kothari and Warner, 2007). Consequently, Fama (1998) and Mitchell and Stafford (2000), among others, advocate the calendar-time (CT) approach, which assumes that the multiyear abnormal returns across firms are not necessarily independent. Two variations of the CT approach are used: alpha from the Fama-French three-factor model and the mean CT abnormal return (MMCTAR).

4.2.1. Fama-French three-factor model

Alpha from Fama-French three-factor model also named the calendar-time portfolio regression returns, is based on the intercept from a time-series regression of a series of portfolio returns on a set of market-wide factors, where the portfolio firms have participated in an event in the past *n* periods (Renneboog and Vansteenkiste, 2019; Dutta and Jog, 2009; Kothari and Warner, 2007). The first step is to construct each calendar month over the entire sample period, a portfolio of all firms experiencing the event in the past T (12, 36, or 60) months. Next, one calculates monthly calendar-time portfolio returns for the event firms. The portfolios are rebalanced each month since new firms enter and some exit. The intercept estimated from the regression of the monthly excess return of each portfolio on the monthly three-factor of Fama and French (Jensen-alpha) is the measure of the average post-event monthly abnormal performance of the event firms.

$$(I-4): \qquad R_{pt} - R_{ft} = \alpha_i + \beta_i\left(R_{mt} - R_{ft}\right) + s_i SMB_t + h_i HML_t + \varepsilon_{it}$$

where

- R_{pt} is the return of calendar month *t* for the portfolio of event firms that experienced the event within the previous *T* months;
- R_{ft} is the risk-free rate (or monthly control firms returns);
- R_{mt} is the return on the market index;
- SMB_t is the difference between the return on the portfolio of small and big stocks;

- HML_t is the difference between the return on the portfolio of high and low book-to-market stocks;
- α_i is the average monthly abnormal return on the portfolio of the event firms over the *T*-month post-event period;
- β_i, S_i, and h_i are sensitivities of the event portfolio to the three factors.

The intercept term alpha provides a test of the null hypothesis that the mean monthly excess return on the calendar-time portfolio is zero. The calendar-time portfolio method controls well for the cross-sectional dependence but remains sensitive to the bad model problem.

4.2.2. Mean Monthly Calendar-Time Abnormal Returns (MMCTAR)

According to Renneboog and Vansteenkiste (2019), the calendar-time abnormal return (CTAR) approach consists to calculate for each calendar month, the abnormal return ($CTAR_{it}$) using the return for each security (R_{it}) and the return on control firm (R_{pt}) as follows:

$$(I-5): \qquad CTAR_{it} = R_{it} - R_{pt}$$

In each calendar month *t*, a mean abnormal return ($MCTAR_t$) is computed across firms in the portfolio:

$$(I-6): \qquad MCTAR_t = \sum_{t=1}^{n_t} x_{it} CTAR_{it}$$

where n_t represents the number of firms in the portfolio in month *t*. The weight, $x_{it} = 1/n_t$ when abnormal returns are equally weighted, and $MaketValue_{it}/\sum MaketValue_{it}$ when abnormal returns are value-weighted. The mean monthly abnormal return (MMCTAR) is as follows:

$$(I-7): \qquad MMCTAR = \frac{1}{T}\sum_{t=1}^{T} MCTAR_t$$

where T is the total number of calendar months. To test the null hypothesis of zero mean monthly abnormal returns, a t-statistic is calculated using the time-series standard deviation of the mean monthly abnormal returns as follows:

$$(I-8): \qquad t_{MMCTAR} = \frac{MMCTAR}{\sigma(MCTAR_t)/\sqrt{T}}$$

Lyon *et al.* (1999) suspect that the calendar-time portfolio methods based on control firms' abnormal returns generally dominate those based on the Fama-French three-factor model. We examine abnormal returns over the holding periods of 12, 36, and 60 months.

4.3. Matching and control firm selection

Since green bond issuance is internal to firms and not exogenous, the main problem is the presence of unobservable variables that can potentially determine both the choice to issue green bonds and corporate outcomes (Fatica and Panzica, 2021). Thus, to examine the issuers' outcomes after green bond funding, we adopt the matching approach as suggested by the previous literature. Specifically, we follow studies that examine the long-run stock market performance using the BHAR or CT approach (Fu and Huang, 2016; Malmendier et *al.,* 2018; Cui and Leung, 2020; Spiess and Affleck-Graves, 1999; Lyon et *al.*, 1999), or corporate outcomes following green bond issuances (Flammer, 2021; Fatica and Panzica, 2021). Our matching method aimed to ensure that control firms (non-green bond issuers) are as similar as possible to green bond issuers (the treated firms), the years before the green bond issuance, in their characteristics, except for the issuance of green bonds.

The procedure we use to choose the control firms is similar to that of Flammer (2021). We require that the treated and the control firms operate in the same country and the same two-digit SIC industry. Then, the control firms are selected based on the firm's size (log of total assets), Tobin's Q (market-to-book ratio), ROA, debt ratio, and the firm's environmental rating. We use the variables in the three-years prior to the green bond issuance year. We used the nearest neighbor method to select the control firms.

As documented by Flammer (2021), using the environmental rating for the matching ensures that treated and control firms have similar environmental performance prior to the green bond issuance. Using profitability (ROA) and firm value (Tobin's Q) eliminates concerns that the treated firms may be more (or less) profitable or have higher (or lower) growth opportunities. Using size and leverage addresses the possibility that treated firms may have better access to capital markets. Matching firms based on country, industry, and year ensures that treated and control firms face the same conditions in their business environment.

Our initial sample is 270 green bond issuers. Finally, we match 259 green bond issuers with 253 similar non-green bond issuers. In some cases, especially in countries or industries with few firms, we use the same control firm as the match for two treated firms. This method allowed us to find a match for six issuer-firms. Finally, we do not find any match for 11 firms because of relevant data availability. Our final sample includes 512 firms, specifically, 259 treated firms and 253 control firms.

Table I-4. Summary statistics

		(1) 3-year period prior to the issuance			(2) Issuance year			(3) Years following the issuance		
		Treated	Control	Diff.Mean	Treated	Control	Diff.Mean	Treated	Control	Diff.Mean
Log-assets	Mean	10.9416	10.6754	0.2662	11.1046	10.75075	0.3539	11.14	10.6329	0.5078***
	Std.	3.0995	3.2276		3.5248	3.5247		2.763	2.795	
	Obs	1,872			512			1,952		
Tobin's Q	Mean	18.891	7.9432	10.947	38.7352	7.7297	31.005	18.8845	7.9929	10.8916
	Std.	238.45	55.929		460.6387	62.8713		235.23	60.5689	
	Obs	1,872			512			1,948		
ROA	Mean	0.1182	0.1421	-0.0238	0.1164	0.1333	-0.0168	-0.1152	0.1211	-0.2364
	Std.	0.2394	0.1967		0.1962	0.1572		5.308	0.1489	
	Obs	1,872			512			1,950		
Debt ratio	Mean	0.985	0.6743	0.3106	1.322	0.6616	0.6608	0.5753	0.7989	-0.2235
	Std.	6.459	1.0988		12.497	0.9649		16.411	1.9229	
	Obs	1,872			512			1,952		
Environmental rating	Mean	0.67971	0.6578	0.0218	0.681	0.6555	0.0255	0.7922	0.6372	0.155***
	Std.	0.26954	0.2708		0.2682	0.2779		0.2656	0.2813	
	Obs	1,822			512			1,866		
Governance rating	Mean	0.3318	0.3669	-0.035**	0.367	0.3358	0.0313	0.4074	0.3741	0.0332**
	Std.	0.2662	0.2821		0.279	0.2747		0.2976	0.2875	
	Obs	1,835			512			1,921		
Social rating	Mean	0.6538	0.6046	0.0492*	0.6817	0.5978	0.0838**	0.677	0.6156	0.0613***
	Std.	0.2847	0.2916		0.2838	0.2951		0.2889	0.2911	
	Obs	1,835			512			1,921		
Innovation score	Mean	0.4533	0.3268	0.1265***	0.4602	0.3276	0.1326***	0.4886	0.3850	0.1036***
	Std.	0.3433	0.3190		0.3549	0.3030		0.3459	0.3040	
	Obs	1,090			429			1,432		
Resource use score	Mean	0.5254	0.4882	0.0372	0.5567	0.4930	0.0637***	0.5840	0.5142	0.0698***
	Std.	0.3206	0.3276		0.3241	0.3166		0.3003	0.3177	
	Obs	1,090			429			1,432		
CO_2 emissions	Mean	73.2578	97.3837	-24.125	64.6473	90.244	-25.596	51.2668	86.549	-35.28***
	Std.	142.299	267.3995		99.881	246.337		97.979	216.631	
	Obs	816			313			1,301		

Note (s): This table reports the means, standard deviations, and difference-in-means (Diff.Mean) for the treated and control firms. The sample includes all firm-year observations of the treated and control firms from 2010–2020. Column (1) shows the summary statistics for the 3-year period (period formed by years 1, 2 and 3) prior to the green bond issuance year. Column (2) provides the summary statistics for the green bond issuance year, and column (3) the summary statistics for the years following the green bond issuance year. Accounting data are obtained from Compustat. The log-assets is the logarithm of the book value of total assets. ROA is the ratio of earnings before interest and taxes (EBIT) to the book value of total assets. Tobin's Q is the ratio of the company's market capitalization to the book value of equity. The debt ratio is the ratio of the book value of long-term debt to the book value of total equity. Environmental and governance ratings are in decimal (not in percentage) and obtained from the Refinitiv ESG database. CO_2 emission is the ratio of CO_2 emissions divided by the book value of total assets. The symbols *, **, and *** imply, respectively, significance at the 10%, 5%, and 1% levels.

Source: Authors' own work

To show the similarities between the treated and the control firms, we report the summary statistics for the 3-year period (i.e the period formed by years 1, 2 and 3) prior to the green bond issuance year, the issuance year, and the years following the issuance year, in Table I-4. In the 3-year period prior to the issuance (column 1) and the issuance year (column 2), treated firms are similar to control firms along their relevant characteristics. The difference-in-means (diff.Mean) of log(assets) is not significant (0.2662 and 0.3539, respectively). The diff.Mean of Tobin's Q is also not significant (10.947 and 31.005, respectively). The diff.Mean of the ROA is -0.0238 and -0.0168, respectively. The diff.Mean of debt ratio is 0.3106 and 0.6608, respectively. The diff.Mean of environmental rating is 0.0218 and 0.0255, and all are not significant. This indicates that the control firms can provide a reliable counterfactual of how the treated firms would behave without green bond issuance.

In column (3), the years following the green bond issuance year, we notice a significant change in treated firms' assets, environmental rating, and CO_2 emissions, compared with the control firms. The diff.Mean are 0.5078 for log(assets), 0.155 for environmental rating, and -35.28 for CO_2 emissions, and all are significant. However, we notice no significant change in Tobin's Q, debt ratio, and ROA.

5. Long-run stock market performance following green bond issuance

This section presents the results of the long-term post-issuance stock market performance. We first report the results for all event firms between 2013 and 2020 using the BHAR approach. We employ the Fama-French three-factor model and the MMCTAR methodology for the robustness check. As for the previous studies examining the BHAR (e.g., Dutta and Jog, 2009; Fu and Huang, 2016; among others), we see that the long-term abnormal returns differ across methodologies.

5.1. Event-time approach: buy-and-hold abnormal return (BHAR)

Table I-5 reports the 12-month, 36-month, and 60-month BHAR results. We focus primarily on BHAR for the entire sample (259 firms). Next, we consider the subsamples of first-time and multiple-time issuers to address the cross-sectional dependence problem induced by overlapping observations, as Lyon et *al.* (1999) stated. Following long-run event studies in mergers and acquisitions (Dutta and Jog, 2009), and SEOs (Fu and Huang, 2016) areas, for the subsample of the 3-year period, we define multiple-time issuers as firms that reissued green bonds within three years of the previous issuance. For the subsample of the 5-year period, multiple-time issuers are firms that reissued green bonds within five years of the previous issuance. Otherwise, event firms are considered first-time issuers. Both equal-weighted and value-weighted BHAR are computed. Value-weighted BHAR is calculated based on the market value-weight of the treated firm at the effective month of issuance. We computed both conventional t-statistic and adjusted t-statistic.

Considering the equal-weighted BHAR, our results show for the entire sample that the 12-month BHAR is 0.1181 with a conventional t-statistic of 1.79 and adjusted t-statistic of 2.09 (adjusted for skewness), 36-month BHAR is 0.2232 with 2.3 of adjusted t-statistic. This indicates 1-year and 3-year periods of higher stock market performance of green bond issuers relative to the control firms. One year and three years of BHAR are significant at 5% when we consider the adjusted t-statistic, and only at 10% if we consider the conventional t-statistic. When considering the subsamples, we see that only multiple-time issuers perform well over three years. Their BHAR is 0.3472 and significant at 1% (adjusted t-statistic is 2.79). The BHAR of the first-time issuers is not significant over three years. Equal-weighted BHAR also indicate that corporate green bond issuers realized positive but no significant abnormal return over five years (60-month period), following the issuance (both for the full sample, as for first-time and multiple-time issuers). That is, corporate green bond issuers perform financially only for a 1 to 3-year period, compared to the matched control firms. After three years, their stock market performance is similar to that of the control firms.

Concerning the value-weighted BHAR, we obtain similar results for the entire sample over a 12-month period: the BHAR is 0.1352 and significant (the adjusted t-statistic is 1.6775). The BHAR is positive over 3-year (BHAR is 0.0315) and 5-year (BHAR is 0.075) periods, but not significant. For the subsamples, only multiple-time issuers realize significant abnormal returns over 3-year (BHAR is 0.20 and adjusted t-statistic is 1.87), and 5-year (BHAR is 0.1671 and adjusted t-statistic is 5.06) periods. The BHAR of first-time issuers are not significant. Indeed, the long-run value-weighted BHAR are slightly different from the equal-weighted BHAR. Thus, only multiple-time issuers perform in the long run relative to the control firms. First-time issuers show similar performance as the control firms.

Table I-5. Buy-and-hold abnormal return following green bond issuance

BHAR	Equal-weighted			Value-weighted		
	1-year	3-year	5-year	1-year	3-year	5-year
Panel A: Full sample						
Nb firms	259	212	93	259	212	93
BHAR	0.1181**	0.2232**	0.1464	0.1352*	0.0315	0.0752
t-statistic	1.7981	1.6355	1.0859	0.9223	0.2142	1.1731
Ajust t-statistic	2.0915	2.3045	1.1632	1.6775	0.9425	1.1488
Panel B: First-time issuers						
Nb firms	N/A	98	33	N/A	98	33
BHAR	N/A	0.0791	0.1143	N/A	-0.1699	-0.0893
t-statistic	N/A	0.7020	0.4404	N/A	-1.5639	-0.6565
Ajust t-statistic	N/A	0.7071	0.9802	N/A	N/A	0.2903
Panel C: Multiple-time issuers						
Nb firms	N/A	114	60	N/A	114	59
BHAR	N/A	0.3472***	0.1641	N/A	0.2046*	0.1671***
t-statistic	N/A	1.4798	1.0628	N/A	0.7949	2.6679
Ajust t-statistic	N/A	2.7904	1.3184	N/A	1.8737	5.0642
Panel D: High materiality industries						
Nb firms	126	112	55	126	112	55
BHAR	0.2385***	0.1991**	0.2066*	0.2729**	0.1963*	0.1812***
t-statistic	1.91	1.93	1.11	0.90	0.75	2.22
Ajust t-statistic	2.99	1.98	1.91	2.04	1.81	4.16
Panel E: Low materiality industries						
Nb firms	133	100	38	133	100	38
BHAR	0.0040	0.2503**	0.057	0.0046	-0.153	-0.0755
t-statistic	0.087	0.94	0.46	0.19	-1.50	-0.77
Ajust t-statistic	0.117	2.05	0.64	0.76	N/A	N/A
Panel F: USA only						
Nb firms	29	17	11	29	17	11
BHAR	0.1540**	0.3503***	0.0836	0.1146*	0.0932*	0.0215
t-statistic	1.88	1.97	0.964	1.18	0.735	0.79
Ajust t-statistic	2.113	3.15	1.54	1.86	1.77	1.43
Panel G: Japan only						
Nb firms	28	21	13	28	21	13
BHAR	0.1040**	0.2130***	0.1254	0.0814	-0.0185	-0.0235
t-statistic	1.468	1.04	1.46	0.69	-0.643	-0.852
Ajust t-statistic	2.017	2.851	1.61	1.46	N/A	N/A
Panel H: China only						
Nb firms	63	57	26	63	57	26
BHAR	0.1240**	0.1982**	0.1321	0.1204*	0.0485	0.0136
t-statistic	1.86	1.54	1.19	1.39	0.84	0.451
Ajust t-statistic	2.37	2.42	1.63	1.74	1.23	1.09

Note (s): BHAR is the mean buy-and-hold abnormal returns based on the average difference in the aggregated performance between corporate green bond issuers (treated) and non-issuers (control firms) over 12-month, 36-month, and 60-month periods starting after the effective month of issuance. Two different BHAR are calculated: equal-weighted BHAR and value-weighted ones. BHAR are calculated using individual treated and control firm returns. For the 12-month period, we have 259 firms, i.e. valid cases for BHAR calculations. Concerning the 36-month period, we have 212 valid cases (firms) for the full sample, 98 valid cases for the subsample of first-time issuers, and 114 for the subsample of multiple-time issuers. Finally, we have 93 firms for the full sample of the 5-year period, i.e. 93 firms that issued green bonds five years ago, 33 valid cases of first-time issuers, and 60 cases of multiple-time issuers. We computed both conventional t-statistics and skewness-adjusted t-statistics. BHAR values are expressed in decimals (not in %). *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively, based either on conventional t-statistic or adjusted t-statistic.

Source: Authors' own work

Panels D and E distinguish between green bond issuers operating in industries with high versus low SASB scores of environment materiality. Environment materiality refers to an organization's significant environmental impacts and the issues that substantively influence the assessments and decisions of stakeholders, i.e., the number of environmental issues that are deemed financially material for firms in a specific industry[4]. Materiality data are obtained from the SASB website. SASB assesses the environment materiality index for each industry from 1 to 6. With the SASB index, we classify green bond issuers into two categories: firms with 1, 2, and 3 SASB indexes are classified in the "*low materiality industries"*, and firms with 4, 5, and 6 indexes are in the "*high materiality industries*".

Results in Panel D show that all the BHAR are positive and significant in industries where the natural environment is financially material to the firms' operations. Panel E reveals that the BHAR are insignificant in low materiality industries, except the 3-year period equal-weighted BHAR. Thus, corporate green bond issuers operating in industries where the natural environment is financially material are more likely to perform in the long run compared to the control firms. This supports Flammer's (2021) argument that shareholders value firms' commitment to the environment in industries where the natural environment is material to the firm's financial performance.

Finally, in Panels F, G, and H, we consider the sample of US, Japanese, and Chinese firms, respectively, to explore if the effect of corporate green bond issuance differs between developed and emerging markets. Perhaps because of the small size of the samples, in general, the results are similar to those obtained using the entire sample. However, the BHAR are slightly higher for the US firms than the total sample. For the sample of Japanese firms, they are slightly lower than for the total sample. The results for the sample of Chinese firms are almost similar to those of the total sample. These similar results do not allow us to conclude that the stock market performance of issuers varies according to country.

5.2. Robustness tests using a calendar-time portfolio approach

We present a series of robustness tests of our results based on BHAR. In particular, we address Fama's critique using the rolling portfolio approach recommended by Fama (1998) and the three-factor regression of Fama-French. We measure long-run performance using average monthly abnormal returns rather than long-run BHAR. These methods yield results

[4] NYU STERN- Center for Sustainable Business : Sustainability Materiality Matrices Explained, May 2019

consistent with our buy-and-hold evidence of stock market performance following green bond issuance. In the analysis, corporate green bond issuers do not underperform the matched control firms.

Table I-6. Robustness tests using the Fama-French three-factor model, and market model

	Fama-French 3-factor model				Market model	
	Alpha	Rm-Rf	SMB	HML	Alpha	MSCI-Rf
Full sample, N=259 firms						
Panel A1: Equal-weighted calendar-time portfolio, the first year after issuance (full sample) N=259 firms						
Coef.	0.0084*	-0.1458	0.1551	0.0523	0.0076*	-0.1015
t-Statistics	1.92	-0.74	1.01	0.25	1.69	-0.48
Panel B1: Equal-weighted calendar-time portfolio, 3 years after issuance (full sample) N=212 firms						
Coef.	0.0076*	0.0121	0.0711	-0.0576	0.0067*	0.1455
t-Statistics	1.85	0.06	0.38	-0.36	1.7	0.68
Panel C1: Equal-weighted calendar-time portfolio, 5 years after issuance (full sample) N=93 firms						
Coef.	0.0043	0.0101	0.1727	-0.0683	0.0040	0.0821
t-Statistics	1.01	0.04	0.83	-0.37	0.92	0.35
High materiality industries						
Panel A2: Equal-weighted calendar-time portfolio, 1 year after issuance (high materiality industries) N=26 firms						
Coef.	0.0096***	-0.0987	0.1057	0.0395	0.0083***	-0.0345
t-Statistics	3.22	-1.33	1.16	0.51	2.67	-0.32
Panel B2: Equal-weighted calendar-time portfolio, 3 years after issuance (high materiality industries) N=112 firms						
Coef.	0.0078**	0.0965	0.1126	0.0214	0.0071*	0.1088
t-Statistics	1.97	1.51	2.00	0.238	1.81	1.39
Panel C2: Equal-weighted calendar-time portfolio, 5 years after issuance (high materiality industries) N=55 firms						
Coef.	0.0016	0.0107	0.1530	-0.0919*	0.0018	0.0407
t-Statistics	0.81	0.12	1.46	-1.83	0.91	0.38

Note (s): Panel A1 corresponds to the first year after the issuance. It includes the entire sample, with N = 259 issuers (3108 Observations). Panel B1 corresponds to the 3-year period after the issuance. N = 212 issuers (7226 Observations). Panel C1 corresponds to the 5-year period after the issuance. N = 93 issuers (5336 Observations). Panel A2, B2, and C2 correspond to the high materiality industry only. We estimate the global Fama-French model using country-specific market indices (obtained from WRDS (Wharton Research Data Services)), as did Flammer (2021). We obtain the global SMB and HML factors from Kenneth French's website. The equally-weighted monthly portfolio returns are used. Symbols *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively. The estimates are in decimals (not in %).

Source: Authors' own work

5.2.1. Robustness test using Fama-French three-factor model, and market model

To confirm our BHAR results, we perform Fama-French three-factor regression. The intercept (alpha) from the regression corresponds to the monthly average abnormal returns of the issuers. Table I-6 presents the results over 12-month, 36-month, and 60-month periods. As for the BHAR approach, we find a positive abnormal return over the 12-month and 36-month periods. For the first-year sample (Panel A1), the constant term (Jensen-Alpha) is

0.0084 and significant at 10%. For the 3-year sample (Panel B1), alpha is also positive (0.0076) and significant. For the high materiality industries, alphas are also significant for the 1-year and 3-year periods at 1% and 5%, respectively (Panels A2, and B2). Alphas obtained from the regressions over five years are not significant. We do not report the results for the low materiality industries since they are not significant as in the BHAR approach. We also estimate the market model using the MSCI All Country World Equity Index, instead of country-specific market indices. Using this alternative market factor yields similar results. Therefore, our findings are consistent with the BHAR results presented earlier. Our results do not show any evidence of long-run underperformance for corporate green bond issuers. In contrast, they seem to indicate the better stock market performance of green bond issuers, in the years following the issuance.

5.2.2. Robustness test using Mean Monthly Calendar-Time Abnormal Returns

In Table I-7, we present the results of the MMCTAR. First, we compute the MMCTAR based on the whole sample. Next, as in the BHAR approach, we consider the subsamples of first-time and multiple-time issuers. In the majority, the results remain similar to those of the previous analysis based on the BHAR and the factor model.

For the full sample (Table I-7, Panel A), the 12-month and 36-month periods of equal-weighted MMCTAR are positive and significant. However, 60-month equal-weighted MMCTAR is not significant. The value-weighted MMCTAR also are not significant. For the subsamples of first-time issuers (Panel B), and multiple-time issuers (Panel C), the results remain similar to those obtained using the BHAR approach. For the multiple-time issuers, the MMCTAR are positive and significant, except for the 60-month period value-weighted MMCTAR, which is not significant. Concerning the subsample of the first-time issuers, all of the equal-weighted MMCTAR are positive and not significant, while all of the value-weighted MMCTAR are negative and not significant. Finally, the results of the subsamples of the high and low materiality industries also confirm those obtained using the BHAR approach. Panel D indicates that all the MMCTAR are positive and significant for the issuers operating in the high materiality industries, except the 60-month value-weighted MMCTAR. For the issuers operating in the low materiality industries (Panel E), the MMCTAR are not significant. This confirms most of our BHAR results.

Overall, our results seem robust since they are confirmed by the Fama-French three-factor model, the market model, and the MMCTAR approach. Thus, we conclude that the issuance of corporate green bonds has no negative impact on the firm's stock market performance. Issuing corporate green bonds appears to be beneficial for the existing shareholders, in the long term. Our results support Flammer (2021) that green bond issuers attract long-term and green investors, post-issuance. Consequently, they contrast the earlier studies, which reveal that debt issuers have significant declines in stock market performance in 1-year, 3-year, and 5-year periods after the offering (Spiess and Affleck-Graves, 1999; Dichev and Piotroski, 1999).

Table I-7. Results of robustness test using MMCTAR approach

MMCTAR	Equal-weighted			Value-weighted		
	1-year	3-year	5-year	1-year	3-year	5-year
			Panel A: All firms			
Nb firms	259	212	93	259	212	93
MMCTAR	0.005132*	0.0096**	0.006242	0.0148	**0.003818**	-0.0041
t-statistic	1.6049	2.0017	1.1313	0.7173	0.3864	-0.2335
Ajust t-statistic	1.7367	2.1199	1.2232	1.3761	0.9092	N/A
			Panel B: First-time issuers			
Nb firms	N/A	98	33	N/A	98	33
MMCTAR	N/A	0.007628	0.002680	N/A	-0.00325	--0.0007
t-statistic	N/A	1.0687	0.3483	N/A	-0.4038	-0.3115
Ajust t-statistic	N/A	1.4008	0.5988	N/A	0.3443	N/A
			Panel C: Multiple-time issuers			
Nb firms	N/A	114	60	N/A	114	60
MMCTAR	N/A	0.01216***	0.009083*	N/A	0.0098**	-0.0059
t-statistic	N/A	2.1919	1.4116	N/A	1.3720	-0.2199
Ajust t-statistic	N/A	2.6723	1.6729	N/A	2.0762	N/A
			Panel D: High materiality industries			
Nb firms	126	112	55	126	112	55
MMCTAR	0.01048*	0.017376***	0.014528**	0.03585**	0.01047**	0.0003
t-statistic	1.289	2.3963	1.8341	1.5184	1.3274	0.2159
Ajust t-statistic	1.7509	3.1957	2.3662	2.1560	1.9886	N/A
			Panel E: Low materiality industries			
Nb firms	133	100	38	133	100	38
MMCTAR	-0.00565	-0.00378	-0.0006504	0.0022	-0.00398	-0.0054
t-statistic	-0.9992	-0.6608	-0.1016	0.8396	-1.0608	-0.1717
Ajust t-statistic	0.9973	0.7214	0.2615	0.7478	0.6071	N/A

Note (s): MMCTAR is the Mean Monthly Calendar-Time Abnormal Returns based on the monthly return of treated and control firms, over 12-month, 36-month, and 60-month periods, starting after the effective month of green bond issuance. MMCTAR are calculated using individual-treated firms and control firms' returns. For the 12-month period, we have 259 issuer firms. Concerning the 36-month period, we have 212 firms for the entire sample, 98 firms for first-time issuers, and 114 for the subsample of multiple-time issuers. Finally, we have 93 firms for the full sample for the 5-year period, i.e., 33 valid cases of first-time issuers and 60 cases of multiple-time issuers. We computed both conventional t-statistic, and adjusted t-statistic. MMCTAR are expressed in decimals (not in %). Symbols *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively, based either on conventional or adjusted t-statistic.

Source: Authors' own work

6. Corporate green bonds and firm long-term outcomes

This section analyzes the long-run firm-level outcomes following green bond issuance. First, we examine the firm financial performance. Next, we analyze the firm environmental performance. We use the same sample of the matched treated and control firms as in the previous sections, and estimate the DiD model following previous event studies.

6.1. The difference-in-differences specification

Following the previous event studies, we adopt a DiD model. DiD is useful when randomization on the individual level is not possible. This approach is employed to estimate the causal effect of a specific policy or treatment by comparing the changes in outcomes over time, between the treatment and the control groups. The DiD relies on the assumption of "parallel trends" between the treatment and the control groups. Accordingly, any difference in the changes in outcomes between the two groups after the treatment should be due to the impact of the treatment.

To use DiD, we need observed outcomes of issuer firms (treated) and non-issuer firms (matched control) before and after the intervention. We follow Flammer (2021) and estimate the following DiD specification using all firm-year observations of the green bond issuers and the control firms from 2010 to 2020.

$$(I-9): \qquad Y_{it} = \alpha_i + \alpha_c + \alpha_t + \beta \times Green_{Bond} + \varepsilon_{it}$$

Y is the outcome variable (operating performance, Tobin's Q, CO_2 emissions, resource use score, green innovation score, and environmental rating). $Green_{Bond}$ is a dummy variable equal to 1 if the firm *i* is in the treatment group at time *t*, and zero if the firm is in the control group. The coefficient α_i captures industry fixed effects, α_c captures country fixed effects, and α_t year fixed effects. The coefficient β is the main coefficient of interest. β captures the treatment effect. It measures the DiD in the outcome variable Y between treated and control firms in the year *t* following the issuance year.

To estimate the model, we use data covering all years after the green bond issuance, except the issuance year. We also estimate the model 3 years prior to the issuance year to capture the pre-trends, 1 year following the issuance year to capture the short-term effect, and 3-year and 5-year periods following the issuance year to capture the long-run effects. We employ the same approach and variables as Flammer (2021). We estimate the panel model with fixed effects using the matching methodology described above. In the model, we use only one explanatory variable named "Green bonds", a dummy variable equal to one if the firm i is in the treatment group at time t, and zero if the firm is in the control group. The DiD estimation relies on the assumption that any difference in the change in outcomes between the two groups after the treatment should be due to the impact of the treatment. Accordingly, we do not include any control variables to avoid the "bad control" problem. We assume we have considered all relevant control variables in the matching process. So, it's not helpful to incorporate them again in the DiD estimation (see Flammer, 2021). However, we confirm our results using an alternative specification, including control variables.

6.2. Firm value and operating performance following green bond issuance

In this subsection, we examined the firm financial performance following corporate green bond issuance. We use two proxies of firm financial performance: firm value (Tobin's Q), and firm operating performance (ROA).

6.2.1. Firm value following green bond issuance

As the stock market performance follows corporate green bond issuance, one may expect an increase in firm value. To confirm this possibility, we examine firm value over 1-year, 2-year, and 5-year periods after the green bond issuance year. The proxy of firm value is Tobin's Q, calculated as the ratio of the company's market capitalization to the book value of equity (see, e.g., Bardos et *al.,* 2020; Cheong and Choi, 2020; Flammer, 2021).

Table I-8 presents the estimates of the DiD specification in columns (1) and (2). In column (1), we report the results for the entire sample and all years following the issuance year. As can be seen, we find evidence of a significant increase in firm value following corporate green bond issuance. The dummy variable for green bond issuers is positive (4.9880) and significant at 5%. However, when we decompose the post-issuance period into the subsamples (column 2), we find that the dummy variable for firms that issue green bonds within one year is also positive (12.45) and significant at a 5% level. The dummy variable for firms that issue green bonds within three years is also positive (14.36) and significant at a 1% level. That is, three years after the issuance year, green bond issuers achieve an increase in their market value, compared to non-green bond issuers. After the 3-year period, the issuer firms show no significant increase in their market value compared to the control firms. The dummy variable for firms that issue green bonds within five years is positive (0.1457) but not significant. That is, corporate green bond issuance positively impacts firm value, only a 3-year period following the issuance year. After that period, there is no significant effect. In line with our BHAR results, these results are probably due to a positive NPV of projects financed by green bonds over three years after the issuance. Thus, examining the issuers' ROA post-issuance is necessary.

Table I-8. Firm value and operating performance following green bond issuance

	Firm value and operating performance			
	Firm value (Tobin's Q)		Return on assets (ROA)	
Variables	1	2	3	4
Green bonds (all years, after issuance)	4.988** (2.0912)		0.0271 (0.032)	
Observations	1,948		1,946	
R-squared	0.5785		0.3993	
Green bonds (short term, 1 year)		12.4509** (7.759)		-0.0131 (0.0137)
Observations		512		512
R-squared		0.202		0.3593
Green bonds (long term, 3 years)		14.369*** (3.44)		0.0284 (0.0468)
Observations		1,007		1,400
R-squared		0.542		0.6536
Green bonds (long term, 5 years &+)		0.1457 (2.6024)		0.0274 (0.0323)
Observations		1,811		1,891
R-squared		0.569		0.3994
Green bonds (pre-issue 3 years)		5.759 (4.7763)		0.0254 (0.0447)
Observations		1,402		1,400
R-squared		0.5484		0.6536
Firm fixed effects	No	No	No	No
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Note (s): Table I-8 presents the estimates of the difference-in-differences specification for firm value (Tobin's Q) in columns (1) and (2), and firms' operating performance (ROA) in columns (3) and (4). In columns (1) and (3), we present the results for the entire sample and all years following corporate green bond issuance. Columns (2) and (4) present the results of the subsamples: Green bonds (short-term, 1 year), Green bonds (long-term, 3 years), Green bonds (long-term, 5 years &+), and Green bonds (pre-issue 3-years). The sample includes all firm-year observations of the treated and control firms from 2010-2020. Data are obtained from Compustat. ROA is the ratio of earnings before interest and taxes (EBIT) to the book value of total assets. Firm value (Tobin's Q) is the ratio of the company's market capitalization to the book value of equity. The only independent variable is the green bond issuance dummy named "Green bonds", which is equal to 1 if firm i is in the treatment group at time t, and zero if firm i is in the control group. We estimate the panel regression with fixed effects, using the robust option of Stata. The estimates are expressed in decimals (not in %), and standard errors are in parentheses. The symbols *, **, and *** imply, respectively, significance at the 10%, 5%, and 1% levels.
Source: Authors' own work

Finally, column (2) examines the 3-year period before the green bond issuance to capture the parallel pre-trends. The coefficient associated with the dummy variable "*Green bonds (pre-issue 3 years)*" captures the pre-trend. As can be seen, we find evidence of a parallel pre-trend of treated and control firms before the corporate green bond issuance year. The coefficient estimated is (5.759) and not significant. The change obtained in firm value after green bond issuance is the treatment effect.

6.2.2. Operating performance following green bond issuance

In the previous sections, we have shown that corporate green bond issuers have higher stock market performance than non-issuers three years after the issuance. Indeed, one may wonder if there is any change in the issuer-firms' profitability following corporate green bond issuance. In this subsection, we examine green bond issuers' operating performance (profitability) in the years following the issuance year. We proxy the operating performance by the ROA, which we define as the ratio of the EBIT to the book value of total assets (see, e.g., Lins et *al.*, 2017; Lee and Loughran, 1998; McLaughlin et *al.,* 1998; among others).

As presented in columns (3) and (4) of Table I-8, we find no significant increase (or decrease) in the operating performance (ROA) following green bond issuance for the full sample, and the subsamples of 1-year, 3-year, and 5-year post-issuance periods. For the full sample (all years following the issuance), the coefficient associated with the dummy variable "*Green bonds (all years, after issuance)*" is positive (0.027) but not significant. For the subsample of the 1-year period, the dummy variable *"Green bonds (short term, 1 year)*" is negative (-0.013) and not significant. For the long-term subsamples, the coefficients of the green bond dummy are positive and not significant: for the 3-year period, the coefficient estimated is 0.0284, and for the 5-year period, the coefficient is 0.0274. Finally, we find evidence of a parallel pre-trend of treated and control firms over the 3-year period before the issuance year. The coefficient estimated is (0.0254) and is not significant. That is, the increase in firm value for the 3-year period, and the positive BHAR obtained after corporate green bond issuance are not necessary due to any increase in profitability of the issuer firms, compared to the matched control firms, after the issuance.

6.3. Long-run environmental performance following green bond issuance

One of our main objectives is to examine the long-term environmental performance of green bond issuers. We hypothesize that, if the greenwashing hypothesis holds, we should have no improvement in the environmental performance of issuers compared to the non-issuers, post-issuance. To confirm the previous studies (Flammer, 2021; Fatica and Panzica, 2021), we first examined the environmental performance and CO_2 emissions of the treated and control firms, considering periods of 1-year, 3-year, and 5-year, after the green bond issuance. In addition, we consider the resource use score (ResourceUse), and green innovation score (InnovationScore), to examine if corporate green bond issuance is associated with low resource consumption and green innovation. This analysis constitutes one of our main contributions since the previous studies do not examine these environmental variables.

We use Refinitiv environmental rating as the dependent variable in our regression to capture the firm-level environmental performance. To explore the CO_2 emissions, we use the total CO_2 emissions scale by total assets as the second dependent variable. The Refinitiv ESG database provides the resource use and innovation score. Refinitiv ESG resource use score (ResourceUse) reflects a company's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management. It measures a company's management commitment and effectiveness toward achieving efficient use of natural resources in the production process. Innovation score (InnovationScore) reflects a company's capacity to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes or eco-designed, dematerialized products with extended durability. It measures a company's management commitment and effectiveness toward supporting the research and development of eco-efficient products or services. Table I-9 and Table I-10 present the results of the analysis.

Table I-9 presents the estimates of the difference-in-differences specification. As can be seen in columns (1) and (3), concerning the entire sample and all years following the issuance, green bond issuers, compared to similar firms, experience an increase in environmental rating and a decrease in CO_2 emissions. The coefficient associated with the green bond dummy is positive (0.0910) and significant at a 1% level for the environmental rating, and negative (-13.8651) and significant at 1% for the CO_2 emissions. The results are also economically significant. Following corporate green bond issuance, the environmental rating increases by 9.11 percentage points. This corresponds to an increase of 13.37% (given the sample mean of issuers equal to 0.681 from Table I-4). Similarly, the emissions are reduced by 13.86 tons of CO_2 by \$1 million of total assets, corresponding to a reduction of 21.43% given the issuance year mean of 64.65 (Table I-4).

Considering the subsamples, we find that issuing corporate green bonds does not produce a significant effect in the short term. For the subsample of a 1-year period, the estimates of the green bond dummy are not significant (columns 2, and 4). Columns (2) and (4) show that corporate green bond issuers reduce their CO_2 emissions and improve their environmental rating, in the long run only. Concerning the 3-year and 5-year periods, the estimates of the green bond dummy are positive and significant at a 1% level for the environmental rating. For the CO_2 emissions, the estimates are negative and significant at a 1% level. Following the issuance, the most significant reduction in CO_2 emissions and the most significant improvement in environmental performance are observed in five years (and more). Three years after the issuance, the environmental rating of the issuers goes up by 10.6%, corresponding to an increase of 15.56%. The CO_2 emissions are reduced by 12.148 tons by $1 million of assets, corresponding to a reduction of 18.79%. Five years (and more) following the issuance year, the environmental rating goes up by 15.32%, corresponding to an increase of 22.50%. The CO_2 emissions are reduced by 19.10 tons by $1 million of assets, corresponding to a reduction of 29.54%.

Finally, we find evidence of parallel pre-trend of treated and control firms over the 3-year period before the issuance, since the estimates of "Green bonds (pre-issue 3 years)" are not significant. Before the issuance, green bond issuers and non-issuers seem similar in CO_2 emissions and environmental performance.

In sum, issuing corporate green bonds does not affect the firm's environmental performance in the short term. Firm-level CO_2 emissions reduction and environmental rating improvement are observed in the 3-year and 5-year periods, post-issuance. After corporate green bond issuance, firms reduce their emissions and improve their environmental performance only in the long term. This seems justified since projects financed by green bonds may take time to produce any output. Our results are consistent with the signaling argument and invalidate the greenwashing hypothesis of corporate green bond issuance. Our results support Flammer (2021) and Fatica and Panzica (2021) findings that corporate green bond issuers show a reduction in CO_2 emissions and an improvement in environmental rating.

Concerning resource use score (ResourceUse), Table I-10 reports that corporate green bond issuers reduce their use of resources in the short and long run, post-issuance (columns 3 and 4). For the subsample of a 1-year period, the estimate of the green bond dummy is positive (0.0661) and significant. For the subsample of a 3-year (and plus) period, the estimate is also positive (0.0775) and significant. Finally, we find evidence of parallel pre-trend of treated and control firms over the 3-year period before the issuance. The estimate of "Green bonds (pre-issue 3 years)" is not significant. Before the issuance, green bond issuers and non-issuers seem similar regarding resource use efficiency. The change obtained after green bond issuance is the treatment effect. The resource use score of the issuers goes up by 6.61% one year after the issuance and 7.75% three years after. That is, corporate green bond issuers are more efficient in terms of the use of resources in comparison with non-green bond issuers in the short and long run, post-issuance.

Table I-9. Long-run environmental performance following corporate green bond issuances

	Environmental performance			
	Environmental rating		CO_2 emissions	
Variables	1	2	3	4
Green bonds (all, after issuance)	0.0911*** (0.0347)		-13.8652*** (1.8359)	
Observations	1,866		1,301	
R-squared	0.81		0.9683	
Green bonds (short term, 1 year)		0.0331 (0.0246)		-2.6015 (1.736)
Observations		503		313
R-squared		0.8696		0.827
Green bonds (long term, 3 years)		0.1060*** (0.0399)		-12.148*** (1.6573)
Observations		1,336		938
R-squared		0.85		0.9
Green bonds (long term, 5 years &+)		0.1532*** (0.0437)		-19.101*** (1.799)
Observations		1,814		694
R-squared		0.812		0.97
Green bonds (pre-issue 3 years)		-0.01756 (0.0357)		2.5244 (1.6474)
Observations		1,374		878
R-squared		0.8492		0.98
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Note (s): This Table presents the estimates of the difference-in-differences specification for the environmental rating in columns (1) and (2), and firm-level CO_2 emissions in columns (3) and (4). In columns (1) and (3), we present the results for the entire sample and all years following corporate green issuance. Columns (2) and (4) present the results of the subsamples: Green bonds (short-term, 1 year), Green bonds (long-term, 3 years), Green bonds (long-term, 5 years &+), and Green bonds (pre-issue 3-years). The sample includes all firm-year observations of the treated and control firms from 2010–2020. Environmental ratings are in decimal (not in percentage) and are obtained from the Refinitiv ESG database. CO_2 emissions are the ratio of CO_2 emissions from the Refinitiv ESG database divided by the book value of total assets obtained from Compustat. The only independent variable in all our regressions is the green bond issuance dummy named "Green bonds", which is equal to one if firm i is in the treatment group at time t, and zero if firm i is in the control group, during the sample period. We estimate the panel regression with fixed effects. The estimates are expressed in decimals (not in %), and standard errors are in parentheses. The symbols *, **, and *** imply, respectively, significance at the 10%, 5%, and 1% levels.

Source: Authors' own work

Finally, concerning the Refinitiv innovation score (InnovationScore), the results indicate that green innovation is a characteristic of green bond issuers rather than a causal effect of corporate green bond issuance. We find that the corporate green bond issuance dummy estimate is positive and significant in all our regressions, including for the subsample of the 3-year period before the issuance year. For the subsample of a 1-year period, the estimate of the green bond dummy is positive (0.1308) and significant. For the subsample of a 3-year (and plus) period after the issuance, the estimate is also positive (0.1182) and significant. Finally, we find no evidence of parallel pre-trend of treated and control firms over the 3-year period prior to the issuance. The estimate of "Green bonds (pre-issue 3 years)" is positive (0.1125) and significant. The change obtained in innovation score after green bond issuance is not the treatment effect. Our findings indicate that green innovation is a characteristic of green bond issuers compared with non-issuers, not a causal effect of green bond funding.

Table I-10. Long-run environmental performance following green bond issuance: Green innovation and resource use score

	Environmental performance			
	InnovationScore		ResourceUseScore	
Variables	1	2	3	4
Green bonds (all, after issuance)	0.1021*** (0.0246)		0.0651*** (0.0234)	
Observations	1,432		1,432	
R-squared	0.3911		0.3845	
Green bonds (short term, 1 year)		0.1308*** (0.0288)		0.0661** (0.0277)
Observations		429		429
R-squared		0.4089		0.4006
Green bonds (long term, 3 years &+)		0.1182*** (0.0344)		0.0775** (0.0278)
Observations		579		579
R-squared		0.4250		0.4425
Green bonds (pre-issue 3 years)		0.1125*** (0.0288)		0.0396 (0.0304)
Observations		1,090		1,090
R-squared		0.4047		0.4363
Country fixed effects	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Source: Authors' own work

6.4. Further analysis

Our baseline DiD estimations employ only the green bond issuance dummy as an explanatory variable. We do not include any control variables. This specification is based on the argument that using the matching approach may mitigate the impact of control variables since these variables are used to match treated and control firms. In addition, the DiD relies on the assumption of "parallel trends" between the treatment and the control groups. Accordingly, any difference in the changes in outcomes between the two groups after the treatment should be due to the impact of the treatment, not to the effect of other variables. As we stated previously, our matching method aimed to ensure that control firms (non-green bond issuers) are as similar as possible to the treated firms (green bond issuers), in their characteristics, except for the issuance of green bonds. As documented by Flammer (2021), using the environmental rating for the matching ensures that treated and control firms have similar environmental performance prior to the green bond issuance. Using measures of profitability (ROA) and firm value (Tobin's Q) rules out concerns that the treated firms may be more profitable or have better growth opportunities. Using size and debt capacity (leverage) addresses the possibility that treated firms may have better access to capital markets. Matching firms based on country, industry, and year ensures that treated and control firms face the same conditions in their business environment. Consequently, assuming we have considered all relevant control variables in the matching process, the main explanatory variable is the green bond issuance dummy. Thus, in the previous estimations, we consider that all the other variables may be irrelevant since treated and control firms are assumed to have the same characteristics. Then, controlling for firms' characteristics such as ROA, debt ratio, firm size, or firm value is unnecessary. However, in this subsection, we confirm our previous results on the impact of green bond issuance on firm outcomes using alternative specifications that include control variables.

First, in addition to country, year, and industry effects, we control for characteristics such as ROA, debt ratio, cash-to-asset ratio, firm size, and firm value (Tobin's Q). The results, as reported in Appendix (Table I-A1 for financial performance and Table I-A3 for environmental performance), are similar to those obtained using a green bond issuance dummy only. Green bond issuance positively affects firm value in the short and long run. However, it does not significantly impact the firm's operating performance (ROA). Corporate green bond issuance also positively impacts the firm's environmental performance, including environmental rating, CO_2 emission reduction, green innovation and resource use scores.

Next, in addition to the control variables (firm characteristics, country, industry, and year effects), we examine if the impact of green bond issuance is more (or less) important for emerging or developed countries. Specifically, we consider firms located in the USA, Japan, and China. We created a dummy variable "China_firms" that equals 1 if the issuer is located in China, and 0 otherwise. A dummy variable "USA_firms" equals 1 if the issuer is located in the USA, and 0 otherwise, and a dummy variable "Japan_firms" equals 1 if the issuer is located in Japan, and 0 otherwise. In all our regressions, we examine the interaction of each of these dummies with corporate green bond issuance dummy by incorporating "Green bonds*China_firms", "Green bonds*USA_firms", and "Green bonds*Japan_firms" in the model. The results are reported in Appendix (Table I-A2 and Table I-A4). As can be seen, being US, Japanese, or Chinese has no specific effect on firm value, after corporate green bond issuance. We found that the coefficients associated with Green bonds*China_firms, Green bonds*USA_firms, and Green bonds*Japan_firms are positive but not significant. Concerning the ROA, the coefficients are negative and not significant except for the 1-year post-issuance period of the USA firms, which is positive (0.0106) and not significant, and the 3-year post-issuance period of Japan, which is negative (-0.077) and significant at 10% only. This conducts us to conclude that corporate green bond issuance has no significant effect on the firm operating performance. For the environmental performance, the interaction effects are also not significant in the majority.

7. Discussion and practical implications

Our study finds some evidence that corporate green bond issuers tend to outperform similar control firms, in the long run. The findings are in line with the previous studies of the announcement period returns, which reveal that issuing corporate green bonds improves firm value in the short run (Baulkaran, 2019; Tang and Zhang, 2020; Flammer, 2021). As the earlier long-run event studies, our results reveal that the announcement period returns of green bond issuers tell an incomplete story (McLaughlin et *al.,* 1998; Lee and Loughran, 1998; Spiess and Affleck-Graves, 1999; Dichev and Piotroski, 1999). The green bond issuers outperform, on an annual basis, matching firms by 11.81%, and by 22.32% on a 3-year period. However, the cost of green bond financing cannot explain this outperformance. As documented by previous studies, investors view green and non-green securities by the same issuer as almost exact substitutes so that the cost of green bond funding is similar to that of conventional bonds (Cheong and Choi, 2020; Larcker and Watts, 2020; Tang and Zhang, 2020; Flammer, 2021; Zerbib, 2019). In addition, the positive stock market reaction following the announcements of green bond issuance is not due to the lower cost of green bond funding (Tang and Zhang, 2020; Flammer, 2021). Therefore, the performance of issuers cannot be associated with any potential financial gain resulting from green bond financing.

In contrast to the earlier long-run event studies that found negative abnormal returns and concluded that, like equity, debt issuances are bad news (Lee and Loughran, 1998; Spiess and

Affleck-Graves, 1999; Dichev and Piotroski, 1999), our evidence suggests that the market interprets green bond funding as good news, consistent with the predictions of agency and asymmetric information theories (Ross, 1977; Harris and Raviv, 1991; Dichev and Piotroski, 1999). Jensen and Meckling (1976) document that the firm obtains an optimal capital structure by making a trade-off between the agency costs of debt and the agency costs of equity. In Ross (1977) model, debt issuance represents a signal of confidence emitted by managers on the profitability of their firm. As a result, investors interpret the news of the bond issue as the firm's ability to benefit from indebtedness. However, our results do not support the asymmetric information models of Myers and Majluf (1984), although this model suggests that equity and convertible debt issuances are bad news than straight debt issuances. In the pecking order theory, like equity, debt issuances are bad news since, due to asymmetric information, all security issues reveal lower-than-expected operating performance. Thus, the market reacts negatively to all forms of external financing (Myers and Majluf, 1984). Finally, our findings contradict the irrelevance theories of the source of financing (Modigliani and Miller, 1958), which implies that the announcement of a capital structure change has no impact on the firm's market valuation. In sum, unlike conventional bond issuances in the empirical literature and consistent with agency and signal theories, our findings suggest that existing shareholders benefit from green bond issuance.

The long-run evidence suggests that the announcement period returns incompletely reflect the informational content of green bond issuances, so the full impact is realized over a more extended period. Intuitively, the stock market performance of the issuers should be explained by better profitability of the projects financed by the proceeds of the issues. Firms that issued green bonds to invest in value-enhancing activities should have better operating performance after the offering (McLaughlin et *al.,* 1998). However, this argument is not valid for green bond issuers. While corporate green bond issuance is followed by an increase in firm value, we find no significant change in issuers operating performance compared with non-issuers. That is, the strong stock market performance obtained is not necessarily related to better profitability of projects financed by green bonds. This finding can be explained by the fact that green bonds are not a unique source of financing profitable projects. We have no evidence that green bond issuers have more profitable projects than non-issuers. The matched control firms with similar growth opportunities may issue conventional bonds or use alternative funding sources to undertake value-enhancing projects that are not necessarily eco-friendly. Suppose the projects financed by green bonds present a similar NPV to those financed using an alternative source of funding. In that case, the impact of green bond issuance on operating performance may be insignificant. Thus, our results are inconsistent with managers' inability to use the proceeds to finance profitable projects, as documented by the previous studies on debt issuance (McLaughlin et *al.,* 1998). On the other hand, our results may be consistent with the view that green projects may take much longer to generate higher profits. All these contradict the earlier long-run event studies that debt issuers have significant declines in operating and stock performance, post-issuance (Lee and Loughran, 1998; Spiess and Affleck-Graves, 1999; Dichev and Piotroski, 1999).

In pursuit of explanations of the post-issuance stock market performance, we find that green bond issuers improve their environmental performance (achieve a higher environmental rating, reduce their CO_2 emissions, improve their resource use efficiency and green innovation score), post-issuance. Based on the positive abnormal returns earned around the announcements (Baulkaran, 2019; Tang and Zhang, 2020; Flammer, 2021), this improvement appears to have been anticipated at the time of the issue. Then, our results are consistent with the signaling argument. By issuing green bonds, firm credibly signal their commitment toward the environment, not directly the profitability of projects financed by the proceeds. Unlike conventional bonds, the stock market responds positively to this signal, consistent with prior studies that find a positive effect of CSR on financial performance (Bardos et *al.*, 2020; Lins et *al.*, 2017; Servaes and Tamayo, 2013) and a negative effect on firm risk (Albuquerque et *al.*, 2019; Chakraborty et *al.*, 2019; Jo and Na, 2012). Our findings support Tang and Zhang (2020) and Flammer (2021) that green bond issuances help attract a clientele of investors that valorize long-term and environmental protection. Thus, the sustainability-oriented strategy has a positive impact on the financial performance of green bond issuers. On the other hand, the results of conventional bond issuance are consistent with the pecking order theory (Myers and Majluf, 1984), in which debt issuance is bad news since it signals that a firm is overvalued (Lee and Loughran, 1998; Spiess and Affleck-Graves, 1999).

Our results support the view that high demand from investors motivated by pro-environmental preferences affects equilibrium prices (Zerbib, 2019). For instance, Tang and Zhang (2020) document that green bond issuances are followed by increased media exposure and the visibility of the issuing firms, which attract investor attention, and expand the investor base and demand for issuers' securities. Fama and French (2007) show that when a category of investors has a taste or disagreement for an asset, equilibrium price shifts, and the capital asset pricing model cannot explain adequately asset returns. In Pastor et *al.* (2019)

model, investors care about firms' social impact, financial wealth, and climate change risk. Consequently, green assets have low expected returns because investors with stronger ESG preferences enjoy holding them and because green assets hedge climate risk. Another explication of our results is that green investors do not necessarily invest for immediate gain. They possibly invest by considering the very long-term performance they anticipate for socially responsible firms. This argument follows Flammer and Tang's study that green bond issuance attracts specifically green and long-term investors. Investors may also interpret green bond issuance as a reputation-building strategy (Gilchrist et *al.,* 2021). Thus, as suggested by Tang and Zhang (2020), they may hold the stock rather than realize the gain in the short run because they believe in the long-term performance resulting from CSR.

In addition, our analysis of various sub-periods provides evidence that the 3-year stock market performance is limited to multiple-time issuers, which we define as firms that reissue green bonds within three years of a previous issuance. If the markets fully incorporated information contained in the issuance, abnormal returns would be limited to the announcements period, so the long-run abnormal returns would be insignificant (Dichev and Piotroski, 1999). The continuation of positive abnormal performance from the announcement period into the post-event period suggests that the stock market underreacts to the information contained in the announcement of corporate green bond issuances. However, it is not surprising that the market does not fully price this systematic post-issuance performance upon the announcement. Markets are not efficient given the possibilities of greenwashing. As we documented previously, debt issuance is a negative signal on the firm financial performance, while investors value positively good ESG practices. Given that not all green bonds are certified, dishonest firms can issue for greenwashing purposes. As news on greenwashing is also a negative signal in addition to that of indebtedness, investing in such firms represents a great risk. The suspicion of greenwashing may push investors to investigate the issuing firm and its projects before investing. Then, some cautious investors may take time to react to green bond issuances, considering the possibilities of greenwashing. As the market reacts slowly, first-time issuers achieve performance over one year, while only multiple-time issuers realize stock performance over three years.

The finding that only multiple-time issuers perform in the long run also deserves some discussion. It appears that the media coverage of green bond issuance plays an essential role in the attractiveness of investors. As media exposure cannot last more than a year, the market fully integrates the issuance information during the year of an issue so that the stock performance of first-time issuers is limited to one year. Regarding multiple-time issuers, the market reactions following each issuance could explain their stock performance over three years. After each issuance, these firms benefit from the media coverage, which sends constantly good news to the market. However, this signal seems to attract investors following each new issue for up to three years after the first issue. After three years, the market fully integrates the information on the issuers' commitment toward environmental protection, and the new green bonds issued no longer significantly impact long-run stock performance. On the other hand, over three years, new publications on issuers' environmental performance will appear to alleviate investor concerns about greenwashing. Thus, new green bond issues will attract more investors, including the most reluctant, and the markets will incorporate completely the information contained in the issuance. The possibility of greenwashing is a market imperfection that pushes investors to be cautious.

This study has practical implications for managers and policymakers. A green bond issuance leads to a positive valuation of the firm, while issuing a conventional bond to finance environmental projects may have a negative impact on the firm's stock market valuation. At the firm level, managers have an interest in issuing green bonds to finance their environmental projects to send a positive signal to investors and other stakeholders such as customers or environmentalists. This action is in the interest of the firm's current shareholders. Otherwise, issuing a conventional bond or equity to finance green projects would send a negative signal to the financial markets, which is not in the interest of current shareholders. Our study also supports the need to develop the green bond market. Given that corporate green bond issuance is beneficial for investors, and has a positive effect on the environment, policymakers aiming at taking action to combat climate change should put in place mechanisms that support the development of the green bond market. The main challenge is to improve credibility in the green bond market by minimizing the possibilities of greenwashing. Policymakers can play this role by providing a robust legal framework or governance tools that protect investors against greenwashing (or discourage issuing green bonds for greenwashing). These actions will contribute to making the green bond market more efficient and allow green projects to find financing more easily.

8. Conclusion

This study examines the long-run financial and environmental performance of corporate green bond issuers over 2013-2020. We start by constructing a comprehensive dataset covering all green bond issuance worldwide, using the Bloomberg database. We collect stock market and accounting data from Compustat, and ESG data from the Refinitiv ESG database. We select the control firms using the matching approach.

We first examine the long-run stock market performance of green bond issuers over 1-year, 3-year, and 5-year periods, following the issuance. We use the BHAR approach and compute both equal-weighted and value-weighted BHAR. Concerning the equal-weighted BHAR, our results indicate the 1-year and 3-year stock market performance of green bond issuers relative to the matched control firms for the full sample. However, when we consider the subsamples, we see that only multiple-time issuers perform well over the 3-year period. Equal-weighted BHAR also indicate that corporate green bond issuers realized positive but no significant abnormal return five years following the issuance. That is, corporate green bond issuers perform only over a 3-year period compared to the control firms. After three years, their stock market performance is similar to that of the control firms. Concerning the value-weighted BHAR, we obtain similar results for the full sample over a 12-month period: the BHAR is positive and significant. However, the BHAR are positive over 3-year and 5-year periods, but not significant. For the subsamples, only multiple-time issuers realize positive and significant abnormal returns over three years and five years. The BHAR of first-time issuers are not significant. We also distinguish between green bond issuers operating in industries with high versus low SASB scores of environmental materiality. We find that only issuers operating in industries where the natural environment is financially material are more likely to perform in the long run, compared to the control firms. This leads us to conclude that only multiple-time issuers, and issuers operating in industries where the natural environment is financially material perform well in the long run.

Next, we examine the long-run firm value and operating performance using the matching method and the DiD estimations. Our results reveal that green bond issuers achieve an increase in their market value three years after the offering, compared to non-issuers. However, when analyzing the operating performance, we find no significant results. Corporate green bond issuers and the control firms exhibit similar returns on assets over 1-year, 3-year, and 5-year periods, following the issuance year. That is, the increase in firm value and the positive BHAR obtained are not necessary due to an increase in profitability of the issuers relative to non-issuers, post-issuance. These results support Flammer (2021) that green bond issuers attract long-term and green investors post-issuance. Taken together, they contrast the earlier studies that debt issuers have large declines in long-run operating and stock market performance after the offering (McLaughlin et *al.,* 1998; Spiess and Affleck-Graves, 1999; Dichev and Piotroski, 1999). In sum, issuing corporate green bonds appears to be beneficial for the existing shareholders, in the long run.

Finally, we examine the long-run environmental performance of green bond issuers. Using DiD estimations, we find that corporate green bond issuers reduce their CO_2 emissions and improve their environmental rating three years after issuance. That is, issuing green bonds contributes to CO_2 emission reduction and the improvement of the firm environmental performance in the long term. This seems justified since projects financed by green bonds may take time to produce output. Thus, our results invalidate the greenwashing hypothesis and support the signaling view of corporate green bond funding. In addition, one of our main contributions results in our findings that corporate green bond issuance is associated with low resource consumption and green innovation. We find that corporate green bond issuers become more efficient in terms of the use of natural resources in comparison with non-green bond issuers in the short and long run, post-issuance. The resource use score of green bond issuers goes up by 6.61% one year after the issuance and 7.75% in the three years. On the other hand, our findings indicate that green innovation is a characteristic of green bond issuers rather than a causal effect resulting from green bond funding. Corporate green bond issuers have higher green innovation scores before and after the offerings.

Like the previous event studies, our study has certain limitations. The main issue is the potential endogenization of green bond issuances. First, one may argue that other significant events would occur during the analysis period and affect the firms' financial or environmental performance. The second concern is dealing with other factors that may affect the firms' environmental performance during the analysis period. Indeed, all factors that can affect the firm environmental performance can also have a strong relationship with green bond issuances. For example, if the government strengthens regulations to limit environmental pollution (e.g., the carbon market), this can encourage firms to invest more in green technologies and, therefore, to issue green bonds to finance these investments. As evidence, our study reveals that green innovation is a characteristic of green bond issuers rather than a causal effect resulting from the issuance of green bonds. The real problem is that it is very difficult or even impossible to identify all external and internal events as well as all other factors that can affect firms over the sample period. Moreover, if one managed to identify all these events and factors, the question would be how to analyze them all in a single study. Nevertheless, the objective of our study is to examine the impact of corporate green bond funding on the firm financial and environmental performance, not to analyze the impact of all factors and events. Therefore, the matching approach remains an effective methodological answer to these concerns, as evidenced by previous work.

By matching the green bond issuers (treated) with similar control firms, the matching method makes it possible to circumvent the endogeneity problem, including that related to the missing variables as well as the incidences of other events that may occur during the period of analysis. This method considers that the treated and the control firms have the same characteristics, operate under the same conditions, and are in the same environments. Given this assumption, any other external shock (event) not taken into account which affects the treated firms will also affect the control firms in the same way (so that the DiD estimated for each of these shocks will be negligible). Thus, the DiD estimate for the green bond issuance dummy will be unbiased. The matching method may also have limitations, although it is widely adopted in the literature. Hence, using another approach (e.g., a quasi-experimental) to confirm our results can be another avenue of future research. It would also be interesting to pursue the analysis by examining the determining factors of green bond issuances.

References

Akerlof, G.A. (1970), "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism", *The Quarterly Journal of Economics*, Vol. 84 No. 3, pp. 488–500, doi: 10.2307/1879431.

Albuquerque, R., Koskinen, Y. and Zhang, C. (2019), "Corporate Social Responsibility and Firm Risk: Theory and Empirical Evidence", *Management Science*, INFORMS, Vol. 65 No. 10, pp. 4451–4469, doi: 10.1287/mnsc.2018.3043.

Atif, M., Hossain, M., Alam, M.S. and Goergen, M. (2021), "Does board gender diversity affect renewable energy consumption?", *Journal of Corporate Finance*, Vol. 66 No. 101665, p. 101665, doi: 10.1016/j.jcorpfin.2020.101665.

Bachelet, M.J., Becchetti, L. and Manfredonia, S. (2019), "The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification", *Sustainability*, Multidisciplinary Digital Publishing Institute, Vol. 11 No. 4, p. 1098, doi: 10.3390/su11041098.

Baldauf, M., Garlappi, L. and Yannelis, C. (2020), "Does Climate Change Affect Real Estate Prices? Only If You Believe In It", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1256–1295, doi: 10.1093/rfs/hhz073.

Barber, B.M. and Lyon, J.D. (1997), "Detecting long-run abnormal stock returns: The empirical power and specification of test statistics", *Journal of Financial Economics*, Vol. 43 No. 3, pp. 341–372, doi: 10.1016/S0304-405X(96)00890-2.

Bardos, K.S., Ertugrul, M. and Gao, L.S. (2020), "Corporate social responsibility, product market perception, and firm value", *Journal of Corporate Finance*, Vol. 62, p. 101588, doi: 10.1016/j.jcorpfin.2020.101588.

Barry, C.B. and Mihov, V.T. (2015), "Debt financing, venture capital, and the performance of initial public offerings", *Journal of Banking & Finance*, Vol. 58, pp. 144–165, doi: 10.1016/j.jbankfin.2015.04.001.

Baulkaran, V. (2019), "Stock market reaction to green bond issuance", *Journal of Asset Management*, Vol. 20 No. 5, pp. 331–340, doi: 10.1057/s41260-018-00105-1.

Beck, U. (2015), "Emancipatory catastrophism: What does it mean to climate change and risk society?", *Current Sociology*, SAGE Publications Ltd, Vol. 63 No. 1, pp. 75–88, doi: 10.1177/0011392114559951.

Chakraborty, A., Gao, L.S. and Sheikh, S. (2019), "Managerial risk taking incentives, corporate social responsibility and firm risk", *Journal of Economics and Business*, Vol. 101, pp. 58–72, doi: 10.1016/j.jeconbus.2018.07.004.

Cheong, C. and Choi, J. (2020), "Green bonds: a survey", *Journal of Derivatives and Quantitative Studies*, Emerald Publishing Limited, Vol. 28 No. 4, pp. 175–189, doi: 10.1108/JDQS-09-2020-0024.

Cui, H. and Leung, C.-M.S. (2020), "The long-run performance of acquiring firms in mergers and acquisitions: Does managerial ability matter?", *Journal of Contemporary Accounting & Economics*, Vol. 16 No. 1, p. 100185, doi: 10.1016/j.jcae.2020.100185.

Cui, X., Zhao, K., Zhou, Z. and Huang, P. (2021), "Examining the uncertainty of carbon emission changes: A systematic approach based on peak simulation and resilience assessment", *Environmental Impact Assessment Review*, Vol. 91, p. 106667, doi: 10.1016/j.eiar.2021.106667.

Dichev, I.D. and Piotroski, J.D. (1999), "The Performance of Long-run Stock Returns Following Issues of Public and Private Debt", *Journal of Business Finance & Accounting*, Vol. 26 No. 9–10, pp. 1103–1132, doi: 10.1111/1468-5957.00288.

Dorfleitner, G., Utz, S. and Zhang, R. (2022), "The pricing of green bonds: external reviews and the shades of green", *Review of Managerial Science*, Vol. 16 No. 3, pp. 797–834, doi: 10.1007/s11846-021-00458-9.

Dutta, A. and Dutta, P. (2015), "Measuring long-run security price performance: a review", *Investment Management and Financial Innovations*, Vol. 12 No. 2.

Dutta, S. and Jog, V. (2009), "The long-term performance of acquiring firms: A re-examination of an anomaly", *Journal of Banking & Finance*, Vol. 33 No. 8, pp. 1400–1412, doi: 10.1016/j.jbankfin.2009.02.004.

Fama, E.F. (1998), "Market efficiency, long-term returns, and behavioral finance", *Journal of Financial Economics*, Vol. 49 No. 3, pp. 283–306, doi: 10.1016/S0304-405X(98)00026-9.

Fama, E.F. and French, K.R. (2007), "Disagreement, tastes, and asset prices", *Journal of Financial Economics*, Vol. 83 No. 3, pp. 667–689, doi: 10.1016/j.jfineco.2006.01.003.

Fatica, S. and Panzica, R. (2021), "Green bonds as a tool against climate change?", *Business Strategy and the Environment*, Vol. 30 No. 5, pp. 2688–2701, doi: 10.1002/bse.2771.

Febi, W., Schäfer, D., Stephan, A. and Sun, C. (2018), "The impact of liquidity risk on the yield spread of green bonds", *Finance Research Letters*, Vol. 27, pp. 53–59, doi: 10.1016/j.frl.2018.02.025.

Flammer, C. (2021), "Corporate green bonds", *Journal of Financial Economics*, Vol. 142 No. 2, pp. 499–516, doi: 10.1016/j.jfineco.2021.01.010.

Fu, F. and Huang, S. (2016), "The Persistence of Long-Run Abnormal Returns Following Stock Repurchases and Offerings", *Management Science*, INFORMS, Vol. 62 No. 4, pp. 964–984, doi: 10.1287/mnsc.2015.2150.

Gianfrate, G. and Peri, M. (2019), "The green advantage: Exploring the convenience of issuing green bonds", *Journal of Cleaner Production*, Vol. 219, pp. 127–135, doi: 10.1016/j.jclepro.2019.02.022.

Gilchrist, D., Yu, J. and Zhong, R. (2021), "The Limits of Green Finance: A Survey of Literature in the Context of Green Bonds and Green Loans", *Sustainability*, Multidisciplinary Digital Publishing Institute, Vol. 13 No. 2, p. 478, doi: 10.3390/su13020478.

Harris, M. and Raviv, A. (1991), "The Theory of Capital Structure", *The Journal of Finance*, Vol. 46 No. 1, pp. 297–355, doi: 10.1111/j.1540-6261.1991.tb03753.x.

Jensen, M.C. and Meckling, W.H. (1976), “Theory of the firm: Managerial behavior, agency costs and ownership structure”, *Journal of Financial Economics*, Vol. 3 No. 4, pp. 305–360, doi: 10.1016/0304-405X(76)90026-X.

Jo, H. and Na, H. (2012), “Does CSR Reduce Firm Risk? Evidence from Controversial Industry Sectors”, *Journal of Business Ethics*, Vol. 110 No. 4, pp. 441–456, doi: 10.1007/s10551-012-1492-2.

Kothari, S.P. and Warner, J.B. (1997), “Measuring long-horizon security price performance”, *Journal of Financial Economics*, Vol. 43 No. 3, pp. 301–339, doi: 10.1016/S0304-405X(96)00899-9.

Kothari, S.P. and Warner, J.B. (2007), “Econometrics of Event Studies”, in Eckbo, B.E. (Ed.), *Handbook of Empirical Corporate Finance*, Elsevier, San Diego, pp. 3–36, doi: 10.1016/B978-0-444-53265-7.50015-9.

Larcker, D.F. and Watts, E.M. (2020), “Where’s the greenium?”, *Journal of Accounting and Economics*, Vol. 69 No. 2, p. 101312, doi: 10.1016/j.jacceco.2020.101312.

Lee, I. and Loughran, T. (1998), “Performance following convertible bond issuance”, *Journal of Corporate Finance*, Vol. 4 No. 2, pp. 185–207, doi: 10.1016/S0929-1199(98)00007-8.

Lins, K.V., Servaes, H. and Tamayo, A. (2017), “Social Capital, Trust, and Firm Performance: The Value of Corporate Social Responsibility during the Financial Crisis”, *The Journal of Finance*, Vol. 72 No. 4, pp. 1785–1824, doi: 10.1111/jofi.12505.

Lyon, J.D., Barber, B.M. and Tsai, C.-L. (1999), “Improved Methods for Tests of Long-Run Abnormal Stock Returns”, *The Journal of Finance*, Vol. 54 No. 1, pp. 165–201, doi: 10.1111/0022-1082.00101.

MacAskill, S., Roca, E., Liu, B., Stewart, R.A. and Sahin, O. (2021), “Is there a green premium in the green bond market? Systematic literature review revealing premium determinants”, *Journal of Cleaner Production*, Vol. 280, p. 124491, doi: 10.1016/j.jclepro.2020.124491.

Malmendier, U., Moretti, E. and Peters, F.S. (2018), “Winning by Losing: Evidence on the Long-run Effects of Mergers”, *The Review of Financial Studies*, Vol. 31 No. 8, pp. 3212–3264, doi: 10.1093/rfs/hhy009.

McLaughlin, R., Safieddine, A. and Vasudevan, G.K. (1998), “The Long-Run Performance of Convertible Debt Issuers”, *Journal of Financial Research*, Vol. 21 No. 4, pp. 373–388, doi: 10.1111/j.1475-6803.1998.tb00692.x.

Mitchell, M.L. and Stafford, E. (2000), "Managerial Decisions and Long-Term Stock Price Performance", *The Journal of Business*, The University of Chicago Press, Vol. 73 No. 3, pp. 287–329, doi: 10.1086/209645.

Modigliani, F. and Miller, M.H. (1958), "The Cost of Capital, Corporation Finance and the Theory of Investment", *The American Economic Review*, American Economic Association, Vol. 48 No. 3, pp. 261–297.

Myers, S.C. and Majluf, N.S. (1984), "Corporate financing and investment decisions when firms have information that investors do not have", *Journal of Financial Economics*, Vol. 13 No. 2, pp. 187–221, doi: 10.1016/0304-405X(84)90023-0.

Paranque, B. and Revelli, C. (2019), "Ethico-economic analysis of impact finance: The case of Green Bonds", *Research in International Business and Finance*, Vol. 47, pp. 57–66, doi: 10.1016/j.ribaf.2017.12.003.

Pástor, L., Stambaugh, R.F. and Taylor, L.A. (2021), "Sustainable investing in equilibrium", *Journal of Financial Economics*, Vol. 142 No. 2, pp. 550–571, doi: 10.1016/j.jfineco.2020.12.011.

Renneboog, L. and Vansteenkiste, C. (2019), "Failure and success in mergers and acquisitions", *Journal of Corporate Finance*, Vol. 58, pp. 650–699, doi: 10.1016/j.jcorpfin.2019.07.010.

Ross, S.A. (1977), "The Determination of Financial Structure: The Incentive-Signalling Approach", *The Bell Journal of Economics*, [RAND Corporation, Wiley], Vol. 8 No. 1, pp. 23–40, doi: 10.2307/3003485.

Schoenmaker, D. and Schramade, W. (2018), *Principles of Sustainable Finance*, Oxford University Press, Oxford.

Servaes, H. and Tamayo, A. (2013), "The Impact of Corporate Social Responsibility on Firm Value: The Role of Customer Awareness", *Management Science*, INFORMS, Vol. 59 No. 5, pp. 1045–1061, doi: 10.1287/mnsc.1120.1630.

Spence, M. (1973), "Job Market Signaling", *The Quarterly Journal of Economics*, Vol. 87 No. 3, pp. 355–374, doi: 10.2307/1882010.

Spiess, D.K. and Affleck-Graves, J. (1999), "The long-run performance of stock returns following debt offerings", *Journal of Financial Economics*, Vol. 54 No. 1, pp. 45–73, doi: 10.1016/S0304-405X(99)00031-8.

Tang, D.Y. and Zhang, Y. (2020), "Do shareholders benefit from green bonds?", *Journal of Corporate Finance*, Vol. 61, p. 101427, doi: 10.1016/j.jcorpfin.2018.12.001.

Zerbib, O.D. (2019), "The effect of pro-environmental preferences on bond prices: Evidence from green bonds", *Journal of Banking & Finance*, Vol. 98, pp. 39–60, doi: 10.1016/j.jbankfin.2018.10.012.

Appendix to Chapter 1

Table I-A1. Firm value and operating performance (with control variables)

Firm value and operating performance						
	Firm value (Tobin's Q)			Return on assets (ROA)		
Variables	All, after issuance	1-year, post	3-year+, post	All, after issuance	1-year, post	3-year+, post
Green bonds	6.797**	10.79**	9.425**	0.0022	-0.0064	-0.0074
	(3.40)	(4.94)	(2.68)	(0.0043)	(0.0049)	(0.0056)
DebtRatio	0.186***	3.51***	1.52*	0.0002	-0.0014**	-0.0033*
	(0.047)	(0.3146)	(0.89)	(0.0001)	(0.0003)	(0.0018)
ROA	-7.54	17.35	22.08	-	-	-
	(10.47)	(54.47)	(15.39)			
CashtoASSET	6.36	-43.71	-6.72	0.0091	0.032	0.0263
	(7.84)	(39.06)	(14.47)	(0.0202)	(0.039)	(0.0287)
QTobin	-	-	-	-0.0002	0.0001	0.0007
				(0.0005)	(0.0005)	(0.0005)
Size_Firm	-4.97***	-12.71***	-9.52***	0.0021	0.0076***	0.008***
	(1.04)	(1.98)	(1.59)	(0.0016)	(0.002)	(0.0022)
Obs	1,401	425	1,076	1,401	305	1,076
R-squared	0.6947	0.6560	0.6029	0.4125	0.4797	0.4315
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' own work

Table I-A2. Firm value and operating performance (with control variables, China, USA, and Japan dummy)

Firm value and operating performance						
	Firm value (Tobin's Q)			Return on assets (ROA)		
Variables	All, after issuance	1-year, post	3-year+, post	All, after issuance	1-year, post	3-year+, post
Green bonds	6.79**	7.40**	8.425**	0.0022	-0.0023	-0.0074
	(3.40)	(2.26)	(3.680)	(0.0043)	(0.0055)	(0.0056)
Green bonds*China_firms	8.68	-14.08	22.42	-0.0176	-0.0041	-0.040
	(29.79)	(11.39)	(37.29)	(0.037)	(0.0101)	(0.044)
Green bonds*USA_firms	6.99	-17.91	9.13	-0.0016	0.0106	-0.022
	(30.12)	(12.81)	(36.94)	(0.037)	(0.0114)	(0.043)
Green bonds*Japan_firms	25.53	0.058	55.53	-0.048	-0.0288	-0.077*
	(29.83)	(9.96)	(36.98)	(0.037)	(0.08)	(0.044)
DebtRatio	0.186***	3.81***	1.52*	0.0002	-0.0014***	-0.003*
	(0.047)	(0.353)	(0.895)	(0.0001)	(0.0003)	(0.0018)
ROA	-7.54	10.02	22.08	-	-	-
	(10.47)	(55.15)	(15.39)			
CashtoASSET	6.36	-20.98	-6.72	0.0091	0.077**	0.026
	(7.84)	(39.07)	(14.47)	(0.0202)	(0.0346)	(0.028)
QTobin	-	-	-	-0.0002	0.00007	0.00007
				(0.0005)	(0.00004)	(0.00005)
Size_Firm	-4.97***	-1.88	-9.52***	0.0021	0.0037**	0.0080
	(1.04)	(1.38)	(1.59)	(0.0016)	(0.0012)	(0.0022)
Obs	1,401	425	1,076	1,401	305	1,076
R-squared	0.5425	0.2529	0.6029	0.4125	0.2029	0.4315
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' own work

Table I-A3. Environmental performance (with control variables)

Panel A	Environmental rating			CO_2 emissions		
	All	1-year	3-year+	All	1-year	3-year+
Green bonds	0.0823***	0.028	0.110***	-12.78***	-5.43	-13.6***
	(0.0252)	(0.020)	(0.041)	(2.84)	(4.71)	(3.51)
DebtRatio	0.0002	-0.0026*	0.0013	-22.58**	-5.89**	-9.02
	(0.0004)	(0.0014)	(0.007)	(5.94)	(2.83)	(9.28)
ROA	0.0816	0.255	0.059	76.74	13.27	56.18
	(0.0873)	(0.220)	(0.131)	(112.16)	(46.6)	(143.2)
CashtoASSET	-0.085	0.248	0.071	2.40	28.4	25.52
	(0.064)	(0.158)	(0.095)	(84.05)	(38.2)	(114.9)
QTobin	0.0004**	0.0007**	0.0004	0.832**	2.72***	0.776*
	(0.0002)	(0.0002)	(0.0002)	(0.241)	(0.501)	(0.423)
Size_Firm	0.062 ***	0.082***	0.055***	-14.76	-23.98	-8.13
	(0.005)	(0.008)	(0.008)	(9.34)	(18.68)	(12.05)
Obs	1,401	425	570	1,401	305	473
R-squared	0.5459	0.5638	0.5291	0.4874	0.5040	0.6081
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Panel B	InnovationScore			ResourceUseScore		
	All	1-year	3-year+	All	1-year	3-year+
Green bonds	0.076***	0.089***	0.089***	0.0552**	0.042**	0.0627***
	(0.024)	(0.028)	(0.034)	(0.0206)	(0.0243)	(0.0277)
DebtRatio	0.00003	0.0005	0.0009	0.0001	-0.0035*	0.0109
	(0.0005)	(0.002)	(0.009)	(0.0004)	(0.0018)	(0.0074)
ROA	-0.0266	-0.239	-0.112	0.0821	0.465*	0.1206
	(0.1128)	(0.307)	(0.169)	(0.095)	(0.267)	(0.137)
CashtoASSET	0.0042	0.599**	0.030	-0.064	0.221	0.112
	(0.0837)	(0.22)	(0.125)	(0.0705)	(0.191)	(0.1016)
QTobin	0.0002	0.0002	0.0006	0.0005**	0.0007**	0.0013***
	(0.0002)	(0.0003)	(0.0004)	(0.0002)	(0.0002)	(0.0003)
Size_Firm	0.057***	0.081***	0.056***	0.087***	0.111***	0.078***
	(0.008)	(0.012)	(0.013)	(0.0071)	(0.010)	(0.0107)
Obs	1,401	425	570	1,401	425	570
R-squared	0.4569	0.4903	0.4728	0.5461	0.5781	0.6172
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' own work

Table I-A4. Environmental performance (with control variables, China, USA, and Japan dummy)

Panel A	Environmental rating			CO_2 emissions		
	All	1-year	3-year+	All	1-year	3-year+
Green bonds	0.0866***	0.0526*	0.092***	-11.17***	-2.38	-12.7***
	(0.027)	(0.022)	(0.0335)	(2.03)	(4.45)	(3.77)
Greenbonds*China_firms	-0.017	-0.0199	-0.0306	-2.24	1.511	-5.49
	(0.028)	(0.0449)	(0.049)	(4.86)	(8.1)	(11.9)
Greenbonds*USA_firms	0.006	-0.0128	-0.0176	2.7	6.4	4.5
	(0.037)	(0.0452)	(0.0457)	(5.0)	(8.88)	(10.1)
Greenbonds*Japan_firms	-0.014	-0.022	-0.049	-2.95	2.55	3.09
	(0.030)	(0.039)	(0.098)	(6.26)	(6.37)	(6.16)
DebtRatio	0.0002	-0.00002	0.004	-22.19***	-6.08**	-14.09
	(0.0004)	(0.0014)	(0.004)	(5.88)	(2.33)	(10.15)
ROA	0.067	0.2103	0.103	52.97	30.13	26.64
	(0.087)	(0.222)	(0.084)	(110.3)	(43.7)	(54.2)
CashtoASSET	-0.129*	-0.1753	-0.030	-19.93	8.91	12.9
	(0.065)	(0.166)	(0.079)	(83.42)	(34.4)	(25)
QTobin	0.0009	-0.0009	-0.0001	1.06***	2.65***	0.724*
	(0.001)	(0.001)	(0.0001)	(0.190)	(0.33)	(0.41)
Size_Firm	0.027***	0.027***	0.031***	-18.9**	-23.09**	-36.8**
	(0.003)	(0.0055)	(0.0051)	(5.73)	(10.2)	(12.47)
Obs	1,401	425	1,076	1,074	305	789
R-squared	0.3691	0.3676	0.3985	0.3735	0.4200	0.2489
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Panel B	InnovationScore			ResourceUseScore		
	All	1-year	3-year+	All	1-year	3-year+
Green bonds	0.091***	0.126***	0.127***	0.0488**	0.0612**	0.055**
	(0.0256)	(0.030)	(0.030)	(0.024)	(0.0289)	(0.0287)
Greenbonds*China_firms	-0.105	-0.109	-0.113	-0.0309*	-0.0283	-0.0375
	(0.42)	(0.60)	(0.63)	(0.020)	(0.057)	(0.059)
Greenbonds*USA_firms	0.1038	0.081	0.038	-0.007	-0.013	0.015
	(0.55)	(0.60)	(0.098)	(0.052)	(0.058)	(0.055)
Greenbonds*Japan_firms	0.138	0.126	0.081	-0.0113	-0.0109	-0.0146
	(0.45)	(0.52)	(0.49)	(0.0427)	(0.050)	(0.0146)
DebtRatio	-0.00002	0.0016	0.0056	0.0002	-0.00002	0.0034
	(0.0005)	(0.0018)	(0.007)	(0.0004)	(0.0018)	(0.006)
ROA	-0.0718	-0.280	0.042	0.0356	0.3841	0.234**
	(0.111)	(0.297)	(0.122)	(0.0957)	(0.285)	(0.107)
CashtoASSET	-0.043	0.151	-0.063	-0.087	-0.184	-0.093
	(0.084)	(0.222)	(0.114)	(0.071)	(0.213)	(0.100)
QTobin	0.0001	-0.0002	-0.00004	0.00001	-0.0003	-0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
Size_Firm	0.018**	0.024**	0.019**	0.032***	0.031***	0.035***
	(0.0056)	(0.007)	(0.006)	(0.0052)	(0.0071)	(0.006)
Obs	1,401	425	1,076	1,401	425	1,076
R-squared	0.2982	0.3204	0.2961	0.2955	0.3121	0.3157
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes

Source: Authors' own work

CHAPTER -II

Corporate Governance and Green Innovation: International Evidence

Abstract

Corporate adaptation to climate change requires technological innovations. This study exploits Tobin's q model of investment to examine the relationship between corporate governance and green innovation. It argues that agency costs and financial market frictions affect investment, and are fundamental factors in R&D activities. By limiting agency conflicts, good governance facilitates access to external financing and encourages green innovation. Using the system-GMM on a sample of 3,896 firms from 2002-2021, covering 45 countries worldwide, we find that the better the corporate governance, the more the firm invests in green R&D. In addition, an increase in the score of each dimension (management, strategy, and shareholder) of corporate governance results in an increase in the probability of green product innovation. Finally, green innovation is positively related to firm environmental performance, emission reduction, and resource use efficiency. Overall, the findings suggest that effective governance is necessary for environmental efficiency.

Keywords: *Corporate governance, Green innovation, Climate change, Sustainable investing, Sustainable finance.*

JEL classification: G30 ; O32 ; Q55 ; Q56

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1. Introduction

Climate change resulting from industrial activities is gaining increasing attention worldwide (Chen and Chang, 2013; Liao et *al*., 2019). Policy-makers have implemented environmental regulations to achieve sustainable development goals (Chen et *al*., 2018; Chen and Chang, 2013). However, firms must adopt the best strategies that combine environmental and financial performance. In recent years, the value of green innovation has been increasingly recognized at the firm level (Usman et *al*., 2020; Chen and Chang, 2013; Chen et *al*., 2018). Green innovation becomes the primary tool for reducing firms' negative externalities on the environment through the development of green technologies, services, processes, and eco-friendly products (Chen et *al*., 2018; Zhang and Zhu, 2019).

Green innovation aims to mitigate the negative impact of industrial activities on the environment (Chen et *al*., 2018; Liao et *al*., 2019). It can be divided into green products and green processes innovation (Chen and Chang, 2013). These include innovation in energy-saving technologies, pollution prevention, waste recycling, green product design, and environmental management (Albort-Morant et *al*., 2016; Zhang and Zhu, 2019). That is, firms use innovative tools to achieve environmental efficiency objectives (Chen et *al*., 2018), and improve their financial performance. Chen and Chang (2013) argue that green product innovation positively affects corporate competitive advantage. Firms engaging in green innovation can minimize production waste, increase their reputation, and thereby increase their competitiveness under consumers' pressures, and regulations of policy-makers. Albort-Morant et *al*. (2016) noted that the competitive advantages result from two main benefits of green technologies: the commercial rewards of creating environmentally-friendly products, and the financial benefits. Thus, successful green innovation helps firms to strengthen their core competencies and to enhance their green image.

Literature reveals internal and external factors influencing firms' green innovation. External determinants include governmental regulations, stakeholder pressures (Zhang and Zhu, 2019; Chen et *al*., 2018), market competition (Albort-Morant et *al*., 2016; Chen and Chang, 2013), and financial resources availability (Liao et *al*., 2019; Amore and Bennedsen, 2016). Internal factors comprise, among others, the board of directors' characteristics such as board gender diversity (Liao et *al*., 2019; He and Jiang, 2019), board geographical diversity (Usman et *al*., 2020), and institutional investors on the board (Chen et *al*., 2018; Amore and Bennedsen, 2016; Zhang and Zhu, 2019). Most of these studies are realized on Chinese firms only. Solving the endogeneity problem is their main limitation. In that regard, Amore and Bennedsen (2016) exploit the changes in antitakeover legislation in the USA during the late 1980s as an exogenous shock to the threat of hostile takeovers (external governance) to deal with endogeneity. Using a sample of U.S. firms, they document that the worse-governed firms generate fewer green patents relative to the well-governed firms. Nevertheless, their study covered the period of 1976-1995, and they do not examine firm investments in green R&D. In addition, the shock used in their framework dates from the late 1980s, while environmental concerns have become more and more critical in recent years. For instance, green innovation experienced rapid growth after 2015 (Takalo and Tooranloo, 2021). Thus, it's necessary to explore the link between internal governance mechanisms and green innovation by using alternative approaches.

Our study aims to examine the impact of corporate governance on green innovation around the world, using Tobin's Q model of investment and green R&D as a measure of green innovation. Despite the importance of corporate governance in managerial decisions, little is known about the relationship between internal governance and investment in environmental R&D. Agency costs and financial market frictions affect corporate investment, and are fundamental factors in R&D activities (O'Connor and Rafferty, 2012). Gompers et *al*. (2003) support the view that corporate governance influences firm investment. They argue that in the absence of monitoring and incentive-based mechanisms, managers tend to undertake inefficient projects for their private interest. Ferrell et al. (2016) consider that firms with stronger governance are more likely to promote environmental protection. Amore and Bennedsen (2016) report that the effect of corporate governance on green innovation depends on the quality of internal governance, and the availability of financial resources. Innovation and R&D activities face a severe problem of asymmetric information and uncertainty, making investments in innovative projects hard to value by the financial market (Howell, 2017). By limiting agency conflicts, effective governance favors efficiency, facilitates access to external financing, and encourages green innovation. Stronger governance provides a structure that sets goals that serve the interests of both shareholders and society.

We analyze a sample of 3,896 firms from 2002-2021, covering 45 countries worldwide. We adopt the Tobin q model of research and development (R&D) and corporate governance of

O'Connor and Rafferty (2012) to explore the relationship between corporate governance and green innovation. Tobin's q model is widely used to examine corporate investments such as R&D and innovation (Hennessy, 2004; Blundell et *al*., 1992; O'Connor and Rafferty, 2012). We employ the green R&D investment to total assets as a measure of green innovation, and Refinitiv corporate governance rating as a measure of corporate governance. Using the system-GMM, we find a positive effect of corporate governance on green innovation. A one-percentage-point increase in the corporate governance ratings leads to an increase in green R&D expenses to the total asset ratio of about 0.77 percentage points.

In contrast with firms' conventional investment, the surplus-cash-to-asset ratio (internal financial constraint) is irrelevant for green innovation since it has no significant effect on green R&D expenditures. Tobin's q has a negative impact on green innovation, indicating that firms with high growth opportunities tend to invest less in green R&D. Given that younger firms generally have high growth opportunities (high q) and limited access to the capital markets, such firms likely prefer to invest their limited resources in their primary activity rather than green innovation. On the other hand, mature firms with low growth potential seem to take advantage of the opportunities offered by green innovation. Our results are robust to various specifications. Considering green R&D expenses as an ex-ante measure, we employ an ex-post measure of green innovation, namely, green product innovation. Using probit estimation, we confirm that the higher the corporate governance rating, the more the firm develops green products. Thus, effective governance fosters green innovation.

In pursuit of the analysis, we consider multiple dimensions of internal governance. Refinitiv ESG corporate governance measure covers three dimensions: management, corporate social responsibility (CSR) strategy, and shareholder dimensions of corporate governance. The latter includes the antitakeover provisions used in the GIM-Index. Using the logit regressions, we find that each of the three dimensions positively affects green product innovation. An increase in the management, the CSR strategy, or the shareholder dimension results in an increase in the probability of green product innovation. Thus, all dimensions of corporate governance matter in firms' green innovation strategy. Finally, we find a positive relationship between green product innovation and the firm environmental performance, including emission reduction and the firm's capacity to reduce the use of resources.

This article contributes to the literature in several ways. First, to the best of our knowledge, this is the first study examining the relationship between corporate governance and investment in environmental R&D. The study provides new evidence on the relationship between internal governance and changes in an essential component of societal value, namely green innovation. Our findings that corporate governance is associated with higher investment in green R&D, and green product innovation are consistent with diverse backgrounds as governance mechanisms moderate environmental decisions, and alleviate problems associated with groupthink (Bernile et *al.*, 2018; Shive and Forster, 2020; Jo and Harjoto, 2012). In contrast with other studies on green innovation, our study is the first to examine green R&D investment using the Tobin q model. Overall, the study suggests that effective governance is necessary for environmental efficiency. It offers new insights for managers and policy-makers on how to use governance tools to combat climate change. Policy-makers aiming to act against climate change should encourage firms to adopt appropriate governance mechanisms.

Second, our work relates to the literature on the nexus between corporate governance and innovation (Chemmanur and Tian, 2018; Sapra et *al.*, 2014; Atanassov, 2013; Amore and Bennedsen, 2016). While these previous studies focus on how external governance and antitakeover provisions affect innovation activities, we focus on internal governance. In addition, we examine the three dimensions of internal governance: management, CSR strategy, and shareholder dimensions. Sapra et *al.* (2014) distinguish ex-ante and ex-post measures of innovation. We consider both the ex-ante (green R&D investment) and the ex-post (green products) measures of green innovation, while previous studies focused only on the ex-post measure using patents. The well-known limitation of patents as an ex-post measure is that they only cover patentable and patented inventions (Amore and Bennedsen, 2016). In contrast with the previous studies, we examine the causal effect using the system-GMM since solving the endogeneity problem is the biggest challenge in corporate governance studies.

Finally, our study expands the growing literature on environmental pollution. Shive and Forster (2020) examine how corporate governance, as proxied by the ownership structure, affects corporate pollution. Flammer (2021) shows that corporate green bond issuance is followed by firm-level CO_2 emission reduction. We complete these studies by demonstrating a positive relationship between green innovation and firm environmental performance, including pollution reduction and resource use efficiency. That is, corporate governance indirectly impacts firms' environmental performance by promoting green innovation. The present study does tackle three of the 17 UN's Sustainable Development Goals (SDGs), namely, goal 9 on industries, innovation, and infrastructure, goal 12 on responsible production and consumption, and goal 13 on climate action.

The rest of the chapter is organized as follows. Section 2 presents the theoretical framework. Section 3 presents the data. Section 4 discusses the methodology. Section 5 examines whether corporate governance affects green innovation. Section 6 presents further analysis. Section 7 discusses the results, and section 8 concludes.

2. Theoretical framework

This section reviews the previous literature on how corporate governance affects innovation and firms' environmental decisions.

2.1. Corporate governance, managerial incentives, and innovation

In the agency view of corporate governance, without monitoring and incentive mechanisms, asymmetric information between outsiders and insiders generally results in a moral hazard from managers who act in their private interest instead of optimal investment, thus reducing firm value (Chemmanur and Tian, 2018; Jensen and Meckling, 1976). Incentive-based mechanisms and monitoring help align managers' objectives with those of the shareholders. Asymmetric information exposes firms to hostile takeovers (Becker-Blease, 2011), which are also considered one of the most important governance mechanisms to discipline managers and provide them with incentives to make value-enhancing decisions (Atanassov, 2013). The existence of hostile takeovers serves as an effective disciplining mechanism to mitigate the moral hazard problem and encourage effort, thus increasing firm value (Chemmanur and Tian, 2018). However, a great concern about active takeover pressures may push managers to sacrifice long-term interests by reducing investment, particularly in hard-to-value areas such as research and development (R&D) and innovation, to boost current profits (Becker-Blease, 2011). The nature of the innovative activity itself, in general, poses a specific financing problem. Innovation and R&D activities face a severe problem of asymmetric information, intangibility, and uncertainty, which make investments in innovative projects hard to value by the financial market (Howell, 2017). That illustrates the managerial myopia hypothesis of Stein (1988), who argues that, in the equity market, investors can't properly evaluate investment in long-run innovation because of information asymmetry. Therefore, the stocks of firms investing in R&D and innovative activities tend to be undervalued by the financial markets. This situation exposes the firms to hostile takeovers since outside shareholders can buy their stocks at low prices. To protect current shareholders and their own interests, managers will invest less in innovation that is difficult to evaluate by the market, and more in routine projects with quicker and more certain returns. In sum, advocates of antitakeover legislation argue that hostile takeovers force managers to invest mainly in short-term projects, diminishing the ability of firms to innovate, while proponents of hostile takeovers claim that the threat of takeovers forces managers to stay focused and innovate (Atanassov, 2013).

Many studies examining the relationship between corporate governance and innovation confirmed the managerial myopia hypothesis, using the threat of hostile takeovers or antitakeover provisions as a proxy of corporate governance. Most of these studies find a positive relationship between antitakeover provisions and innovation (Chemmanur and Tian, 2018; Atanassov, 2013; Becker-Blease, 2011). Antitakeover provisions stimulate innovation by reducing short-term pressures from the stock market, allowing managers to focus on long-term value creation (Chemmanur and Tian, 2018). This positive effect is more pronounced when the firm operates in competitive product markets and in the presence of internal governance mechanisms (Chemmanur and Tian, 2018; Atanassov, 2013). In addition, Sapra et *al*. (2014) developed a parsimonious model to investigate how external mechanisms for corporate governance (such as antitakeover laws) interact with the firm's internal mechanisms (such as managerial incentive contracts) to affect firm-level innovation. In contrast, with previous studies, their model reveals that innovation varies non-monotonically in a U-shaped manner with the takeover pressure faced by firms. The U-shaped relation arises through the interaction between expected takeover premia and private benefits of control, both of which vary with takeover pressure.

While incentive-based mechanisms such as linking executive compensation to firm financial performance motivate managers to make optimal decisions (Ferrell et *al*., 2016; Haque, 2017) and are likely to favor innovation that creates long-term value, Scherer and Voegtlin (2020) consider that it is not clear whether these mechanisms impact innovations that contribute to sustainable development. They argue that the shareholder value approach of corporate governance puts great emphasis on enhancing profits to create long-term shareholder value. Accordingly, green innovation is subject to this goal to be worth undertaking. Thus, when corporate goals conflict with sustainable development goals, efficiency implies sacrificing societal well-being for the benefit of shareholders. In contrast, rather than focusing exclusively on profits, the stakeholder approach of corporate governance proposes that the management should balance the various concerns and interests of different stakeholders. This approach is powerful in contributing to green innovation when stakeholders who take an interest in sustainable development are integrated into firm decision-making procedures.

2.2. Corporate governance, CSR activities, and green innovation

The literature reveals the relationship between internal governance and firm environmental practices (Shive and Forster, 2020; Dyck et *al*., 2019; Jo and Harjoto, 2012). Corporate governance mechanisms affect the firm environmental performance by increasing managers' sensitivity towards stakeholders' environmental preferences (Jo and Harjoto, 2012). Ferrell et *al*. (2016) consider well-governed firms more likely to be socially responsible and promote efforts to help protect the environment. Effective governance mechanisms provide a structure that sets goals that serve the interests of shareholders and society (García-Sánchez et al., 2019).

One of the main reasons that corporate governance may impact green innovation is that firm governance is the system by which firms are directed and controlled. Corporate governance affects the firm's policies by ensuring effective management that can deliver the long-term success of the company's operations. That is why Hosono et *al*. (2004) argue that corporate governance matters as a determinant of R&D intensity. Chemmanur and Tian (2018) also report evidence consistent with the hypothesis that effective governance spurs innovation by insulating managers from short-term pressures arising from the equity market, allowing them to focus on long-term value creation. In their framework, corporate governance favors innovation, particularly in firms that are subject to a larger degree of information asymmetry and operating in competitive product markets. Furthermore, Almagtome et al. (2020) document that corporate governance fosters the investment environment by enhancing reliability, transparency, and accountability at the firm-level. They report that effective governance makes firms environmentally responsible and more acceptable to society.

The board of directors is the central axis among corporate governance tools, and the main determinant of corporate strategy and policies (Naciti, 2019; Fama and Jensen, 1983). In that regard, Bernile et *al*. (2018) find evidence that diversity in corporate boards affects firms policies, as these boards monitor and advise. They show that the persistence of corporate policies increases with board diversity, and this effect is more significant over longer horizons. In their framework, firms with diverse boards invest more in R&D, and these investments are more productive, leading to greater and higher quality innovation output associated with greater board diversity. Their evidence supports the argument that the board of directors, as the representation of shareholders and the firm's principal governance body, plays a critical role in corporate environmental policies (Atif et *al*., 2021; Haque, 2017).

Corporate governance mechanisms and the board members are the major contributors to elicit societal activities (Chams and García-Blandón, 2019). The board of directors (BoD) is the main determinant of corporate strategy (Naciti, 2019). The BoD plays a substantial role in decision-making processes and monitoring at the organizational level (Fama and Jensen, 1983). It determines policies for the management, and makes decisions on major issues such as innovative activities (Naciti, 2019). According to Liao et *al*. (2015), the company's climate policy may be influenced by the interactions between the board, individual board members, and stakeholder constituents, in addition to an objective assessment of the severity of the agency problem. They argue that corporate climate strategy often involves significant investments with complex consequences that may affect each stakeholder differently. Since stakeholders have broader objectives, the board should be sufficiently diverse and independent to provide better governance in the decision-making context.

Lu and Herremans (2019) consider that diversity brings a greater variety of skills to the board. They find evidence that board gender diversity is positively associated with firms' environmental performance, mainly in the more environmentally impacting industries. Nadeem et *al*. (2017) study the impact of board gender diversity on corporate sustainability and support that women's presence on boards encourages firms to adopt environmentally friendly practices and become socially responsible through good governance practices. Using a sample of US firms, Atif et *al*. (2021) find gender-diverse boards beneficial in terms of greater renewable energy use, and the interaction between board gender diversity and renewable energy consumption improves the firm financial performance.

Firms with greater board diversity also promote green innovation. Based on Chinese manufacturing firms, Liao et *al*. (2019) find a positive effect of female independent directors on green innovation. Galbreath (2019) combines institutional and resource-based theories to examine 649 firms in Australia, and documents that women in leadership roles are likely to be more receptive to the normative forces, and take action to improve the implementation rates of green innovations. In the study of He and Jiang (2019), women on the board have to enjoy at least two seats to play a positive role in the firm's green innovation. In addition, an increase in women on boards increases the likelihood of green product innovation rather than green process innovation. Regarding geographical diversity, Usman et *al*. (2020) observe that foreign directors on Chinese firms' boards foster green innovation. The authors explained this by a resource dependence perspective which posits that foreign directors, as boundary spanners, replicate their green knowledge and experience in Chinese firms.

Furthermore, governance mechanisms such as CEO compensation policies, and the firm's ownership structure affect corporate environmental strategies. Hong and Minor (2016) find firms with shareholder-friendly governance more likely to provide compensation to executives linked to the firm's ESG performance. Specifically, providing executives with direct incentives for CSR is an effective tool to increase firm ESG performance. Incentive schemes induce managers to provide optimal effort as they are utility maximizers (Ferrell et *al*., 2016). In the presence of managerial incentives, CSR activities should reflect optimal investment, instead of agency costs. Ferrell et *al*. (2016) consider well-governed firms in which management is adequately incentivized, more likely to have managers engaging in appropriate CSR conduct. Socially responsible firms often adhere to value-maximizing corporate governance practices. Thus, CSR may be consistent with maximizing shareholder wealth as well as achieving broader societal goals. Choi et *al*. (2021) document that the greater the performance-based pay, the stronger the positive relationships between CSR and innovation activities. In line with arguments that incentive-based mechanisms can persuade executives to undertake climate protection initiatives, Haque (2017) finds ESG-based compensation positively associated with carbon reduction initiatives.

In their study, Krueger et *al*. (2020) reveal that climate change risk is one of the major concerns for investors. In consequence, institutional investors on the boards may use their power to persuade executives to improve the firm environmental performance. Along this line, Shive and Forster (2020) document a negative association between CO_2 emissions and governance characteristics such as mutual fund ownership and larger boards, suggesting that the increased oversight due to institutional investors on the board is a driver of reduced emissions. Haque (2017) considers that shareholders are more likely to influence firms to pursue climate protection initiatives. Green innovation aims to mitigate the deterioration of the environment and the resulting global warming. Thus, the presence of investors concerned about environmental issues on the board of directors, especially those with a larger share of their portfolios oriented to environmental, social, and governance (ESG) standards, may positively affect green innovation. Dyck et *al*. (2019) confirm that institutional investors push for more substantial firm environmental performance. Dai et *al*. (2020) find that customer activism is a disciplining mechanism in suppliers' CSR behavior. Thus, good governance practices are important determinants of corporate environmental policies, and are potentially relevant for green innovation.

Pressures from regulators and firms' stakeholders are among the key determinants of green innovation. Under pressure, firms are more willing to increase their investment in green innovation. Zhang and Zhu (2019) document a positive effect of consumer pressures on green product innovation and a positive effect of regulatory pressures on green process innovation. Chen et *al*. (2018) divided institutional pressures into three categories: (1) coercive pressure from governmental regulations; (2) normative pressure (values and norms), which comes from investors, customers, suppliers, media, the public, and non-governmental organizations; (3) and mimetic pressure occurs because firms imitate their competitors' to gain legitimacy. The authors document that both coercive and normative pressures promote green innovation. Their results imply that external stakeholders on firms' boards promote green innovation. Amore and Bennedsen (2016) use the adoption of the second-generation antitakeover laws by the U.S. states during the late 1980s as a proxy of external governance to document that the worse-governed firms generate fewer green patents relative to the well-governed firms. In addition, they support the argument that larger institutional owners mitigate the negative effect of bad external governance on green innovation by monitoring managers, suggesting that agency conflicts may be an important determinant of green innovation. In a recent study, Asni and Agustia (2022) also document that effective governance encourages green innovation. They show that corporate governance mechanisms, such as the board of directors, independent commissioners, and ownership concentration, positively impact green innovation. Specifically, the optimal board size results in effective coordination and cooperation in making green innovation decisions. The independent commissioners represent stakeholders' interests and direct the board of directors to implement green innovation in supporting sustainability for all stakeholders. Concentrated ownership influences executives to prefer innovation policies. In the study of Du and Cao (2023), it is hard for non-family shareholders to promote family firms' green innovation solely through ownership structure. Non-family shareholders can facilitate green innovation only when they participate in corporate governance by appointing directors. The directors appointed by non-family shareholders may help family firms promote green innovation by bringing valuable resources.

According to Scherer and Voegtlin (2020), the stakeholders' approach in corporate governance promotes green innovation, while the shareholder value model can be appropriate within the framework of green innovation if the government provides incentives such as green subsidies to foster such innovations. In the study of García-Sánchez et *al*. (2019), CSR-oriented governance mechanisms like board independence, the presence of a sustainability committee, and CSR-related incentives for managers complement one another to enhance the company's ESG performance. CSR-oriented governance ensures that managerial investment decisions align with the interests of shareholders and other stakeholders. This mechanism makes CEOs less likely to choose short-term investments and avoid uncertainty related to CSR strategy. All these arguments conduct us to suppose a positive relationship between all dimensions of corporate governance and green innovation.

3. Data description

This section presents the data sources, the main variables, and the descriptive statistics.

3.1. Accounting and stock market data

We collect firm-specific information, accounting, and financial data using Compustat. These include firms' industry 4-digit SIC codes (The Standard Industrial Classification codes), country of location, total assets and liabilities, long-term debt, total equity, cash, research and development expenses, capital expenditures, total revenue, sales, EBIT (Earnings Before Interest and Taxes), stock prices, shares outstanding, etc. We construct the main variables following previous studies (Xu and Kim, 2022; Atif et *al*., 2021). Firm size (log-assets) is the logarithm of the book value of total assets. The debt ratio is the ratio of the book value of long-term debt to the book value of total equity. Return on assets (ROA) is the ratio of the EBIT to the book value of total assets. Tobin's Q (firm value) is the ratio of the company's market capitalization to the book value of equity. The cash-to-asset ratio is the firm's total cash to total assets. We convert the 4-digit SIC codes into 2-digit SIC codes.

3.2. Corporate governance and environmental data

We obtained corporate governance and environmental data from the Thomson/Refinitiv ESG database. Refinitiv offers one of the most comprehensive ESG databases, covering over 70% of the global market cap across more than 450 different ESG metrics, with history dating back to 2002. This regroups 10 main themes, including emissions, environmental product innovation, board structure, shareholders, and so on. The ratings are available on close to 9,000 firms worldwide.

Corporate governance data collected from Refinitiv includes corporate governance rating, and the three dimensions of firm governance: CSR strategy, management, and shareholders.

Environmental data includes environmental rating, environmental R&D expenses, green product innovation, emission reduction score, resource use score, and carbon dioxide emissions (CO_2 emissions). The ratings are in decimal (not in percentage), and the CO_2 emissions are expressed in tons. Following Flammer (2021), we compute CO_2 emissions as the ratio of CO_2 emissions divided by the book value of total assets.

3.3. Measurements of green innovation and corporate governance

3.3.1. Green innovation

Sapra et *al*. (2014) distinguish ex-ante and ex-post measures of innovation. R&D expenditures are often used as the ex-ante measure, and patents as the ex-post measure of innovation. In the previous literature, green innovation has been measured in several ways. Indicators such as green R&D investments (Lee and Min, 2015), eco-labeling products (Lin et *al*., 2014), green patents (Usman et *al*., 2020; Amore and Bennedsen, 2016), and ISO14001 (Li et *al*., 2017) are used as measures. In this study, we adopt both the ex-ante and the ex-post measures of green innovation. First, considering our adoption of Tobin's q model for investment, we follow O'Connor and Rafferty (2012), and Lee and Min (2015), and use green R&D investments as a proxy of green innovation. For the robustness checks, and in the second part of our research, we employ green R&D expenses and the "green product" as measures of green innovation. Green R&D expenses, expressed in dollars, are the total amount of environmental R&D expenses (without clean-up and remediation costs). "Green product" from Refinitiv is a dummy variable that equals 1 if the firm reports on at least one product line or service that is designed to have a positive effect on the environment or which is environmentally labeled and marketed, in a given year, and 0 otherwise.

3.3.2. Corporate governance

Many authors (e.g., Sapra et *al*., 2014; Amore and Bennedsen, 2016) use the adoption of the second-generation antitakeover laws by the US states during the late 1980s as an exogenous shock and proxy of corporate governance. However, this shock applies only to U.S. firms. Moreover, one can argue that this shock is less appropriate to analyze green innovation since it dates from the late 1980s, while green innovation has experienced rapid growth after 2015 (Takalo and Tooranloo, 2021; Atanasov and Black, 2016). In addition, our study covers the period of 2002-2021. In the earlier studies, Gompers et *al*. (2003) governance index (GIM-index), and Bebchuk et *al*. (2009) index (E-index) are used as proxies of corporate governance. The GIM-index is constructed using the 24 governance provisions of Gompers et *al*. (2003), while the E-index consists of 6 of these 24 provisions. These governance provisions data are from the IRRC (Investor Responsibility Resource Center) database, which covers U.S. firms only. There have been eight publications of these indexes (1990, 1993, 1995, 1998, 2000, 2002, 2004, and 2006) (Chemmanur and Tian, 2018). Since our study covers U.S. and non-U.S firms and the period of 2002-2021, we adopt the corporate governance ratings from the Refinitiv ESG database as a measure of firm governance, following Flammer (2021).

In contrast with G-index or E-index, Refinitiv corporate governance ratings are available for all years since 2022. The corporate governance score from Refinitiv covers nearly 100 items grouped into three dimensions: CSR strategy, management, and shareholders. The CSR strategy covers strategy, ESG reporting, and transparency. It reflects the firm's practices to communicate that it integrates financial, social, and environmental dimensions into its decision-making processes. Transparency, for instance, is an important aspect of firm governance. Management dimension includes board structure (diversity, independence, committees), and compensation. It measures a firm's commitment and effectiveness towards following best practice corporate governance principles. Many authors use only board characteristics as a proxy for corporate governance (Shive and Forster, 2020; Usman et *al*., 2020). Finally, the shareholders' dimension covers shareholders' rights and takeover defenses. It measures a company's effectiveness towards equal treatment of shareholders and the use of antitakeover devices. This dimension of Refinitiv corporate governance is equivalent to the antitakeover provisions in the GIM-index and is essential when agency problems are severe. In sum, the Refinitiv corporate governance rating seems appropriate to our study since it covers both the agency problems and CSR concerns. It also covers firms worldwide.

3.3.3. Summary statistics

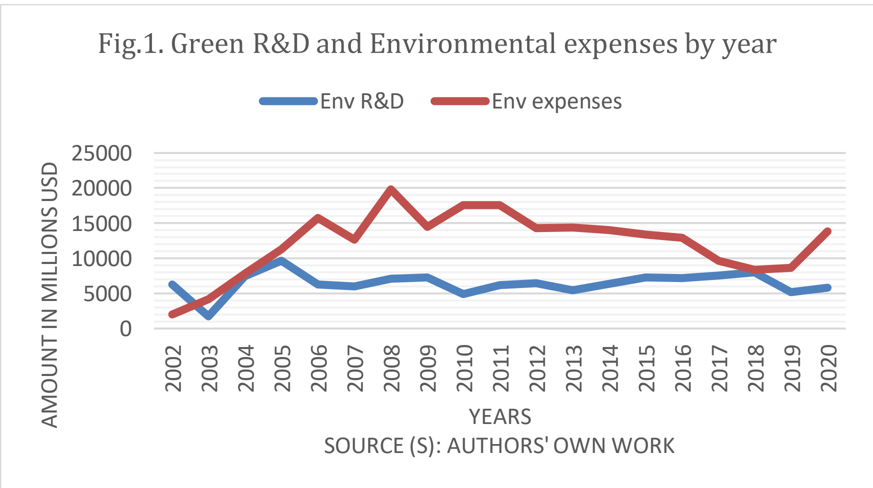
We start our data construction by collecting all firm-level data included in Compustat and Refinitiv ESG databases from 2002-2021. Next, we merge the two datasets. We drop firms with null or negative book values and firms with negative debt ratios from our sample. We also drop firms with negative cash, cash-to-asset ratio, R&D-to-asset, or capital expenditures. All the sample firms are up to 3,896, with a maximum of 23,715 observations covering 45 countries from 2002-2021. Table II-1 presents the descriptive statistics. Figure II-1 presents the average annual green R&D and environment expenses by firm. Figure II-2 shows the average sectorial green R&D and environment expenses by firm. Figure II-3 presents the percentage of firms that report green products by year, and Figure II-4 shows the percentage of firms that report green products by sector.

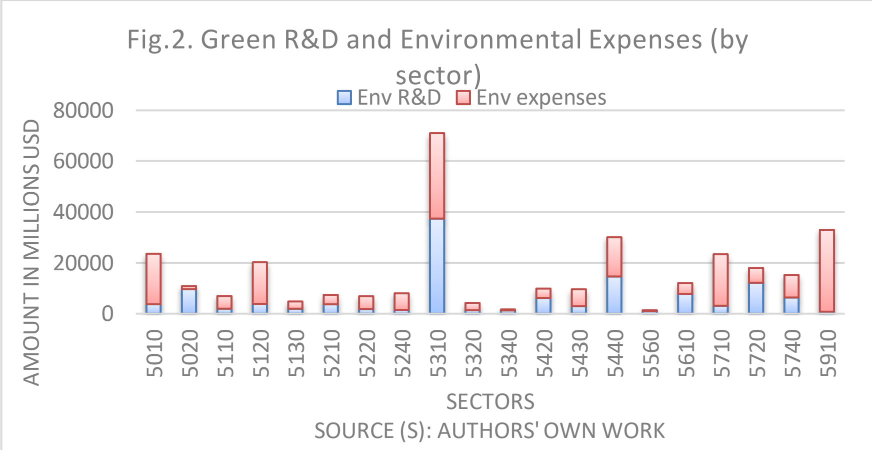
Table II-1.
Summary statistics

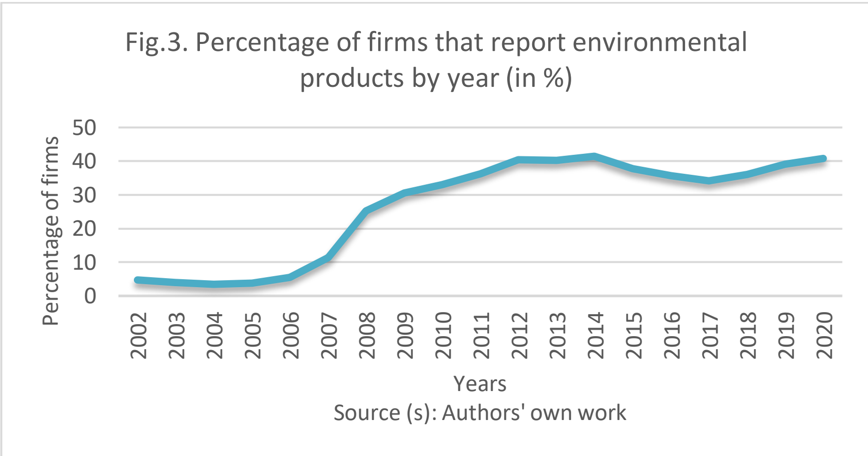
Variables	Obs	Mean	Median	Std. dev.	Min	Max
Tobin's Q	23,715	4.7697	1.8517	27.6108	0.000012	983.35
Corporate Governance rating	23,715	0.5190	0.5720	0.3007	0.0079	0.9832
Green R&D to total assets	2,887	0.0056	0.0012	0.0149	0	0.2197
Cash-to-total assets	23,715	0.1159	0.0761	0.1303	0	0.9992
Env expense to total assets	11,921	0.00811	0.0022	0.0533	0	2.1287
R&D to total assets	23,715	0.0466	0.0172	0.1008	0	5.5478
Capital expenditures to assets	23,715	0.0629	0.0279	0.0854	0	0.1132
Return on assets (ROA)	23,715	0.0624	0.0665	0.1493	-4.7189	3.1167
Debt ratio	23,715	1.1055	0.3742	13.6226	0	2170.615
Log(Total assets)	23,715	11.9388	9.8533	12.9006	5.6474	14.5775
Environmental product	23,715	0.3231	0	0.4676	0	1
Environmental project financing	23,715	0.0106	0	0.1027	0	1
Environmental rating	23,715	0.5070	0.4887	0.3179	0.0777	0.9749
ResourceUseScore	23,715	0.3517	0.2906	0.3339	0	0.9988
EmissionsScore	23,715	0.3575	0.2987	0.3346	0	0.9988
CO_2 emissions to total asset	21,257	524.26	16.91	61139.99	0	1.03e+07
Management score	23,715	0.5094	0.5121	0.2831	0.0001	0.9998
CSR strategy score	23,715	0.3122	0.1944	0.3319	0	0.9996
Shareholder score	23,715	0.5054	0.5048	0.2869	0.0001	0.9998

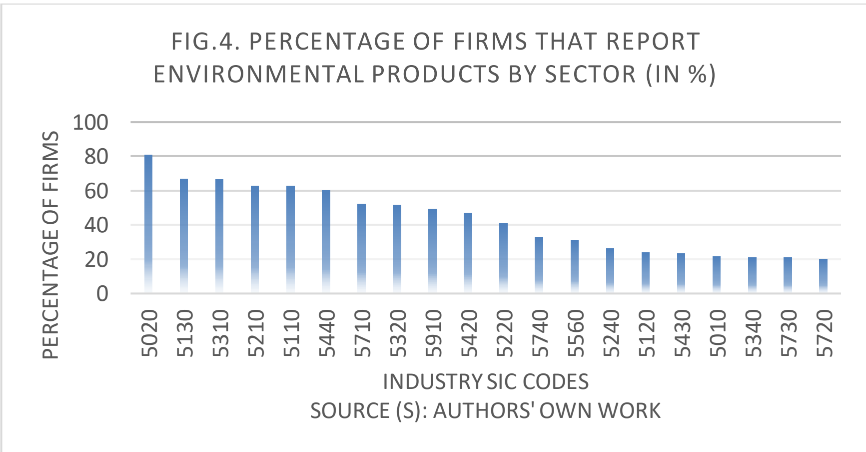
This Table reports the mean, the median, the standard deviation, the minimum, and the maximum for the sample firms. The sample includes all firm-year observations from 2002 to 2021. All the sample firms are up to 3,896, with a maximum of 23,715 observations. Accounting data are obtained from Compustat. ROA is the ratio of EBIT to the book value of total assets. Tobin's Q is the ratio of the company's market capitalization to the book value of equity. The debt ratio is the ratio of the book value of long-term debt to the book value of total equity. Environmental rating and corporate governance rating are in decimal (not in percentage) and obtained from the Refinitiv ESG database. CO_2 emission is the ratio of CO_2 emissions divided by the book value of total assets.

Source: Authors own work









4. Methodology

For the analysis, we follow many studies on corporate governance and innovation. In the first part, we adopt Tobin's q model of R&D and corporate governance approach, employed by O'Connor and Rafferty (2012). In the second part, we use the logit model.

4.1. Tobin's q Model of R&D and Corporate Governance

We adopt Tobin's q model of investment to model the relationship between corporate governance and the level of green innovation activities, following literature (e.g., O'Connor and Rafferty, 2012; Hosono et *al*., 2004). Tobin's q model is generally used to examine corporate investment, such as innovative or R&D activities (Hennessy, 2004; Hosono et *al*., 2004; Blundell et *al*., 1992; O'Connor and Rafferty, 2012). The basic q investment equation is derived from a standard model of a perfectly competitive firm that maximizes the net wealth of existing shareholders when facing convex adjustment costs in changing its capital stock (Blundell et *al*., 1992). The previous studies applying Tobin's q model to investment decisions, generally start with the theoretical model as follows:

$$(II-1): \qquad (\frac{I}{A})_{it} = \beta q_{it} + X_{it}\gamma + \varepsilon_{it}$$

In the model, the dependent variable (*Y*) often used in the literature is R&D expenditures divided by total assets. *I* is the investment in capital goods or R&D, *A* is the firm total assets, *q* is the average Tobin's q, *X* is a matrix of explanatory variables that measure frictions, and ε_{it} is the error term.

The model is based on the assumption that the observable variable q is a good proxy for the theoretical marginal q', so that q captures completely the investment opportunities in the firm. This implies that the explanatory variables X are expected to have no significant effect on investment I. However, market frictions and agency costs exist, and influence corporate investment (Stein, 1988; Fazzari and Athey, 1988). Thus, it is allowed to incorporate corporate governance and the availability of financial resources (cash-to-asset) in the model, leading to the Tobin q model of R&D and corporate governance (O'Connor and Rafferty, 2012). The theoretical model is as follows:

$$(II-2): \qquad (\frac{I}{A})_{it} = \beta q_{it} + \gamma_{Gov} GOV_{it} + \gamma_s \, SURPLUS_{Cash}{}_{it} + \varepsilon_{it}$$

where the dependent variable is green R&D expenditures (*I*) divided by the total assets (*A*), GOV_{it} is the corporate governance score, and $SURPLUS\_Cash_{it}$ is the ratio of surplus cash to assets.

In addition to corporate governance, we included Tobin's q, and the cash-to-asset ratio, following literature (Hennessy, 2004; O'Connor and Rafferty, 2012). Tobin's q is a proxy for the firm's investment opportunities. It captures firm value, growth opportunities, and control for all profit opportunities such as ROA or ROE (O'Connor and Rafferty, 2012). The cash ratio controls for liquidity and financial constraint (Hennessy, 2004; Hosono et *al*., 2004), so it's unnecessary to include the debt ratio in the model (O'Connor and Rafferty, 2012). Adding a cash-to-asset ratio is necessary because liquidity is an important determinant of investment, with the effect being most pronounced for weak firms (Hennessy, 2004). This specification fits our analysis because, by assumption, we consider corporate governance as the main determinant of green innovation, independently of investment opportunities.

4.2. Empirical Strategy

Endogeneity problem occurs when examining the effect of corporate governance on firms' decisions or outcomes (O'Connor and Rafferty, 2012; Jo and Harjoto, 2012). Thus, the main challenge is obtaining unbiased estimates of γ_{GOV}. O'Connor and Rafferty (2012) point out three (3) potential sources of bias. First, the simultaneity bias occurs when shocks to R&D are correlated with firms' governance. Indeed, even if the corporate governance variables are predetermined, simultaneity bias can arise if the error term exhibits serial correlation. The serial correlation will occur if shocks to R&D are persistent. Secondly, measurement bias may occur because the average q is used as a proxy for the theoretical marginal q'. Since the actual value of q is unobserved, the average q is necessarily measured with errors that would induce biases when using OLS (Hennessy, 2004; Blundell et *al*., 1992). Bias also arises if the unobserved effects are correlated with both R&D and corporate governance (O'Connor and Rafferty, 2012). All this implies that corporate governance structure can be a part of the firm's green innovation strategy, so that the OLS estimates would have biases.

The best way to obtain consistent estimates of the parameters in equation (2) is to use the generalized method of moments (GMM) techniques (Blundell et *al*., 1992; O'Connor and Rafferty, 2012; Roodman, 2009). Three different approaches of GMM are proposed: the difference-GMM (Arellano and Bond, 1991), the levels-GMM (Arellano and Bover, 1995), and the system-GMM estimator (Blundell and Bond, 1998). In this study, we adopt the system-GMM to address the endogeneity concerns. The system-GMM estimator is the best option within the three approaches (Hillier et *al*., 2011; O'Connor and Rafferty, 2012) since it simultaneously estimates the equation in both differences and levels. This approach uses all the available information in the dataset, so is more efficient than other GMM estimators (Blundell and Bond, 1998; Roodman, 2009). The system-GMM solves two important problems: individual factor heterogeneity and endogeneity. It also solves a weak instrument problem that occurs with the instrumental variables approach and the first-difference GMM (Hillier et *al*., 2011). Our reference model to capture the impact of corporate governance on green innovation can be rewritten in the general form as follows:

$$(II-2a): \qquad Y_{i,t} = \alpha_0 + \beta X_{i,t} + \varepsilon_{i,t}$$

where the dependent variable $Y_{i,t}$ is green R&D investment to total asset, $X_{i,t}$ is a matrix of explanatory variables including corporate governance rating, Tobin's Q, and Cash-to-asset ratio. The system-GMM estimators are designed for panel analysis when some regressors are endogenous, and the process is dynamic with current realizations of the dependent variable influenced by the past ones (Roodman, 2009). The general model of the data-generating process (II-2a) is:

$$(II-2b): \qquad Y_{i,t} = \alpha Y_{i,t-1} + \beta X_{i,t} + \varepsilon_{i,t} \qquad , \qquad or$$

$$(II-2c): \qquad \Delta Y_{i,t} = (\alpha - 1) Y_{i,t-1} + \beta X_{i,t} + \varepsilon_{i,t}$$

$$with \qquad \varepsilon_{i,t} = \mu_i + v_{i,t} \qquad , \qquad E(\mu_i) = E\left(v_{i,t}\right) = E\left(\mu_i v_{i,t}\right) = 0$$

So, the model can be considered for the level or increase of Y (Roodman, 2009). The disturbance term has two orthogonal components: the fixed effects μ_i, and the idiosyncratic shocks, $v_{i,t}$. The next procedure to estimate the system-GMM is the first-difference transform, which gives its name to "difference-GMM": the general form can be written as:

$$(II-2d): \qquad \Delta Y_{i,t} = \alpha \Delta Y_{i,t-1} + \beta \Delta X_{i,t} + \Delta v_{i,t}$$

The final step is to estimate equations (II-2b) and (II-2d) simultaneously (Blundell and Bond, 1998). By doing this, we obtain a system comprising both equations in levels and first differences. The system-GMM is expressed as follows:

$$(II-3): \qquad \begin{cases} Y_{i,t} = \alpha Y_{i,t-1} + \beta X_{i,t} + \varepsilon_{i,t} \\ \Delta Y_{i,t} = \alpha \Delta Y_{i,t-1} + \beta \Delta X_{i,t} + \Delta v_{i,t} \end{cases}$$

The first difference in the regression equation (II-2d) eliminates any possible bias that may result from the fixed effects. However, the lagged dependent variable is still potentially endogenous because the $Y_{i,t-1}$ term in $\Delta Y_{i,t-1} = Y_{i,t-1} - Y_{i,t-2}$ is correlated with the $v_{i,t-1}$ in $\Delta v_{i,t} = v_{i,t} - v_{i,t-1}$. Likewise, any predetermined variables in X that are not strictly exogenous become potentially endogenous because they too may be related to $v_{i,t-1}$ (Roodman, 2009; Arellano and Bond, 1991). The system-GMM technique relies on the "internal" instruments based on lags of the instrumented variables. Arellano and Bond (1991) propose to use the lagged values of the explanatory variables as instruments in the regression equations. The lags of the regressors remain orthogonal to the error and are available as instruments. As documented by Roodman (2009), in both the levels and the difference estimator, instrumenting with $Y_{i,t-2}$ seems preferable for maximizing sample size. In the differenced case, $Y_{i,t-2}$ is mathematically related to $\Delta Y_{i,t-1} = Y_{i,t-1} - Y_{i,t-2}$ but not to the error term $\Delta v_{i,t} = v_{i,t} - v_{i,t-1}$ as long as the $v_{i,t}$ are not serially correlated. Following this literature, we adopt GMM techniques that rely on "internal" instruments. We use the lags 1 to 2 of the green R&D expenses to total asset ratio as instruments for the dependent variable, both in the difference-GMM and the system-GMM models. For the explanatory variables, we use lags 1 to 4. We test the validity of the instruments using the Hansen (1982) test for overidentifying, and the Arellano-Bond (1991) serial correlations test.

5. Estimating the impact of corporate governance on green innovation

First, we examine the effect of corporate governance on green R&D investment using the system-GMM approach. Next, we check the robustness of our result using several approaches.

5.1. Corporate governance and Green R&D investment

Table II-2 presents the results of the system-GMM estimation. For comparison, we also present the OLS, the fixed effects, the dynamic fixed effects (although they are not robust for all forms of bias described above), and the difference-GMM results. In general, the GMM results show the positive relationship between corporate governance (governance) and green innovation as proxied by green R&D expenditures. These findings support the argument that good governance stimulates green innovation activities. Moreover, as can be seen in columns (1), (2), and (3), the Arellano-Bond (1991) tests for the OLS, the fixed effect, and the dynamic fixed effect models indicate the presence of serial correlations. The serial correlations are not present for the difference-GMM (column 4) and the system-GMM (column 5). Thus, only the GMM estimates are reliable.

The OLS estimates (column 1) for corporate governance rating, and cash-to-asset ratio (cash) are positive and significant. However, these results contain the 3 sources of bias, so they are not reliable estimates for the influence of corporate governance on green innovation. We estimate the panel model with firms and year-fixed effects to account for the bias from firms' level unobservable effects. The results for corporate governance (column 2) decline sharply and become non-significant. Then, we estimate the dynamic version of the fixed effect panel model and obtain a similar result (column 3). While controlling for unobservable bias, the fixed effects and the dynamic model estimators suffer from the biases, as the Arellano-Bond tests for the serial correlations (AR1) in the residuals remain significant for all these estimations. So, we estimate the GMM models.

Table II-2.
Corporate governance and Green R&D expenditures

Dependant variable: Environmental R&D expenditures to total asset					
Parameter	OLS 1	Fixed effects 2	Dynamic fixed effects 3	Difference GMM. 4	System-GMM 5
L.greenRnDtoASSET (rho)	-	-	0.4170***	-0.0630*	-0.2018***
	-	-	(0.0189)	(0.0367)	(0.0438)
Governance x 100	1.146***	-0. 0311	0.0441	0.1083**	0.7701***
	(0.1064)	(0.1340)	(0.1296)	(0.0467)	(0.2919)
Q Tobin x100	0.0212	0. 0512	-0.0419	0.00741	-0.0439**
	(0.148)	(0.0585)	(0.0513)	(0.011)	(0.0176)
Cash x100	2.917***	0. 5900*	0.0327	-0.1036	0.2649
	(0.3636)	(0.3115)	(0.2901)	(0.9106)	(0.9947)
R^2	0.052	0.0014	0.8360	s/o	s/o
Nb. Obs	2,863	2,863	2,294	1929	1929
Firms	751	751	751	751	751
Period	2002-2021	2002-2021	2002-2021	2002-2021	2002-2021
Arellano-Bond test for AR1	3.85***	2.72***	-1.82*	-1.24	-0.91
Arellano-Bond test for AR2	1.70*	1.42	1.24	-1.28	-1.25
Hansen overidentification test	s/o	s/o	s/o	11.00	10.46

Table II-2 presents the regression results. The dependent variable is green R&D expenses to total assets (greenRnDtoASSET). The coefficients appear first, and the standard errors are in parentheses. We present the estimates of the system-GMM in column (5), the difference-GMM in column (4), the dynamic fixed effects in column (3), the fixed effects in column (2), and the OLS in column (1). The sample includes all firm-year observations from 2002–2021. Corporate governance ratings are in decimal and are obtained from the Thomson/Refinitiv ESG database. Firm value (QTobin) is the ratio of the company's market capitalization to the book value of equity. Cash-to-asset ratio (Cash) is the ratio of the total cash to total assets. L.GreenRnDtoASSET is the lag 1 of green R&D expenditures to total assets. We report the Arellano-Bond (1991) serial correlations test statistics, and the Hansen overidentification Chi 2 statistic test. We use the lags 1 to 2 of green R&D expenses to total asset ratio as instruments for the dependent variable, both in the difference-GMM and the system-GMM models. For the explanatory variables, we use lags 1-4. There are 11 degrees of freedom for the Hansen overidentifying test in the system-GMM, and 10 degrees of freedom in the difference-GMM. The symbols ∗, ∗∗, and ∗∗∗ indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels. R^2 are in decimals (not in percentage).

Source: Authors own work

As described earlier, the system-GMM provides the most robust results. The difference-GMM estimates are presented in column 4, and the system-GMM results are in column 5. As can be seen, the Hansen (1982) tests, and the Arellano-Bond (1991) serial correlation tests suggest that both the difference-GMM and the system-GMM results are valid. Our findings reveal that corporate governance affects positively green R&D investments in the two models. As for the OLS, the coefficients estimated are positive and significant both for the difference-GMM and the system-GMM. The coefficient from the system-GMM (0.7701), while higher than the estimate in the difference-GMM (0.1083), remains lower than the OLS estimate (1.146). Indeed, the OLS estimate of governance rating seems to have a positive bias. Then, corporate governance structure may be part of a firm's green R&D strategy, as noticed by O'Connor and Rafferty (2012) and Stein (1988) for innovative activities.

Note that the estimate from the difference-GMM is about 7 times lower than the estimate from the system-GMM, and 10 times lower than the estimate from the OLS. The governance rating is significant at a 1% level in the system-GMM estimation, while it's significant at 5% in the difference-GMM. The economic significance is also high for the system-GMM. A one-percentage-point increase in the corporate governance ratings leads to an increase in green R&D expenses to the total asset ratio of about 0.77 percentage points.

As in the dynamic fixed effect model, the cash-to-asset ratio estimates from the system-GMM and the difference-GMM are insignificant. Thus, internal financing is not relevant to green innovation strategy. Tobin's q is significant only in the system-GMM model. In contrast with traditional innovation (O'Connor and Rafferty, 2012), Tobin's q has a significantly negative impact on green innovation (at a 5% level) in the system-GMM. The negative sign indicates that firms with higher growth opportunities tend to invest less in environmental R&D activities. A one-percentage-point increase in Tobin's q leads to a decrease in green R&D expenses to the total asset ratio of about 0.044 percentage points. Given that younger firms have higher growth opportunities (high Tobin's q) and limited access to the capital markets, it is likely that such firms prefer to invest in their primary activity rather than green innovation. On the other hand, mature firms have fewer growth opportunities (low Tobin's q) and may be interested in green innovation, which in some ways constitutes new business opportunities for them.

5.2. Robustness checks

In this section, we check if our results that well-governance implies more green innovation activities are robust to a variety of specifications. First, we follow O'Connor and Rafferty (2012), and drop Tobin's q from the model. Second, we drop Tobin's q, and cash-to-asset ratio from the model, and use only corporate governance as the explanatory variable. Finally, we use an alternative measure of green innovation, namely, "green product". Overall, our findings confirm that corporate governance has a positive effect on green innovation.

Table II-3.
Robustness tests: corporate governance and green R&D expenditures

Dependant variable: Environmental R&D expenditures to total asset						
	Dropping Tobin's q and cash			Dropping Tobin's q		
Parameter	Fixed effects 1	Difference G.M.M. 2	System GMM 3	Fixed Effects 4	Difference G.M.M. 5	System GMM 6
L.greenRnDtoASSET (rho)	s/o	-0.0825	-0.224***	s/o	-0.0737*	-0.214***
		(0.0621)	(0.0484)		(0.0399)	(0.0457)
Governance x 100	0.0013	0.0800	0.7653**	- 0.0315	0.2420	0.8316***
	(0.1321)	(0.5225)	(0.3139)	(0.134)	(0.3653)	(0.3096)
Cash x100	s/o	s/o	s/o	0.5729*	0. 9324	0.4273
				(0.3107)	(1.0297)	(0.9983)
R^2	0.029	s/o	s/o	0.064	s/o	s/o
Nb. Obs	2,887	1954	1954	2,865	1931	1931
Firms	751	751	751	751	751	751
Period	2002-2021	2002-2021	2002-2021	2002-2021	2002-2021	2002-2021
Arellano-Bond test for AR1	-	-1.31	-0.50	-	-1.15	-0.62
Arellano-Bond test for AR2	-	-1.25	-1.26	-	-1.29	-1.26
Hansen overidentification test	s/o	4.41	6.21	s/o	5.40	6.47

Table II-3 presents the results of robustness tests when dropping Tobin's Q (columns 4, 5, and 6), and when dropping Tobin's Q and cash-to-asset ratio from the model (columns 1, 2, and 3). We present the system-GMM, the difference-GMM, and the fixed effects results. The coefficients appear first, and the standard errors are in parentheses. The sample includes all firm-year observations from 2002–2021. We use the lags 1 to 2 of the green R&D investment to asset ratio as instruments for the dependent variable, both in the difference-GMM and the system-GMM. For the explanatory variables, we use lags 1-4. We report the Arellano-Bond (1991) test statistics, and the Hansen statistic tests. In the system-GMM, there are 8 degrees of freedom for the Hansen overidentifying test, and 7 degrees of freedom for the difference-GMM, when we drop only Tobin's Q. When we drop both the Tobin's Q and the cash-to-asset ratio from the model, there are 5 degrees of freedom for the Hansen overidentifying test in the system-GMM, and 4 degrees of freedom in the difference-GMM. The symbols *, **, and *** indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels. R^2 are in decimals.

Source: Authors own work

5.2.1. Dropping Tobin's q from the model

As we stated previously, the assumptions of Tobin's q model imply that the observable variable q captures completely the investment opportunities in the firm, so that other variables are expected to have no significant effect on the investment. However, our results show that these assumptions are invalid in the context of green innovation since corporate governance influences green R&D activities. This indicates the possibility that agency costs and financial market frictions documented by Stein (1988), and Fazzari and Athey (1988) may impact green R&D activities as they affect the other types of investments. As Tobin's q captures all profit opportunities in the firm, O'Connor and Rafferty (2012) advocate the possibility that corporate governance influences Tobin's q by affecting the firm's financial performance. Thus, if corporate governance only influences innovative activity by first influencing the firm's market valuation, we can expect a weak relationship between governance and innovation once we incorporate Tobin's q in the model. To consider this possibility, we follow the same approach as O'Connor and Rafferty (2012) and drop Tobin's q from the model. We estimate the system-GMM, the difference-GMM, and the fixed effects models.

As presented in Table II-3 (columns 4, 5, and 6), the results remain robust, except for the difference-GMM (column 5), in which the corporate governance coefficient increases but becomes non-significant because the standard error also increases. The corporate governance coefficient using the difference-GMM (0.2420) doubled relative to the previous estimates (0.1083) in Table II-2. Still, at the same time, the standard error is about 9 times higher (0.3653 vs. 0.0467 in Table II-2). It follows that Tobin's q is a relevant variable in the model. Tobin's q model of R&D and corporate governance seems the most appropriate to model green R&D activities.

In the system-GMM, the estimate of corporate governance increases a little (0.8316 versus 0.7701 in Table II-2) but remains lower than the OLS estimates in Table II-2. The standard error estimated using the system-GMM remains similar to that estimated using all the explanatory variables (0.3096, Table II-3 versus 0.2919, Table II-2). Thus, the system-GMM seems more robust to biases induced by missing variables than the difference-GMM.

5.2.2. Dropping Tobin's q and cash-to-asset ratio from the model

We also consider another specification dropping all the explanatory variables in the model, except corporate governance. This specification is based on the argument that corporate governance can control both for cash holding and growth opportunities (Tobin's q). The agency theory considers high cash holding a poor governance since opportunistic managers can use it for their own interests, instead of optimal investing (Jensen, 1986). The high cash holding is an agency problem, the opposite of good governance. To take into account this possibility, we estimate the model using corporate governance as the only explanatory variable. Our results remain robust to this specification.

The results reported in columns 1, 2, and 3 (Table II-3), remain similar to those obtained when dropping only Tobin's q from the model. The coefficient of corporate governance from the system-GMM remains positive, significant, and closer to that estimated using all the explanatory variables. This again proves that the system-GMM is robust for various specifications, and less sensitive to the three sources of biases, and the bias resulting from the missing or superfluous variables. The results for the difference-GMM remain unchanged, but the coefficient associated with corporate governance rating declines while the standard error increases sharply. This again indicates that all the variables incorporated in the initial model are relevant.

5.2.3. An alternative measure of green innovation

The green R&D expenses used in the GMM estimations are the ex-ante measure of green innovation. To check for the possibility that our results are sensitive to the proxy of green innovation, we use an ex-post measure. Especially, we employ "green product" innovation as an alternative measure of green innovation, following Lin et *al*. (2014). Green product is a dummy variable that takes the value of 1 if the firm declares an "environmental product" in the year t, and 0 otherwise. With this novel measure, we estimate the model using instrumental variable probit regression (ivprobit). As for the GMM, we use the lag of corporate governance as an "internal instrument" of corporate governance. We do not use any instrument for the other variables. We report both the results of ivprobit, and the regular probit. If the Wald test of exogeneity is significant for the ivprobit, the null hypothesis of no endogeneity is rejected. However, if the test is not significant, there is no sufficient information to reject the null, so a regular probit/logit regression may be the most appropriate.

As shown in column 1 (Table II-4), the Wald test of exogeneity is significant at a 1% level. Thus, the ivprobit is the most appropriate when using the green product as a proxy of green innovation. Table II-4 also shows that the estimates from the ivprobit regression (column 1) are closer to that from the probit regression (column 2). In the ivprobit regression, the coefficient associated with corporate governance rating is significant at a 5% level, while the estimate from the probit regression is significant at 1%. Tobin's Q is also negative and significant. Then, our results are robust when using an alternative measure of green innovation. The main difference when using this measure is that cash holding has a significantly negative impact on green innovation, indicating the negative effect of agency problems.

In sum, corporate governance has a positive effect on green innovation. The system-GMM estimations using an ex-ante measure of green innovation show that the better the corporate governance, the more the firm invests in green R&D activities. This result remains robust to various specifications. The probit estimations reveal that the higher the governance rating, the higher the likelihood that the firm develops green products. Thus, stronger governance fosters green innovation.

5.2.4. An alternative measure of corporate governance: GIM-Index

We also adopt the GIM-Index of Gompers et *al*. (2003) as an alternative measure of corporate governance. The index is constructed based on the 24 Takeover Defenses listed in GIM and the IRRC data. Firms included in the IRRC database are primarily S&P1500 firms and, therefore, U.S. firms. The GIM-Index is obtained from the page of Andrew Metrick on the Yale University website and is available for the years 1990, 1993, 1995, 1998, 2000, 2002, 2004, and 2006. Given that GIM-Index data are only available for the U.S. firms through 2006, we limit the sample to the 2002-2008 period for the analysis. This leaves us with 242 U.S. firms. Following the literature, we assume the values for each index in missing years are the same as in the previous year (Becker-Blease, 2011; Markus and Swift, 2020). For example, a GIM-Index value in 2003 is that of 2002, and the index of 2007 is that of 2006. Using this variable, we confirm that corporate governance is positively associated with green product innovation (Table II-4, column 5).

5.2.5. Additional control variables

The financial literature documents that capital structure varies along the firms' life cycle. For instance, the younger and the growth firms are financially constrained as they face higher information asymmetric and agency costs (Singh et *al*., 2023). To account for the effects of the business cycle, which might be affecting financing costs and thus green innovation, we control for firm age and sales growth, following literature (Singh et *al*., 2023; La Rocca et *al*., 2011). Sales growth is the percentage change in firm annual sales, and firm age is the natural logarithm of the number of years since its foundation. In addition, we control for ROA, debt ratio, and firm size. Overall, our results hold.

The probit estimation using green product innovation dummy as the dependent variable confirms that the higher the corporate governance rating, the higher the likelihood of green product innovation (Table II-4, column 3). Corporate governance has a significantly positive impact on green product innovation, while Tobin's q and cash-to-asset ratio have a significantly negative impact on green product innovation. Firm age, ROA, and firm size have a significantly positive effect on green product innovation. Sales growth and debt ratio do not affect green product innovation.

Table II-4.
Robustness tests: corporate governance and green product innovation

	Dependent variable: green product				
	Ivprobit Newey's 2-step estimator	Probit Vce (robust)	Control variables	Inventor departures	GIM-Index
Parameter	1	2	3	4	5
Governance x 100	4.3339**	4.8761***	3.9512**	4.4807***	-
	(2.0475)	(1.7860)	(2.1362)	(2.017)	
GIM-Index x 100	-	-	-	-	4.0211***
					(1.0632)
QTobin x100	-0.0759**	-0.0629*	-0.1064**	-0.0701**	-0.0438*
	(0.0334)	(0.0339)	(0.0517)	(0.0342)	(0.0243)
CashtoASSET x 100	- 46.9820***	- 54.64***	- 47.793***	-49.76***	- 38.59***
	(4.9003)	(3.9131)	(4.322)	(4.028)	(3.493)
Age	-	-	0.683***	-	-
			(0.0246)		
Sales Growth x100	-	-	-0.0665	-	-
			(0.4183)		
ROA	-	-	0.5601***	-	-
			(0.0653)		
Firm size	-	-	0.1785***	-	-
			(0.0071)		
Debt ratio	-	-	-0.0022	-	-
			(0.0031)		
Inv_dep	-	-	-	-0.5704**	-
				(0.2431)	
Inv_dep*Well_gov	-	-	-	-0.0013	-
				(0.0813)	
Industry effects	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes
Wald chi2	108.88***	220.17***	112.29***	156.42***	178.12***
Wald test of exogeneity	100.75***	s/o	s/o	s/o	s/o
Nb. Obs	19,816	23,715	23,715	1265	1265
Firms	3,860	3,890	3,890	242	242
Period	2002-2021	2002-2021	2002-2021	2002-2008	2002-2008

Table II-4 presents the results of robustness tests using the "green product" as a proxy of green innovation. We present the instrumental variable probit (ivprobit) and the regular probit results. The coefficients appear first, and the standard errors are in parentheses. All regressions include a constant. In the ivprobit model, we use lag 1 of corporate governance as an instrument, and we do not use any instrument for the other variables. There are 3 degrees of freedom for the Wald test. The symbols *, **, and *** indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels.

Source: Authors own work

As presented in Table II-5, the results remain robust for the dependent variable green R&D expenditures to total asset, except for the difference-GMM (column 4), in which the corporate governance coefficient becomes non-significant compared to the baseline model (Table II-2). The coefficient associated with corporate governance is positive (0.3233) in the difference-GMM but non-significant. As in the baseline estimation, the system-GMM results show a positive relationship between corporate governance and green R&D expenditures.

Table II-5.
Robustness tests: Corporate governance and Green R&D expenditures

Dependant variable: Environmental R&D expenditures to total asset					
Parameter	OLS 1	Fixed effects 2	Dynamic fixed effects 3	Difference GMM. 4	System-GMM 5
L.greenRnDtoASSET (rho)	-	-	0.2973***	-0.1393***	-0.1305***
	-	-	(0.02200)	(0.0140)	(0.0141)
Governance x 100	1.1627***	0.0986	0.1067	0.3233	0.5751***
	(0.1103)	(0.1388)	(0.1444)	(0.3227)	(0.2091)
Q Tobin x100	-0.0197	-0.0490	-0.0118	-0.0469	-0.0376**
	(0.134)	(0.457)	(0.467)	(0.0661)	(0.0185)
Cash x100	3.786***	-0.2015	-0.4079	-0.3239	1.0924
	(0.389)	(0.2856)	(0.3092)	(0.6830)	(0.9463)
Age x 100	0.0258	-0.00997	-0.0594	0.0186	0.0308*
	(0.0177)	(0.137)	(0.1374)	(0.0268)	(0.0174)
Sales Growth x100	-0.0818**	0.0242	0.109	0.0295	-0.0998***
	(0.0355)	(0.352)	(0.344)	(0.0649)	(0.0331)
ROA	0.0012	-0.0087	-0.0094**	-0.0077	0.0174
	(0.0065)	(0.0036)	(0.0039)	(0.0137)	(0.0121)
Firm size	0.0197	-0.0442	-0.0501	0.0257	0.0304**
	(0.0143)	(0.153)	(0.149)	(0.0279)	(0.0136)
Debt ratio*100	-0.1058***	0.0013	-0.0068	-0.0142	-0.1379**
	(0.0373)	(0.0201)	(0.0256)	(0.0336)	(0.0632)
Year effects	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	s/o	s/o
Industry effects	Yes	Yes	Yes	s/o	s/o
R^2	0.052	0.0046	0.9493	s/o	s/o
Nb. Obs	2,863	2,863	2,294	1929	1929
Firms	751	751	751	751	751
Period	2002-2021	2002-2021	2002-2021	2002-2021	2002-2021
Arellano-Bond test for AR1	4.64***	3.56***	-2.32**	-0.76	-0.88
Arellano-Bond test for AR2	1.88*	1.74*	1.52	-1.06	-1.05
Hansen overidentification test	s/o	s/o	s/o	11.92	25.27

Table II-5 presents the regression results. The dependent variable is green R&D expenses to total assets (greenRnDtoASSET). The coefficients appear first, and the standard errors are in parentheses. We present the estimates of the system-GMM in column (5), the difference-GMM in column (4), the dynamic fixed effects in column (3), the fixed effects in column (2), and the OLS in column (1). The sample includes all firm-year observations from 2002–2021. Corporate governance ratings are in decimal and are obtained from the Thomson/Refinitiv ESG database. Firm value (QTobin) is the ratio of the company's market capitalization to the book value of equity. Cash-to-asset ratio (Cash) is the ratio of the total cash to total assets. L.GreenRnDtoASSET is the lag 1 of green R&D expenditures to total assets. We report the Arellano-Bond (1991) serial correlations test statistics, and the Hansen overidentification Chi 2 statistic test. We use the lags 1 to 2 of green R&D expenses to total asset ratio as instruments for the dependent variable, both in the difference-GMM and the system-GMM models. For the explanatory variables, we use lags 1-4. There are 25 degrees of freedom for the Hansen overidentifying test in the system-GMM, and 24 degrees of freedom in the difference-GMM. The symbols *, **, and *** indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels. R^2 are in decimals (not in percentage).

Source: Authors own work

The corporate governance coefficient estimated using the system-GMM remains positive (0.5751) and significant at a 1% level. Tobin's q is negative and significant as in the initial estimation. Debt ratio and sales growth are also negative and significant. On the other hand, firm size is significant at 5%, and firm age is significant at 10% only. Thus, the results for the system-GMM remain unchanged even if the coefficient associated with corporate governance rating declines. The results obtained using the OLS, the fixed effects, and the dynamic fixed effects also remain similar to those obtained in the baseline estimation. Corporate governance is positive and significant in the OLS but not significant in the fixed effects and the dynamic fixed effect models. This again proves that the system-GMM is robust for various specifications, and less sensitive to the three sources of biases, and the bias resulting from the missing or superfluous variables. Our basic model, therefore, seems appropriate for modeling the relationship between corporate governance and investment in green R&D.

6. Further analysis

6.1. Inventor departures

Markus and Swift (2020) document that stronger corporate governance weakens managerial job security, resulting in valuable inventors leaving the firm. To complete their analysis, we examine how an interaction term of corporate governance strength with inventor departures from a firm affects green innovation. To measure the strength of corporate governance, we construct a dummy variable named "well_gov" that is equal to one if the Refinitiv governance rating of the firm *i* is higher than the sample mean at time *t*, and zero otherwise. Following Markus and Swift (2020), we construct the variable representing an inventor's departure from a firm ("Inv_dep") using the Harvard Dataverse. We identify the year in which a firm's inventor was named on a patent of another firm. We consider that the inventor left the firm in the year following the year he was last named on a patent of his previous employer. We sum all inventor departures by the firm for each year. Finally, we examine the interaction of these variables by incorporating "well-gov*inv_dep" in the model. Using a sample of the U.S. firms (Table II-4, column 4), we find that the coefficient associated with the interaction term is negative but insignificant, while the inventor departure is negative and significant. The results complement Markus and Swift (2020) and indicate that too much pressure on management can harm green innovation. This leads us to conclude that effective governance must not only consider the interests of shareholders but also incentives for managers and technicians in order to favor green innovation. Thus, for pursuing our analysis, we consider the three dimensions of firm governance.

6.2. Dimensions of corporate governance and green innovation

The corporate governance rating used in the previous analysis includes three dimensions: CSR strategy, management, and shareholders. When analyzing green innovation, the main question is whether certain dimensions are more important than others. The CSR strategy covers CSR strategy, ESG reporting, and transparency which is one of the most relevant aspects of corporate governance. The management dimension includes board structure (independence, diversity, committees), and compensation. So, it considers incentive-based mechanisms and monitoring which are essential governance tools. Finally, the shareholders dimension covered shareholder rights and takeover defenses. This dimension is important when agency problems are severe.

Table II-6.
Dimensions of corporate governance and green product innovation

Dependent variable: green product		
	Contemporaneous values	Lag 1
Parameter	Model 1	Model 2
ManagementScore	0.2729***	0.2860***
	(0.0388)	(0.0408)
CSRStrategyScore	2.0282***	1.9212***
	(0.0348)	(0.0367)
ShareholdersScore	0.1172***	0.0768**
	(0.0369)	(0.0388)
QTobin x100	0.0634*	0.0606*
	(0.0336)	(0.0356)
CashtoASSET	0.1051	0.0154
	(0.0883)	(0.0960)
Size_Firm	0.1744***	0.1712***
	(0.0041)	(0.0044)
ROA	0.6383***	0.6044***
	(0.0901)	(0.0972)
DebtRatio	-0.0018	-0.0029
	(0.0012)	(0.0019)
TwoDig_SicCode (industry effects)	Yes	Yes
CountryID (country effects)	Yes	Yes
Year effects	Yes	Yes
LR chi2(11)	10867.95***	8781.15***
Nb. Obs	23,715	19,816
Firms	3,890	3,860
Period	2002-2021	2002-2021

Table II-6 presents the results of the logit regressions examining the impact of corporate governance dimensions on green innovation. In column 1, we use the contemporaneous values of the explanatory variables, while in column 2, we use the lagged values. The coefficients appear first, and the standard errors are in parentheses. The sample includes all firm-year observations from 2002-2021. The symbols *, **, and *** indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels.

Source: Authors own work

In this section, we explore the relationship between each of the three dimensions of corporate governance and green innovation. We adopt an ex-post measure of green innovation. We employ the "green product" innovation dummy that takes the value of 1 if the firm reports an "environmental product" in the year t, and 0 otherwise. With this novel measure, we perform logit regressions, using both the contemporaneous values (model 1), and the lag 1 of the explanatory variables (model 2). We control for firm size, debt ratio, ROA, Tobin's Q, industry, and country effects.

The results reported in Table II-6 show the significant positive impact of each of the three dimensions of corporate governance on green innovation, both in model 1 and model 2. An increase in the management dimension score, as in the CSR strategy, or the shareholder dimension scores of corporate governance, results respectively in an increase in the probability of green product innovation. Thus, all dimensions of corporate governance matter in firms' green innovation strategy.

6.3. Relationship between green innovation and firm environmental performance

In the previous sections, we show that corporate governance promotes green innovation. Green innovation comprises innovation in energy savings, pollution prevention, waste recycling, green product design, and environmental management technologies (Zhang and Zhu, 2019; Albort-Morant et *al*., 2016). By investing in environmental innovation, the firm may have one or both of the following objectives: environmental protection, and taking advantage of opportunities resulting from climate change. Suppose the objectives pursued by the firms engaging in green innovation include their will to protect the environment. In that case, one can expect a positive relationship between green innovation and the firm environmental performance. For instance, these firms may also use products resulting from green innovation and undertake other actions to combat environmental degradation. However, if the firms engage in green innovation only for financial gain, it is not sure that there will be a positive relationship between green innovation and firm environmental performance. This would be the case if, for example, firms invest in green innovation just to improve their image, and the resulting product is mainly for sale. Albort-Morant et *al*. (2016) argued that successful green innovation helps firms strengthen their core competencies and enhance their green image. Chen and Chang (2013) noted that firms engaging in green innovation could minimize production waste, reduce pollution, and increase their reputation and competitiveness. In this section, we examine the relationship between green innovation and firms' environmental performance.

We examine whether green innovation is associated with firm environmental performance, using panel regressions with fixed effects. Following the previous studies (Flammer, 2021, among others), we employ Refinitiv environmental rating (Envrn_score) to measure firm environmental performance. In addition, we consider the resource use score (ResourceUse) and emission reduction score (EmissionsScore), to examine if green innovation is associated with low resource consumption, and global emission reduction, including CO_2 emissions. Refinitiv ESG resource use score reflects a company's performance and capacity to reduce the use of materials, energy, or water, and to find more eco-efficient solutions by improving supply chain management. The emissions reduction score measures a firm's commitment and effectiveness toward reducing environmental emissions in its production and operational processes. Our relevant explanatory variable is the "green product" innovation dummy (Green_innovDummy). We control for firm size, Tobin's Q, ROA, debt ratio, and cash-to-asset ratio. All regressions include constant, firm and year fixed effects. In columns 1, 2, and 3, we use the contemporaneous values (model 1), while in columns 4, 5, and 6, we use lag 1 of the explanatory variables (model 2). The results are presented in Table II-7.

Table II-7.
Green innovation and environmental performance

Dependant variables: Env score, Resources use score, Emission reduction score						
	Contemporaneous values			Lag 1		
Parameter	Envrn_score (1)	ResourceUse 2	EmissionsScore 3	Envrn_score 4	ResourceUse 5	EmissionsScore 6
Green_innovDummy	0.2706***	0.1217***	0.1125***	0.1915***	0.0907***	0.0840***
	(0.0022)	(0.0025)	(0.0025)	(0.0026)	(0.0028)	(0.0028)
QTobin x100	0.0070*	0.0068*	0.0126***	0.0098**	0.0070	0.0171***
	(0.0036)	(0.0041)	(0.0041)	(0.0044)	(0.0049)	(0.0048)
CashtoASSET	-0.0568***	-0.0439***	-0.0434***	-0.0655***	-0.0521***	-0.0480***
	(0.0081)	(0.0094)	(0.0093)	(0.0097)	(0.0109)	(0.0108)
Size_Firm	0.0430***	0.0452***	.0498***	.0470***	.0484***	0.0535***
	(0.0007)	(0.0008)	(0.0008)	(0.0008)	(0.0009)	(0.0009)
ROA	0.0042	0.0079	0.0064	.0313***	.0351***	0.0261***
	(0.0064)	(0.0072)	(0.0071)	(0.0077)	(0.0085)	(0.0084)
DebtRatio x 100	-0.0091*	-0.0102*	-0.0148**	-0.034***	-0.0346**	-.0404***
	(0.0052)	(0.0058)	(0.0058)	(0.012)	(0.0133)	(0.0132)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.4557	0.3858	0.3283	0.3404	0.3217	0.3083
Firms	3,890	3,890	3,890	3,860	3,860	3,860
Nb. Obs	23,715	23,715	23,715	19.816	19.816	19,816

This Table presents the results of the relationship between green innovation and firm environmental performance, using a panel model with fixed effects. The dependent variables are Refinitiv environmental rating (Envrn_score), resource use score (ResourceUse), and emission reduction score (EmissionsScore). The coefficients appear first, and the standard errors are in parentheses. The relevant explanatory variable is the "green product" innovation dummy (Green_innovDummy). All regressions include constant, firm, and year fixed effects. We control for firm size (Size_Firm), Tobin's Q, ROA, debt ratio (DebtRatio), and cash-to-asset ratio (CashtoASSET). The sample includes all firm-year observations from 2002-2021. The symbols *, **, and *** indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels. Adjusted R^2 are in decimals (not in percentage).

Source: Authors own work

Both in models 1 and 2, green product innovation is positively and significantly associated with the firm environmental rating at the 1% level. The same results are obtained when we employ the resource use score, and the emission reduction score to capture the company's effort to combat environmental degradation. Green innovation is associated with the improvement of the firm environmental performance, and environmental efficiency characterized by low resource consumption, and pollution reduction. These results support the view that environmental degradation is driven by the lower investment in environmental technologies (Akey and Appel, 2021; Xu and Kim, 2022). In conclusion, companies do not engage in green innovation only to improve their competitiveness but also to combat environmental degradation. Green innovation is a corporate strategy that combines both environmental and financial performance.

7. Discussion and implications

Our study finds some evidence that the better the corporate governance, the more the firm invests in environmental R&D activities and develops green products. The findings are consistent with diverse backgrounds as effective corporate governance mechanisms moderate environmental decisions (Shive and Forster, 2020) and provide a structure that sets goals that serve the interests of shareholders and society (Ferrell et *al.*, 2016). The findings align with the previous empirical studies that effective governance mechanisms encourage green innovation (Asni and Agustia, 2022; Du and Cao, 2023; Amore and Bennedsen, 2016). Chemmanur and Tian (2018) also report evidence consistent with the hypothesis that stronger governance spurs innovation by insulating managers from short-term pressures arising from the equity market, allowing them to focus on long-term value creation. Thus, our results suggest that corporate governance fosters innovation that is beneficial for society.

In pursuit of the analysis, we find that all dimensions of corporate governance (shareholders', CSR strategy, and management) are positively related to green product innovation, suggesting that governance variables should be considered collectively. The shareholders' dimension covers shareholders' rights and takeover defenses, so it is similar to the governance provisions in the GIM-Index. Thus, our results align with Becker-Blease (2011) who finds a positive relationship between the GIM-Index and firm innovation, and Amore and Bennedsen (2016) who document that U.S. firms exposed to the passage of antitakeover laws experienced a 13% drop in green patents.

Hutchinson and Gul (2004) consider that information asymmetry is higher for innovative firms because managers have private information about the projects that they cannot disclose. Jia et *al*. (2019) argue that agency risk can create an inefficient allocation of resources among innovation activities as the costs of innovation take the form of the opportunity costs of foregoing other value-enhancing activities. They suggest that stronger governance reduces such risk. In our analysis, the CSR strategy covers ESG reporting and transparency; the management dimension includes board structure and compensation. More transparency and monitoring imply a reduction in information asymmetry. Moreover, appropriate compensation policies incentivize managers to make optimal decisions. Consequently, agency costs should be moderated, and efficient monitoring should ensure value-increasing decisions on the part of managers. In sum, our results complement the previous studies and indicate that both internal and external governance can be beneficial to green innovation.

Our findings have significant implications. For researchers, this study improves the understanding of the relationship between internal governance and changes in an essential component of societal value, namely green innovation. Drawing on financial and corporate governance literature, we predict that stronger governance increases investment in productive green R&D. The study also has implications for policy-makers, managers, and society at large on how to improve sustainability through corporate governance and help firms combat climate change, hence facilitating in achieving UN's Sustainable Development Goals on climate action. Green innovation implies considering the three dimensions of internal governance (management, CSR strategy, and shareholder). Firms must adopt governance mechanisms that enable transparency, effective control, and better incentives for managers and technicians. The main challenge is to find sustainable governance mechanisms that consider many stakeholders' interests. Policymakers can help by providing a robust legal framework that punishes poor governance or by providing green subsidies within well-governed firms. For society, corporate governance indirectly impacts firms' environmental performance by promoting green innovation. Overall, the study suggests that effective governance is necessary for environmental efficiency.

8. Conclusion

This study examines the relationship between corporate governance and green innovation, worldwide. We employ green R&D investment as an ex-ante measure of green innovation, and green product innovation as an ex-post measure. We argue that the agency costs and the financial market frictions affect corporate investment, and are important factors in the context of green innovation. By limiting agency conflicts, good governance facilitates access to external financing and encourages innovation.

First, we exploit Tobin's q model of investment to examine the relationship between corporate governance and green R&D intensity. Using the system-GMM, we find that the better the corporate governance, the more the firm invests in environmental R&D activities. Moreover, in contrast with ordinary investment, Tobin's q has a negative impact on green R&D expenses, and the surplus-cash-to-asset ratio has no significant effect. These results remain robust to various specifications, including the use of an alternative measure of green innovation. The probit estimations using the green product innovation as an ex-post measure, confirm that the higher the firm's governance rating, the more the firm develops green products. Our results are consistent with Amore and Bennedsen's (2016) findings that U.S. firms exposed to the passage of antitakeover laws, which weakened the disciplinary role of the market for corporate control, experienced a 13% drop of green patents. Thus, our study suggests that effective corporate governance fosters innovation that is beneficial for society.

We also explore whether each of the three dimensions of corporate governance affects green innovation. Using the logit regressions with the contemporaneous and the lagged values of the explanatory variables, we find a significantly positive impact of each of the three dimensions of corporate governance on green product innovation. An increase in the management dimension, the CSR strategy dimension, or the shareholder dimension scores of corporate governance, results respectively in an increase in the probability of green product innovation. Thus, all dimensions of corporate governance matter in firms' green innovation strategy. Finally, we find a positive relationship between green product innovation and the firm environmental performance, including emission reductions, and resource use efficiency. Overall, our results suggest that effective governance is necessary for environmental efficiency.

This study makes several contributions to the literature. First, it provides new evidence on the relationship between internal governance and changes in an essential component of societal value, namely green innovation. To the best of our knowledge, this is the first study examining the relationship between corporate governance and investment in environmental R&D. The evidence supports the arguments that corporate governance affects firms' policies (Bernile et al. 2018). Our findings that corporate governance is associated with higher investment in green R&D, and green innovation are consistent with diverse backgrounds as governance mechanisms moderate environmental decisions, and alleviate problems associated with groupthink (Shive and Forster, 2020; Jo and Harjoto, 2012). The evidence also supports Ferrell et al. (2016) that well-governed firms are more likely to help protect the environment. That is, effective governance provides a structure that sets goals that serve the interests of both shareholders and society.

As with similar studies, our study has limitations that might form the basis for future research. Since green R&D is a new form of investment, the results are based on a relatively small number of observations. As more data become available, future research could provide larger-scale evidence and a more refined characterization of the long-term implications of green R&D investments.

References

Akey, P. and Appel, I. (2021), "The Limits of Limited Liability: Evidence from Industrial Pollution", *The Journal of Finance*, Vol. 76 No. 1, pp. 5–55, doi: 10.1111/jofi.12978.

Albort-Morant, G., Leal-Millán, A. and Cepeda-Carrión, G. (2016), "The antecedents of green innovation performance: A model of learning and capabilities", *Journal of Business Research*, Vol. 69 No. 11, pp. 4912–4917, doi: 10.1016/j.jbusres.2016.04.052.

Almagtome, A., Khaghaany, M. and Önce, S. (2020), "Corporate Governance Quality, Stakeholders' Pressure, and Sustainable Development: An Integrated Approach", *International Journal of Mathematical, Engineering and Management Sciences* Vol. 5 No. 6, doi: 10.33889/ijmems.2020.5.6.082.

Amore, M.D. and Bennedsen, M. (2016), "Corporate governance and green innovation", *Journal of Environmental Economics and Management*, Vol. 75, pp. 54–72, doi: 10.1016/j.jeem.2015.11.003.

Arellano, M. and Bond, S. (1991), "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", *The Review of Economic Studies*, Vol. 58 No. 2, pp. 277–297, doi: 10.2307/2297968.

Arellano, M. and Bover, O. (1995), "Another look at the instrumental variable estimation of error-components models", *Journal of Econometrics*, Vol. 68 No. 1, pp. 29–51, doi: 10.1016/0304-4076(94)01642-D.

Asni, N. and Agustia, D. (2022), "Does corporate governance induce green innovation? An emerging market evidence", *Corporate Governance: The International Journal of Business in Society*, Vol. 22 No. 7, pp. 1375–1389, doi: 10.1108/CG-10-2021-0389.

Atanasov, V.A. and Black, B.S. (2016), "Shock-Based Causal Inference in Corporate Finance and Accounting Research", *Critical Finance Review*, Vol.5, pp.207-304, doi:10.2139/ssrn.1718555.

Atanassov, J. (2013), "Do Hostile Takeovers Stifle Innovation? Evidence from Antitakeover Legislation and Corporate Patenting", *The Journal of Finance*, Vol. 68 No. 3, pp. 1097–1131, doi: 10.1111/jofi.12019.

Atif, M., Hossain, M., Alam, M.S. and Goergen, M. (2021), "Does board gender diversity affect renewable energy consumption?", *Journal of Corporate Finance*, Vol. 66, p. 101665, doi: 10.1016/j.jcorpfin.2020.101665.

Bebchuk, L., Cohen, A. and Ferrell, A. (2009), "What Matters in Corporate Governance?", *The Review of Financial Studies*, Vol. 22 No. 2, pp. 783–827, doi: 10.1093/rfs/hhn099.

Becker-Blease, J.R. (2011), "Governance and innovation", *Journal of Corporate Finance*, Vol. 17 No. 4, pp. 947–958, doi: 10.1016/j.jcorpfin.2011.04.003.

Bernile, G., Bhagwat, V. and Yonker, S. (2018), "Board diversity, firm risk, and corporate policies", *Journal of Financial Economics*, Vol. 127 No. 3, pp. 588–612, doi: 10.1016/j.jfineco.2017.12.009.

Blundell, R. and Bond, S. (1998), "Initial conditions and moment restrictions in dynamic panel data models", *Journal of Econometrics*, Vol. 87 No. 1, pp. 115–143, doi: 10.1016/S0304-4076(98)00009-8.

Blundell, R., Bond, S., Devereux, M. and Schiantarelli, F. (1992), "Investment and Tobin's Q: Evidence from company panel data", *Journal of Econometrics*, Vol. 51 No. 1, pp. 233–257, doi: 10.1016/0304-4076(92)90037-R.

Chams, N. and García-Blandón, J. (2019), "Sustainable or not sustainable? The role of the board of directors", *Journal of Cleaner Production*, Vol. 226, pp. 1067–1081, doi: 10.1016/j.jclepro.2019.04.118.

Chemmanur, T.J. and Tian, X. (2018), "Do Antitakeover Provisions Spur Corporate Innovation? A Regression Discontinuity Analysis", *Journal of Financial and Quantitative Analysis*, Vol. 53 No. 3, pp. 1163–1194, doi: 10.1017/S0022109018000029.

Chen, X., Yi, N., Zhang, L. and Li, D. (2018), “Does institutional pressure foster corporate green innovation? Evidence from China’s top 100 companies”, *Journal of Cleaner Production*, Vol. 188, pp. 304–311, doi: 10.1016/j.jclepro.2018.03.257.

Chen, Y.-S. and Chang, K.-C. (2013), “The nonlinear effect of green innovation on the corporate competitive advantage”, *Quality & Quantity*, Vol. 47 No. 1, pp. 271–286, doi: 10.1007/s11135-011-9518-x.

Choi, B.-K., Ahn, J.-Y. and Choi, M.-C. (2021), “Corporate Social Responsibility, CEO Compensation Structure, and Corporate Innovation Activities”, *Sustainability*, Vol. 13 No. 23, p. 13039, doi: 10.3390/su132313039.

Dai, R., Liang, H. and Ng, L. (2021), “Socially responsible corporate customers”, *Journal of Financial Economics*, Vol.142 No.2, pp.598–626, doi: 10.1016/j.jfineco.2020.01.003.

Du, S. and Cao, J. (2023), “Non-family shareholder governance and green innovation of family firms: A socio-emotional wealth theory perspective”, *International Review of Financial Analysis*, Vol. 90, p. 102857, doi: 10.1016/j.irfa.2023.102857.

Dyck, A., Lins, K.V., Roth, L. and Wagner, H.F. (2019), “Do institutional investors drive corporate social responsibility? International evidence”, *Journal of Financial Economics*, Vol. 131 No. 3, pp. 693–714, doi: 10.1016/j.jfineco.2018.08.013.

Fama, E.F. and Jensen, M.C. (1983), “Separation of Ownership and Control”, *The Journal of Law & Economics*, Vol. 26 No. 2, pp. 301–325.

Fazzari, S.M. and Athey, M.J. (1987), “Asymmetric Information, Financing Constraints, and Investment”, *The Review of Economics and Statistics*, Vol. 69 No. 3, pp. 481–487, doi: 10.2307/1925536.

Ferrell, A., Liang, H. and Renneboog, L. (2016), “Socially responsible firms”, *Journal of Financial Economics*, Vol. 122 No. 3, pp. 585–606, doi: 10.1016/j.jfineco.2015.12.003.

Flammer, C. (2021), “Corporate green bonds”, *Journal of Financial Economics*, Vol. 142 No. 2, pp. 499–516, doi: 10.1016/j.jfineco.2021.01.010.

Galbreath, J. (2019), “Drivers of Green Innovations: The Impact of Export Intensity, Women Leaders, and Absorptive Capacity”, *Journal of Business Ethics*, Vol. 158 No. 1, pp. 47–61, doi: 10.1007/s10551-017-3715-z.

García-Sánchez, I.-M., Hussain, N., and Martínez-Ferrero, J. (2019), “An empirical analysis of the complementarities and substitutions between effects of ceo ability and corporate governance on socially responsible performance”, *Journal of Cleaner Production*, Vol. 215, pp. 1288–1300, doi: 10.1016/j.jclepro.2019.01.130.

Gompers, P., Ishii, J. and Metrick, A. (2003), "Corporate Governance and Equity Prices", *The Quarterly Journal of Economics*, Vol. 118 No. 1, pp. 107–156, doi: 10.1162/00335530360535162.

Hansen, L.P. (1982), "Large Sample Properties of Generalized Method of Moments Estimators", *Econometrica*, Vol. 50 No. 4, pp. 1029–1054, doi: 10.2307/1912775.

Haque, F. (2017), "The effects of board characteristics and sustainable compensation policy on carbon performance of UK firms", *The British Accounting Review*, Vol. 49 No. 3, pp. 347–364, doi: 10.1016/j.bar.2017.01.001.

He, X. and Jiang, S. (2019), "Does gender diversity matter for green innovation?", *Business Strategy and the Environment*, Vol. 28 No. 7, pp. 1341–1356, doi: 10.1002/bse.2319.

Hennessy, C.A. (2004), "Tobin's Q, Debt Overhang, and Investment", *The Journal of Finance*, Vol. 59 No. 4, pp. 1717–1742, doi: 10.1111/j.1540-6261.2004.00677.x.

Hillier, D., Pindado, J., Queiroz, V. de and de la Torre, C. (2011), "The impact of country-level corporate governance on research and development", *Journal of International Business Studies*, Vol. 42 No. 1, pp. 76–98, doi: 10.1057/jibs.2010.46.

Hong, B., Li, Z. and Minor, D. (2016), "Corporate Governance and Executive Compensation for Corporate Social Responsibility", *Journal of Business Ethics*, Vol. 136 No. 1, pp. 199–213, doi: 10.1007/s10551-015-2962-0.

Hosono, K., Tomiyama, M. and Miyagawa, T. (2004), "Corporate governance and research and development: Evidence from Japan", *Economics of Innovation and New Technology*, Vol. 13 No. 2, pp. 141–164, doi: 10.1080/10438590410001628125.

Howell, S.T. (2017), "Financing Innovation: Evidence from R&D Grants", *American Economic Review*, Vol. 107 No. 4, pp. 1136–1164, doi: 10.1257/aer.20150808.

Hutchinson, M. and Gul, F.A. (2004), "Investment opportunity set, corporate governance practices and firm performance", *Journal of Corporate Finance*, Vol. 10 No. 4, pp. 595–614, doi: 10.1016/S0929-1199(03)00022-1.

Jensen, C. and Meckling, H. (1976), "Theory of the firm: Managerial behavior, agency costs and ownership structure", *Journal of Financial Economics*, Vol. 3(4) No. 4, pp. 305–360, doi: 10.1016/0304-405X(76)90026-X.

Jensen, M.C. (1986), "Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers", *The American Economic Review*, Vol. 76 No. 2, pp. 323–329.

Jia, N., Huang, K.G. and Man Zhang, C. (2019), "Public Governance, Corporate Governance, and Firm Innovation: An Examination of State-Owned Enterprises", *Academy of Management Journal*, Vol. 62 No. 1, pp. 220–247, doi: 10.5465/amj.2016.0543.

Jo, H. and Harjoto, M.A. (2012), "The Causal Effect of Corporate Governance on Corporate Social Responsibility", *Journal of Business Ethics*, Vol. 106 No. 1, pp. 53–72, doi: 10.1007/s10551-011-1052-1.

Krueger, P., Sautner, Z. and Starks, L.T. (2020), "The Importance of Climate Risks for Institutional Investors", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1067–1111, doi: 10.1093/rfs/hhz137.

La Rocca, M., La Rocca, T. and Cariola, A. (2011), "Capital Structure Decisions During a Firm's Life Cycle", *Small Business Economics*, Vol. 37 No. 1, pp. 107–130, doi: 10.1007/s11187-009-9229-z.

Lee, K.-H. and Min, B. (2015), "Green R&D for eco-innovation and its impact on carbon emissions and firm performance", *Journal of Cleaner Production*, Vol. 108, pp. 534–542, doi: 10.1016/j.jclepro.2015.05.114.

Li, D., Zheng, M., Cao, C., Chen, X., Ren, S. and Huang, M. (2017), "The impact of legitimacy pressure and corporate profitability on green innovation: Evidence from China top 100", *Journal of Cleaner Production*, Vol. 141, pp. 41–49, doi: 10.1016/j.jclepro.2016.08.123.

Liao, L., Luo, L. and Tang, Q. (2015), "Gender diversity, board independence, environmental committee and greenhouse gas disclosure", *The British Accounting Review*, Vol. 47 No. 4, pp. 409–424, doi: 10.1016/j.bar.2014.01.002.

Liao, Z., Zhang, M. and Wang, X. (2019), "Do female directors influence firms' environmental innovation? The moderating role of ownership type", *Corporate Social Responsibility and Environmental Management*, Vol. 26 No. 1, pp. 257–263, doi: 10.1002/csr.1677.

Lin, H., Zeng, S.X., Ma, H.Y., Qi, G.Y. and Tam, V.W.Y. (2014), "Can political capital drive corporate green innovation? Lessons from China", *Journal of Cleaner Production*, Vol. 64, pp. 63–72, doi: 10.1016/j.jclepro.2013.07.046.

Lu, J. and Herremans, I.M. (2019), "Board gender diversity and environmental performance: An industries perspective", *Business Strategy and the Environment*, Vol. 28 No. 7, pp. 1449–1464, doi: 10.1002/bse.2326.

Markus, A. and Swift, T. (2019), "Corporate governance and the impact to the R&D lab", *Journal of Strategy and Management*, Vol. 13 No. 1, pp. 91–110, doi: 10.1108/JSMA-06-2019-0100.

Naciti, V. (2019), "Corporate governance and board of directors: The effect of a board composition on firm sustainability performance", *Journal of Cleaner Production*, Vol. 237, p. 117727, doi: 10.1016/j.jclepro.2019.117727.

Nadeem, M., Zaman, R. and Saleem, I. (2017), "Boardroom gender diversity and corporate sustainability practices: Evidence from Australian Securities Exchange listed firms", *Journal of Cleaner Production*, Vol. 149, pp. 874–885, doi: 10.1016/j.jclepro.2017.02.141.

O'Connor, M. and Rafferty, M. (2012), "Corporate Governance and Innovation", *Journal of Financial and Quantitative Analysis*, Vol. 47 No. 2, pp. 397–413, doi: 10.1017/S002210901200004X.

Roodman, D. (2009), "How to do Xtabond2: An Introduction to Difference and System GMM in Stata", *The Stata Journal*, Vol. 9 No. 1, pp. 86–136, doi: 10.1177/1536867X0900900106.

Sapra, H., Subramanian, A. and Subramanian, K.V. (2014), "Corporate Governance and Innovation: Theory and Evidence", *Journal of Financial and Quantitative Analysis*, Vol. 49 No. 4, pp. 957–1003, doi: 10.1017/S002210901400060X.

Scherer, A.G. and Voegtlin, C. (2020), "Corporate Governance for Responsible Innovation: Approaches to Corporate Governance and Their Implications for Sustainable Development", *Academy of Management Perspectives*, Vol. 34 No. 2, pp. 182–208, doi: 10.5465/amp.2017.0175.

Shive, S.A. and Forster, M.M. (2020), "Corporate Governance and Pollution Externalities of Public and Private Firms", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1296–1330, doi: 10.1093/rfs/hhz079.

Singh, R., Gupta, C.P. and Chaudhary, P. (2023), "Dividend policy and corporate life cycle: a study of Indian companies", *Managerial Finance*, Vol. ahead-of-print, doi: 10.1108/MF-01-2023-0053.

Stein, J.C. (1988), "Takeover Threats and Managerial Myopia", *Journal of Political Economy*, Vol. 96 No. 1, pp. 61–80, doi: 10.1086/261524.

Takalo, S.K., Tooranloo, H.S. and Shahabaldini parizi, Z. (2021), "Green innovation: A systematic literature review", *Journal of Cleaner Production*, Vol. 279, p. 122474, doi: 10.1016/j.jclepro.2020.122474.

Usman, M., Javed, M. and Yin, J. (2020), "Board internationalization and green innovation", *Economics Letters*, Vol. 197, p. 109625, doi: 10.1016/j.econlet.2020.109625.

Xu, Q. and Kim, T. (2022), "Financial Constraints and Corporate Environmental Policies", *The Review of Financial Studies*, Vol. 35 No. 2, pp. 576–635, doi: 10.1093/rfs/hhab056.

Zhang, F. and Zhu, L. (2019), "Enhancing corporate sustainable development: Stakeholder pressures, organizational learning, and green innovation", *Business Strategy and the Environment*, Vol. 28 No. 6, pp. 1012–1026, doi: 10.1002/bse.2298.

CHAPTER -III

Corporate Governance Mechanisms and Renewable Energy Transition

Abstract

The intensity of carbon emissions has led to the serious problem of global warming, and the consequences in terms of climatic disasters are gaining increasing attention. In anticipation of stronger environmental regulations and carbon risks, well-governed firms may invest in low-polluting technologies or opt for clean energy. The present study examines the relationship between governance mechanisms and renewable energy (RE) consumption, and explores the interaction between RE production and RE use. Based on a sample of 3,896 firms covering 45 countries worldwide, it shows that appropriate governance mechanisms positively impact RE use. These include the existence of a sustainability committee, ESG-based compensation policy, financial performance-based compensation, sustainability external audit, transparency, board gender diversity, and board independence. Using a bivariate probit, the study shows that the decision to use RE implies the decision to produce RE by the firms, and vice versa. Finally, while RE use positively impacts firm value and environmental performance, we find no significant impact on current profitability. Thus, investors view RE use as a competitive advantage and anticipate the firm's future financial performance. Overall, the findings suggest that RE transition requires, first of all, establishing appropriate governance mechanisms within companies.

Keywords: Corporate governance, Executive compensation, Sustainability committee, Renewable energy transition, Climate change risk

JEL classification: G34 ; M14 ; P18 ; Q56 ; Q20

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1. Introduction

Energy is a crucial resource for the economy of all countries worldwide (Wang, 2022; Bildirici and Gökmenoğlu, 2017; Yu *et al.*, 2022). For instance, one of the essential distinctions between developed and developing nations is access to electricity (Opoku *et al.*, 2021). To date, economic activity in many countries largely depends on fossil energy consumption (Destek and Aslan, 2020), which accounts for more than 80% of global primary energy production (Yu *et al.*, 2022). However, using such energies results in pollution that harms the environment (Bildirici and Gökmenoğlu, 2017). Fossil fuel energy is responsible for about 80% of global emissions of carbon dioxide (CO_2) and 60% of global emissions of greenhouse gases (GHG) (Yu *et al.*, 2022; Bildirici and Gökmenoğlu, 2017). The intensity of CO_2 emissions is the primary cause of climate change, with multiple consequences regarding climatic disasters (Choi *et al.*, 2020; Bernstein *et al.*, 2019). Floods, heat waves, land drought, wildfires, a rise in sea level, and other disasters are the most common manifestations of extreme climatic events that are becoming increasingly frequent with global warming. These events are also costly for firms and governments. For instance, concerning Canada, experts predict that climatic disasters could cost the economy, almost $139 billion over the next 30 years [1].

Environmentalists, civil societies, policymakers, regulators, firms, and investors are increasingly concerned about the effects of climate change (Krueger *et al.*, 2020; Haque, 2017). The urgency of reducing CO_2 emissions to limit global warming has encouraged countries worldwide to transition toward low-carbon economies (Zhu *et al.*, 2022). Since the energy sector is responsible for the majority of global emissions of GHG, developing clean energy is crucial to address the issue of global warming (Wang, 2022). Renewable energy (RE) has the potential to reduce environmental pollution (Yu *et al.*, 2022). Access to clean and RE constitutes one of the Sustainable Development Goals (SDGs) of the United Nations (U.N). Being a globally accepted solution, developing RE sectors has been a meaningful action (Zhang *et al.*, 2021). RE adoption may improve environmental quality by reducing the carbon footprint at the country level (Zhu *et al.*, 2022; Yu *et al.*, 2022) in the long term.

While empirical studies have extensively documented the importance of RE for environmental protection, discussions on the challenges of firm-level consumption are largely missing. As a major cause of climate change, GHG emissions result mainly from firms' activities (Shive and Forster, 2020; Balachandran and Nguyen, 2018). The increase in RE use depends on the firms' efforts because they consume a lot of energy and generate the largest share of GHG (Atif *et al.*, 2021). Zhang *et al.* (2021) argue that internal governance mechanisms matter for firms' adoption of RE. Along this line, Pearl-Martinez and Stephens (2016) consider board gender diversity necessary to transition toward clean energy. Our study aims to build on this previous literature by exploring the nexus between multiple governance mechanisms and the use of RE by firms worldwide.

Studying the relationship between corporate governance and energy transition is still in its beginning. To the best of our knowledge, little is known about corporate governance and RE use. Apart from Atif *et al.* (2021) and Zhang *et al.* (2021), who studied only board characteristics, no serious study has examined the relationship between internal governance and RE use. Atif *et al.* (2021) find a positive effect of female directors on RE consumption, while Zhang *et al.* (2021) document that CEO duality tends to reduce RE use. However, regarding environmental efficiency, studying other governance mechanisms is necessary since corporate governance can not be limited to board structure. For instance, if corporate social responsibility (CSR) activities contradict firms' financial performance, executives may invest less in environmental protection when their compensation is tied to firm profitability. As firms are profit-maximizing entities, managers may opt for fossil fuel energy when using RE would negatively affect their profit or cause production instability (Zhang *et al.*, 2021).

Furthermore, linking executive compensation to CSR performance is a recent development in corporate governance (García-Sánchez *et al.*, 2019a; Flammer *et al.*, 2019). In the agency theory, as managers are utility maximizers, incentive schemes and monitoring induce them to provide optimal effort (Ferrell et al., 2016). Hong *et al.* (2016) associate corporate governance literature with the agency cost perspective of CSR and find that firms with more shareholder-friendly governance are more likely to provide compensation to executives linked to firm ESG (Environmental, Social, and Governance) performance outcomes. They provide evidence identifying corporate governance as a determinant of managerial incentives for ESG performance. Karim *et al.* (2018) find that firms' environmental performance is negatively associated with the proportion of cash-based compensation and positively related to equity-based payment. On the other hand, a sustainability committee as a corporate governance tool could also foster investment in sustainable development activities, including CO_2 reduction initiatives. The existence of a sustainability committee indicates how proactive the firm is regarding ecological issues (Liao *et al.*, 2015). Agency theory implies that committees responsible for specific corporate concerns may be necessary for satisfying stakeholder pressure for increased accountability (Dixon-Fowler *et al.,* 2017). Hence, sustainability committees are more likely to advocate using RE, which may improve the firm's environmental performance.

Although the literature suggests that board committees and the chief executive officer (CEO) compensation may significantly influence firm policies (Flammer *et al.,* 2019; Eberhardt-Toth, 2017), no study explores the role of these variables on RE use. Our research aims to examine the impact of these variables on RE consumption. Specifically, we tend to answer the question: Do firms' internal governance tools affect RE adoption? Our first objective is to analyze the impact of sustainability committees and the CEO compensation policies on RE consumption. As RE use depends on its availability, our second objective is to examine the interaction between the decision to use and the decision to produce RE by exploring the role of governance mechanisms. These objectives constitute an exceptional contribution since, to date, no studies have been conducted in this direction.

To examine whether governance mechanisms affect firms' RE consumption, we investigate panel data of 3,896 firms for 2002-2021, covering 45 countries worldwide. We follow Ferrell *et al.* (2016) and argue that well-governed firms are more likely to be socially responsible and promote efforts to help protect the environment. We postulate that corporate governance mechanisms, such as the existence of the board sustainability committee and the CEO compensation policies, are fundamental factors affecting firm environmental decisions, including RE adoption. First, we estimate the panel models with fixed effects. We find a significantly positive impact of most of the governance mechanisms we examined on RE use. Specifically, the sustainability committee, financial performance-based compensation, CEO compensation related to ESG performance policies, sustainability external audit, and transparency, positively affect RE consumption. We also test the relationship between board characteristics and RE use, and find a significantly positive effect of board gender diversity, and board independence. Surprisingly, we find no significant impact of audit committee independence on RE consumption. Indeed, the percentage of independent board members on the audit committee does not affect firm-level RE use. These results remain robust to various specifications, including using an alternative measure of RE consumption, the logit regressions, and correcting for the endogeneity concerns. In sum, the findings reveal the importance of corporate governance in the RE transition.

In the second part of the study, we explore the interaction between the decision to use RE and the decision to produce RE. Using a bivariate probit regression, we find the interdependence of the two decisions. The decision to use implies the decision to produce RE, and vice versa. The bivariate probit results also reveal that firms with appropriate governance mechanisms are more likely to generate and use RE than other firms. In addition, we document that RE consumption results in less CO_2 emissions. Moreover, RE use is positively associated with the firm's environmental performance. Finally, while RE consumption positively impacts firm value, we find no significant effect on the firm's current profitability (ROA). Therefore, firms may consider RE transition as a strategy against climate change that is in the interest of the existing shareholders since it has no negative impact on profitability.

This study makes important contributions to the literature. First, to the best of our knowledge, this is the first study investigating the relationship between multiple corporate governance mechanisms (such as sustainability committee, ESG-based compensation, financial performance-based compensation, sustainability external audit, audit committee independence, transparency) and RE adoption. The present study completes the existing literature on corporate governance and sustainability. It does tackle three of the 17 U.N's SDGs: Goal 7 on access to affordable and clean energy, goal 12 on responsible production and consumption, and goal 13 on climate action. Thus, the findings have many implications for academic research and policy-making. From a theoretical perspective, the study contributes to the literature on corporate governance and environmental pollution, which is still in its infancy (Shive and Forster, 2020), by investigating the relationship between corporate governance and RE use as well as RE development. It offers new insights for managers and policymakers on how to use governance tools to address climate change concerns. Given specific governance mechanisms in the firm increase RE adoption, policymakers aiming to combat climate change and its impacts should encourage firms to adopt these mechanisms.

This is also the first study examining the interdependence between the decision to use and the decision to produce RE by firms. The current study has the advantage of being the first to demonstrate that the energy transition requires, first of all, establishing appropriate governance mechanisms within firms. On the one hand, it contributes to the literature on corporate governance and technological innovation. On the other hand, it contributes to the literature on the relationship between technological innovation and environmental pollution. The analysis goes beyond the papers of Atif *et al.* (2021) and Zhang *et al.* (2021), which focus on a few characteristics of the corporate board without exploring whether firms using RE also produce part or all of that energy. It further demonstrates that using RE reduces pollution at the firm level. By doing so, the study has shown the importance of corporate governance for the use of RE as well as the investment in energy transition, and, thus, pollution reduction. It expands the growing literature on firm environmental efficiency.

Finally, the study contributes to the financial literature relating to environmental and financial performance. This is the first study examining the relationship between RE consumption and firm value. We find that RE consumption increases the firm market value without impacting its current profitability. Indeed, investors view RE use as a competitive advantage and anticipate the firm's future financial performance. This finding mainly implies that corporate governance is beneficial in terms of RE transition and that RE consumption is associated with a higher stock market valuation. In consequence, firms have an interest in communicating their use of RE in order to send a positive signal to investors, attract green investors, and raise funds at a lower cost. This signal seems credible since RE use is related to firm-level CO_2 emission reduction (Flammer, 2021). Thus, our study contributes to the financial literature, technological innovation financing, and CSR/ESG literature. It can help firms and fund managers make tactical and strategic decisions.

The rest of the chapter is organized as follows. Section 2 provides the study's background. Section 3 presents the theoretical framework. Section 4 reviews the empirical literature and develops the hypotheses. Section 5 presents the research design. Section 6 reports the findings. Section 7 presents further analysis. Section 8 discusses the results, and finally, section 9 concludes the chapter.

2. Background

The concerns about global warming incentive energy transition to the RE sector (Dogan *et al.*, 2022). Energy generated from fossil fuel sources accounts for 80% of CO_2 emissions and 60% of total GHG emissions in the world (Yu *et al.*, 2022). Among the most emitters, G-7 countries are responsible for 66.79% of the world's CO_2 emissions in 2014 (Destek and Aslan, 2020). U.S.A and China are the most polluters, with almost 31% of the world's total emissions, respectively (Wang, 2022; Bildirici and Gökmenoğlu, 2017). Since the energy sector account for the majority of emissions, the common view is that increasing RE use has pollution-reducing effects (Destek and Aslan, 2020) and may help achieve the SDGs and

COP26 targets (Bildirici and Gökmenoğlu, 2017; Dogan *et al*., 2022). For instance, in G-7 countries, empirical findings indicate that biomass energy consumption reduces CO_2 emissions in France, Germany, Japan, and the U.S.A; hydroelectricity usage reduces emissions in Italy and the U.K; wind energy consumption reduce emission in Canada, and solar energy reduce emission in France and Italy (Destek and Aslan, 2020; Yu *et al*., 2022; Chang *et al*., 2022). Then, it becomes urgent to put into practice policies about the energy transition.

Political drivers of the transition from fossil fuels to RE include international commitments to reduce GHG emissions (Dogan *et al*., 2022). In that regard, after the United Nations Framework Convention on Climate Change (UNFCC) signed at the Earth Summit in Rio de Janeiro in 1992, many countries have increased their support of RE against the threat of climate change (Bildirici and Gökmenoğlu, 2017). The UNFCC is the primary international, intergovernmental forum for negotiating the global response to climate change. The 17 U.N's SDGs and 169 targets demonstrate the scale and ambition of the U.N's 2030 Agenda for Sustainable Development [2]. Specifically, Goal 7 aims to ensure, by 2030, universal access to affordable, reliable and modern energy services, and increase the share of RE in the global energy mix. Goal 13 recommends taking urgent action to combat climate change and its impacts, specifically, integrating climate change measures into national policies, strategies, and planning. The Kyoto Protocol, adopted in 1998 and entered into force in 2005, marked a turning point in promoting emission reduction and RE adoption (Dogan *et al*., 2022; Bildirici and Gökmenoğlu, 2017). It may significantly impact the energy transition.

The Paris Agreement, the first universal agreement on climate, pointed out that solving the problem of global warming requires the joint efforts and cooperation of all countries around the world, and practical actions (Wang, 2022). It follows negotiations held at the Paris Climate Conference (COP21) of the UNFCC. It was approved by all 196 delegations on December 12, 2015, and entered into force on November 4, 2016. The agreement plans to contain global warming by 2100. Carbon neutrality is the essential element of the implementation of this agreement. The European Green Deal, a european climate policy, suggested by the European Commission and presented at the 2019 United Nations COP25 Climate Conference in Madrid, sets goals for the E.U countries to achieve carbon neutrality by 2050 (Chang *et al*., 2022). In 2021, the 26th U.N Climate Change Conference in Glasgow (COP26) brought together parties representing almost 200 countries to accelerate action towards the goals of the Paris Agreement and the UNFCC [3]. The Glasgow Climate Pact, the outcome of COP26, is a crucial effort to accelerate the energy transition to achieve zero emissions by 2050 (Dogan *et al*., 2022). Among others, it was agreed to recognize the emergency of climate change, to move away from fossil fuels, and to complete the Paris rulebook. In that regard, countries reaffirmed the Paris Agreement goal of limiting the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit it to 1.5 °C. In addition to the Glasgow Climate Pact, private financial institutions and central banks announced moves to realign trillions of dollars towards achieving global net zero emissions.

Regarding COP21, the U.S.A and E.U planned to achieve carbon neutrality by 2050, Russia and China by 2060, and India by 2070. However, despite all these promises, the average temperatures recorded continue to increase. According to the Copernicus Climate Change Service, summer 2023 is the hottest on record, and the year 2023 currently ranks as the second warmest year, just 0.01°C behind 2016 [4]. In that context, to accelerate action by governments, corporations, and civil society, the U.N Secretary General, M. Guterres, warned on September 19, 2023, during the U.N Climate Ambition Summit, that humanity has "opened the gates of hell" and is heading towards a "dangerous and unstable world". Alternatively, he complimented climate advocates and those who are taking action to eliminate fossil fuels. Thus, we need mechanisms to accelerate the energy transition.

3. Theoretical framework

Agency and stakeholder theories are often at the heart of the debate on the relationship between corporate governance and sustainability. Stakeholder theory states that firm managers must understand and consider the interests of all stakeholders in their decision-making process (Dmytriyev et al., 2021). This theory is the starting point for reflection on the mechanisms through which a firm obtains and loses its legitimacy (Suchman, 1995; Naciti, 2019). Legitimacy generally comes from stronger corporate governance and social responsibility practices, and is fundamental to the reputation and survival of firms (Suchman, 1995). Accordingly, sustainable development strategies result from the interaction between the standard of corporate governance and the pressure from stakeholders. Good governance makes firms environmentally responsible and more socially acceptable (Almagtome et al., 2020). Thus, appropriate governance mechanisms may facilitate RE consumption, a globally accepted solution to address the issue of climate change (Wang, 2022; Zhang et al., 2021), one of the most prominent societal concerns.

Agency theory points out the bad governance and the good governance view of CSR. One of the central debates in this literature is whether CSR, including environmental protection activities, is a long-term strategy resulting from appropriate governance mechanisms or arises because of the moral hazard from managers who act in their private interest instead of optimal investment (Gillan *et al.*, 2021). From the poor governance view, agency theory postulates that information asymmetry generally results in the opportunism of insiders who favor their interests instead of optimal investment (Jensen and Meckling, 1976). Thus, executives' motivation to engage in CSR consists of agency problems, the waste of precious resources, and poor governance (Ferrell *et al.*, 2016). In contrast, good governance mechanisms guarantee investor confidence by providing a structure that sets goals that serve the interests of shareholders and society (García-Sánchez *et al.*, 2019a). These mechanisms consist, among others, of monitoring and managerial incentives (Fama and Jensen, 1983; Jensen and Meckling, 1976). Considered the principal internal governance mechanism, the board of directors (BoD) plays a crucial role in decision-making processes and monitoring at the organizational level (Fama and Jensen, 1983). The BoD represents the main internal governance structure that supports managers in decisions that are better for the firm in the long run. The board effect on RE consumption would be mainly due to its monitoring role (García Lara *et al.*, 2017). The BoD sets guidelines for management, makes decisions on important corporate issues such as sustainability (Naciti, 2019), and thus affects corporate environmental policies and the choice to use clean energy.

From a good governance perspective, CSR activities are only helpful when the CSR orientation is integrated into corporate governance (Naciti, 2019). Corporate governance mechanisms are fundamental in formulating and implementing environmental strategies since CSR is relevant for meeting stakeholder expectations (García-Sánchez et al., 2019a). The board members and other governance mechanisms are the major contributors to elicit various societal activities (Chams and García-Blandón, 2019). In addition, in the agency theory, as managers are utility maximizers, incentive schemes and monitoring induce them to provide optimal effort. With managerial incentives and monitoring, environmental protection activities such as energy policies may reflect optimal investment instead of agency costs (Ferrell et al., 2016). Ferrell et al. (2016) consider well-governed firms in which management is incentivized correctly more likely to have managers engaging in appropriate CSR conduct. They argue that socially responsible firms often adhere to value-maximizing corporate governance practices. Thus, CSR is consistent with maximizing shareholder wealth and achieving broader societal goals. The stakeholder theory also supports this view.

One of the implications of the stakeholder theory is that firm managers must understand and consider the interests of all stakeholders (Dmytriyev et al., 2021). In this governance approach, incentive mechanisms such as ESG performance-based compensation policies may positively affect RE adoption (Haque, 2017). In contrast, financial performance-based compensation policies may positively impact RE consumption only if the choice to use RE is financially profitable for firms. According to Scherer and Voegtlin (2020), the shareholders' approach of corporate governance significantly emphasizes increasing profits to generate long-term shareholder value. Therefore, efficiency entails sacrificing societal well-being for shareholder benefit when corporate objectives conflict with SDGs. On the other hand, the stakeholder approach proposes that management should balance the various concerns and interests of multiple stakeholders rather than solely focusing on profits (Scherer and Voegtlin, 2020). This approach favors corporate sustainability and the use of clean energy, which contribute to societal well-being.

Furthermore, Almagtome *et al.* (2020) argue that corporate governance fosters the investment environment by enhancing reliability, transparency, and accountability at the firm-level. Thus, to maximize societal value, the board of directors should understand the social and environmental consequences of the firm's operations. Manning *et al.* (2019) posit that corporate governance explains variations in corporate sustainability. Specifically, board monitoring effectiveness and stakeholder engagement incentivize managers to become more accountable for the firm's sustainability. Hussain *et al.* (2018) support the complementary theoretical assertions of agency theory and stakeholder theory regarding the board's role in enhancing the firm's sustainability performance. They show that most internal governance mechanisms improve the firm's environmental performance. Specifically, the more independent and gender-diverse board with a designated sustainability committee that meets more frequently better monitors management decisions regarding environmental issues (Hussain *et al.*, 2018). Stronger internal governance helps firms meet sustainability goals and attain legitimacy. Thus, it is socially desirable to have appropriate governance mechanisms for monitoring corporate behavior and fostering corporate sustainability.

According to Liao *et al.* (2015), the company's climate policy may be influenced by the interactions between the board, individual board members, and stakeholder constituents, in addition to an objective assessment of the severity of the agency problem. Since the firm's climate strategy may affect each stakeholder differently, the board must be sufficiently representative to balance the interests of various and diverse stakeholders. Haque (2017) documents that the board of directors, as the representation of shareholders, enhances carbon performance at the firm level. García-Sánchez *et al.* (2019b) argue that CSR-oriented governance mechanisms like board independence, sustainability committee, and managerial incentives complement one another to enhance the firm's environmental performance. CSR-oriented governance ensures that managers' investment decisions align with the shareholders' and other stakeholders' interests. This mechanism makes CEOs less likely to choose short-term investments or avoid long-run CSR strategies. Additionally, an environmental committee as a governance mechanism favors the firm's proactive approach to environmental issues (Liao *et al.*, 2015). Finally, effective internal governance is positively associated with reducing GHG emissions (Shive and Forster, 2020). Thus, as RE aims at mitigating environmental pollution, the appropriate governance mechanisms may be a necessary condition for its adoption by firms.

4. Literature review and hypotheses

In this section, we present the hypotheses. We focus on the board of directors' characteristics, CEO compensation policies, and sustainability committee, which are the fundamental governance tools.

4.1. Board gender diversity, sustainability, and RE consumption

The board of directors is the central axis among corporate governance tools, and the primary determinant of corporate strategy and policies (Naciti, 2019; Fama and Jensen, 1983). Many studies explain the connection between the board of directors and sustainability. One of the key characteristics of corporate boards is diversity (Haque, 2017). For instance, Bernile *et al.* (2018) document that the persistence of corporate policies increases with board diversity. Specifically, gender diversity benefits the firm by providing several advantages. One way through which the presence of women on the board is beneficial to the firm is that the female directors are better monitors, leading to a decrease in agency costs through the improvements in the monitoring effectiveness of the board (García Lara *et al.*, 2017; Cardillo *et al.*, 2021). Furthermore, female directors care more about the communities that they operate in and are generally more sustainability-conscious than male directors (Opoku *et al.*, 2021; Atif *et al.*, 2021). Empirical studies found firms with females on their boards have relatively higher environmental performance (Gillan *et al.*, 2021; Chams and García-Blandón, 2019). Nadeem *et al.* (2017) provide the support that women's presence on boards encourages firms to adopt environmentally friendly practices and become socially responsible through good governance. Ullah *et al.* (2022) observe that female directors with foreign experience transmit ESG-related knowledge from developed countries to China. Gillan *et al.* (2021) report that board gender diversity has a relatively large positive effect on ESG performance compared to other board characteristics. Therefore, gender diversity may positively affect RE use.

Recent research documents that female directors encourage the implementation of climate change policies, including CO_2 emission reduction initiatives, green innovation, and energy efficiency. Liao *et al.* (2015) and Atif *et al.* (2021), among others, observe that female directors express greater concerns for the environment than male directors, and are more likely to engage in environmental activities. Ben-Amar *et al.* (2017) reveal a positive relationship between board gender diversity and the likelihood of disclosing GHG emissions. Liu (2018) shows that firms with female directors are less likely to be subject to environmental violations. Gender diversity also enhances carbon reduction initiatives and climate change mitigation strategies, as it reduces GHG emissions intensity (Liu, 2018; Haque, 2017). Nuber and Velte (2021) show that female directors need to reach at least two seats on the board to have a significant positive impact on corporate environmental policy, while Nguyen *et al.* (2021) notice a positive but insignificant association between gender diversity and firms' environmental performance in China. Thus, as RE consumption results in CO_2 emission reduction, the increase in the percentage of female directors may positively impact RE adoption.

Finally, women are more concerned about energy access, sustainability, and the environment (Opoku *et al.*, 2021). Pearl-Martinez and Stephens (2016) argue that gender diversity is essential for RE transition. They consider that increasing gender diversity in energy decision-making will distribute political power to encourage a more sustainable society. In the same way, Opoku *et al.* (2021) note that the increase in seats held by women in national parliaments is positively associated with the increase in energy efficiency. Considering that energy is a critical resource for firms and the role of board gender diversity in corporate strategy, we follow Atif *et al.* (2021). We argue that firms with more female directors may be more likely to address the challenge of climate change by promoting energy transition. We assume a positive relationship between board gender diversity and RE use.

H1.a: Board gender diversity is positively related to RE consumption.

4.2. Board independence, sustainability, and RE consumption

The fundamental characteristic of the board of directors is its degree of independence, which is determined by the proportion of outsiders (García-Sánchez *et al.*, 2019b). Like board gender diversity, board independence is an important governance mechanism in constraining managerial discretion, decreasing agency costs, and promoting socially responsible behavior (Haque, 2017; García-Sánchez *et al.*, 2019a). Agency theory implies that independent directors should hold a majority of board seats because they can effectively monitor managerial decisions and have a lower risk of conflict of interest (Naciti, 2019). Outside board members are more concerned with societal goals, while inside directors are shareholders focused and generally concentrate on profit maximization (Chams and García-Blandón, 2019). Since they typically have little financial interest in the company, independent board members are more likely to advocate long-term investment in environmental issues and resist management pressures (Liao *et al.*, 2015; Haque, 2017). Hence, board independence is substantial in corporate environmental policies, including adopting clean and RE.

According to the argument proposed by Liao *et al.* (2015), the firm's climate strategy frequently requires significant investments with uncertain outcomes that could impact each stakeholder differently. Thus, exchanging a broader range of experiences and viewpoints on a diverse and independent board is necessary since environmental decisions should result from a compromise between competing interests. Although Nguyen *et al.* (2021) observe a positive but insignificant association between board independence and firms' environmental performance in China, Haque (2017) documents that board independence has a positive effect on carbon reduction initiatives, and thus supports the argument for monitoring and resource provisioning roles of the board. Furthermore, Liao *et al.* (2015) find a positive association between board independence and the propensity to disclose GHG information, indicating that a board with more independent directors shows a higher tendency to be ecologically transparent. Thus, firms with more independent board members may use more RE, a strategy to reduce environmental pollution.

Separating board chair and CEO roles increases board independence (Naciti, 2019). As Chams and García-Blandón (2019) mentioned, CEO duality occurs when the CEO fulfills a double role as the firm's president and chairman of the board. The dual task of the CEO has an impact on the board of directors' decision-making process and the firm's operations as it increases the conflict of interests. The overlapping membership between the top management team and the firm’s board can diminish the strength of the internal governance in regulating managerial decisions since managers who are board members can directly influence the board’s decision-making process (Hong *et al.*, 2016). A higher share of executive directors means a less independent board whose decisions are more likely to favor the interest of shareholders instead of broader stakeholders (Zhang *et al.*, 2021). Consequently, CEOs may be reluctant to pursue pollution control projects because such investments might only pay off in the long run. At the same time, independent boards may be more likely to realize the potential of emissions-control projects and resist any management pressure (Liao *et al.*, 2015). Thus, firms with more independent board members may invest more in pollution reduction by using RE.

H1.b: Board independence is positively related to RE consumption.

4.3. Sustainability committee, sustainability, and RE consumption

Dixon-Fowler *et al.* (2017) consider board committees as permanent sub-groups of directors with narrowly defined objectives and given specialized responsibilities regarding crucial activities, that can significantly influence the firm’s policy and strategy. Working in sub-groups of committees facilitates information pooling and decision-making since sub-groups increase efficiency through the division of labor, prevention of groupthink and herding, and optimal heterogeneity (Adams *et al.*, 2021). Sub-groups are essential in group operations and corporate governance, as board committees affect firm performance more meaningfully than the board as a whole. Considering corporate boards as groups and committees as sub-groups, Adams *et al.* (2021) document that 25% of all director meetings occurred in committees in 1996, which increased to 45% by 2010.

Agency theory implies that a specialized CSR/sustainability committee is often created to establish a monitoring process or to ensure that company decisions and actions are coherent with the interests of specific stakeholders (García-Sánchez *et al.*, 2019b). The main functions of the sustainability committee consist of guiding the company towards CSR actions, managing risks and opportunities concerning sustainability, meeting corporate objectives, and fulfilling obligations to stakeholders (García-Sánchez *et al.*, 2019a). To be effective, the committee must be independent, powerful, and includes environmental stakeholders and sustainability managers that may increase the ability of the committee to influence the firm’s environmental performance (Dixon-Fowler *et al.*, 2017). Eberhardt-Toth (2017) argues that an independent committee is more sensitive to stakeholder demands because the independent members have an outsider's perspective on the company. In addition, the board chair membership makes the committee powerful since it enables the chairman to set CSR topics to discuss at the board meetings. Dixon-Fowler *et al.* (2017) expect environmental stakeholder directors and the sustainability manager on sustainability committees to provide specialized ecological knowledge and expertise, which may influence corporate environmental decision-making. Environmental stakeholder directors will encourage the pursuit of proactive climate strategies, recognize relevant environmental issues and opportunities, provide specialized advice, and create cooperative relationships between the firm and stakeholders such as environmental NGOs, experts, and policymakers, which, in turn, will increase both environmental and financial performance of the firm.

Previous research shows that sustainability committees have a positive impact on CSR. Liao *et al.* (2015) find that a board with an environmental committee shows a higher tendency to be ecologically transparent. However, the committee's impact is negligible if it is not sufficiently large, independent, or active. Dixon-Fowler *et al.* (2017) find empirical support for a positive association between board environmental committees and firms' environmental performance. In contrast, Orazalin *et al.* (2023) observe that the presence of a board sustainability committee does not affect outcome-based carbon performance. Eberhardt-Toth (2017) focuses on the composition of an effective CSR committee that contributes considerably to ESG performance. They found evidence of higher ESG performance in firms having a sustainability committee with a larger proportion of independent directors, a non-membership of the CEO, a higher average age of directors, a female chair, and a smaller size for the committee. Thus, firms with a sustainability committee may be more likely to use clean and RE.

In sum, the CSR/sustainability committee may increase the awareness of environmental issues, including CO_2 emission reduction initiatives, will endeavor to convince CEOs to take into account the climate change issues in their strategies, may enhance the awareness of employees of the environmental aspects of their jobs, will help the firm incorporate the opinions of its staff and stakeholders into the planning of CO_2 emission strategies, and will identify gaps in current practices and achieve ongoing improvements. By advocating CO_2 reduction initiatives, the sustainability committee will, directly and indirectly, pressure the company to plan and implement sustainable projects, including RE adoption. To the extent that the existence of a sustainability committee conveys a firm's commitment to environmental issues and that committees may significantly influence environmental strategies (Dixon-Fowler *et al.*, 2017), we expect a positive relationship between the sustainability committee and RE use.

H2: The sustainability committee in the firm is positively related to RE consumption.

4.4. Executive compensation, sustainability, and RE consumption

In corporate governance literature, compensation policies can be used to incentivize managers to pay attention to stakeholders' expectations and long-term value creation (Flammer *et al.*, 2019). Executive compensation generally comprises a fixed component and a variable part that depends on firm performance and often takes the form of a bonus or stock options. Bonus payments induce the CEO to perform well in the short term. In contrast, stock options induce the CEO to perform better every year to build the firm's long-term performance so that the employee stock options' value increases (Rekker *et al.*, 2014). The executive's decisions are supposed to affect the stock price, which will rise with expectations of the firm performing well. Therefore, if CEOs' engagement in CSR is driven by their attempt to increase shareholder value, one can expect a positive association between financial performance-based compensation and sustainability. In contrast, if CSR activities decrease shareholder value, one can expect a negative relationship between financial performance-based compensation and environmental protection policies.

In the agency cost view, CEOs obtain non-pecuniary benefits from corporate spending on CSR activities and do so at the expense of shareholders (Karim *et al.*, 2018; Gillan *et al.*, 2021). A well-governance argument is that CEOs consider CSR activities as a business strategy to increase firm value and align their interests with those of shareholders (Karim *et al.*, 2018). Agency theory predicts that incentive-based mechanisms align the interests of outsiders and insiders, and motivate managers to make optimal decisions, which in turn improve firm value (Haque, 2017; Ferrell *et al.*, 2016). The contractual incentives are motivational factors that help align the CEO's objectives with those of the shareholders and solve the agency problem (García-Sánchez *et al.*, 2019a). Therefore, if the board defines the CEO's pay accordingly, spending on environmental protection might be consistent with optimal contracting or good governance, and not a manifestation of agency problems (Gillan *et al.*, 2021). Moreover, firms with appropriate governance mechanisms can give managers monetary compensation associated with CSR/ESG performance (García-Sánchez *et al.*, 2019a). This type of compensation is often called "*sustainable executive compensation*" or "*ESG-based compensation*." It is commonly referred to as "*CSR contracting*" or "*pay for social and environmental performance*" as opposed to the traditional "*pay for financial performance*" (Flammer *et al.*, 2019).

ESG-based compensation may result in an optimal investment in environmental protection and RE use. Flammer *et al.* (2019) argue that CSR contracting enhances corporate governance by incentivizing managers to direct attention to stakeholders that are less salient but financially material to the firm in the long run. For CSR contracting to be effective, CSR activities must provide sufficient returns for the firm financial performance to be worth investing in, and executive compensation contracts providing incentives for CSR must lead to improved CSR performance within firms (Hong *et al.,* 2016). Haque (2017) defends that a sustainable executive compensation policy seems necessary to motivate executives to address environmental concerns. In addition, firms may use an ESG-based compensation policy to encourage employees to develop energy-efficient products and implement innovative carbon mitigation projects. Providing executives with incentives for CSR is an effective tool to increase firm ESG performance (Hong *et al.,* 2016). Karim *et al.* (2018) support that CEOs consider ESG performance as a business strategy that increases firm value and aligns their interests with those of shareholders. They find environmental performance negatively related to cash-based compensation and positively to equity-based compensation. Jian and Lee (2015) distinguish optimal and abnormal CSR investments, and find CEO total compensation positively associated with normal CSR, suggesting that the CEO is rewarded for investing in the optimal level of CSR. However, the CEO receives lower compensation when CSR investment deviates from the optimal level. Thus, stronger governance penalizes CEOs by reducing their compensation if they over-invest in CSR.

In line with arguments that incentive-based mechanisms can persuade executives to undertake climate protection initiatives, Haque (2017) documents that ESG-based compensation is positively associated with carbon reduction initiatives. Haque and Ntim (2020) confirm that executive compensation has a positive effect on process-oriented carbon performance. Flammer *et al.* (2019) document that CSR contracting increases the long-term orientation and environmental initiatives, and reduces the CO_2 emissions. Thus, linking CEO compensation to firm ESG performance may result in pollution reduction and the use of clean and RE. Finally, many studies report a positive relationship between the firm environmental performance and financial performance (Daugaard, 2020; Lee *et al.*, 2015), and others found a positive stock market reaction following firms' environmental decisions (Flammer, 2021). Indeed, financial performance-based compensation may also result in RE use.

In sum, as managers are utility maximizers, incentive schemes may induce them to use RE. Thus, ESG performance-based compensation may positively affect RE consumption, which in turn may reduce firm-level CO_2 emissions. Alternatively, the financial performance-based compensation may increase RE use only if RE use positively affects the firm financial performance. Since RE use is a corporate initiative to reduce CO_2 emissions, and given our discussion on the potential reasons for CEOs to engage in sustainability, we expect that a CEO motivated by intrinsic rewards will undertake climate protection initiatives, and encourage RE consumption. Then, we make the following hypotheses:

H3a: Financial performance-based compensation policy increases RE use.

H3b: ESG performance-based compensation policy increases RE use.

5- Research design

This section presents the data sources, the measurement of the main variables, the methodology, and the summary statistics.

5.1. Data sources and sample selection

We start our sample and variable construction by collecting all firm-level data included in the Refinitiv ESG and Compustat databases from 2002-2021. Thomson/Refinitiv ESG and Compustat databases are largely used in international studies. Refinitiv data are available on close to 9,000 firms globally, with history going back to 2002. These include data on firms' annual energy, CO_2 emissions (expressed in tons), environmental rating, and corporate governance indicators. Data on firms' energy comprise total energy consumption in thousands of megawatt hours (MWh), RE consumption in thousands of MWh, RE consumption dummy, the total energy produced, and RE produced. RE consumption variables constructed using data from Refinitiv ESG comprise the share of RE use over total energy consumption, and the RE consumption dummy variable, which equals one if the firm uses RE and 0 otherwise. Corporate governance data include board characteristics (board gender diversity, board size, board independence, CEO duality, board meeting), corporate governance rating, and the existence of governance mechanisms such as the sustainability committee, ESG performance-based compensation policies, CEO compensation related to financial performance policies, sustainability external audit, audit committee independence, and the use of GRI Report guidelines.

We collect financial data and firm-specific information using Compustat North America and Compustat Global. These include firms' industry 4-digit SIC code (The Standard Industrial Classification codes), country of location, total assets and liabilities, long-term debt, total equity, total cash, research and development expense, capital expenditures, total revenue, sales, EBIT (earnings before interest and taxes), stock prices, shares outstanding, and so on. Following previous studies (e.g., Flammer, 2021), we define the firm size (Size_Firm) as the logarithm of the book value of the total assets. The debt ratio is the book value of the long-term debt to the book value of total equity. Return on assets (ROA) is the ratio of the EBIT to the book value of total assets. Tobin's Q (firm value) is the ratio of the company's market capitalization (computed as the number of shares outstanding times the adjusted closing price) to the book value of equity. We also compute the cash-to-asset ratio as the firm's total cash to total assets. We convert the 4-digit SIC codes into 2-digit SIC codes. Following the previous studies (Flammer, 2021), we compute CO_2 emissions as the ratio of CO_2 emissions from Refinitiv divided by the total sales (revenues) from Compustat.

To obtain the final sample, we merge Refinitiv ESG and Compustat databases. Since Refinitiv does not cover all firms incorporated in Compustat and vice versa, combining the two datasets allows us to eliminate all firms for which we do not have financial data and those for which we do not have data on governance and energy policy. We drop all firms with null or negative book values and firms with negative debt ratios from our sample. We also eliminate firms with negative cash or Cash-to-asset ratio. All variables are winsorized at the 1% and 99% levels to control the effect of outliers. The final sample includes 3,896 firms covering 45 countries worldwide, corresponding to 23,716 firm-year observations from 2002-2021 (see Appendix III-A1 for details).

5.2. Definition of variables

5.2.1. Dependent variables

The primary dependent variables in this study are RE consumption and RE production. Based on existing literature (Atif *et al.*, 2021; Zhang *et al.*, 2021), this work uses two measures of RE consumption. First, given the significant differences in the sizes of companies, the study refers to Atif *et al.* (2021). It employs the ratio of RE use to total energy consumption to measure RE consumption (RE_Used). In the robustness test using logit regressions, the study employs an alternative measure of RE use: RE use dummy (Renew_Dummy), a dummy variable equal to one if the firm *i* uses RE in a given year *t*, and 0 otherwise. RE production dummy (RE_Prod_Dummy) is a dummy variable that equals one if the firm produces RE, and zero otherwise. In a further analysis, the study employs other dependent variables: firm operating performance (ROA), defined as the ratio of the EBIT to the book value of total assets (see Bardos et *al.,* 2020; Atif et al., 2021); firm value (Tobin's Q), defined as the ratio of the firm's market capitalization to the book value of equity (see Bardos et *al.,* 2020; Flammer, 2021). The study also employs environmental rating (Environmental perf) collected from the Refinitiv ESG database, and CO_2 emissions (TotCO2toRevenues) computed as the ratio of the firm's total CO_2 emissions divided by the total revenues (Flammer, 2021).

5.2.2. Independent variables: corporate governance mechanisms

The independent variables of interest in this study are governance mechanisms. These include board independence (Board_indep), board gender diversity (Gender_diversity), sustainability committee (CSR_committee), ESG performance-based compensation (ESG_Comp), financial performance-based compensation (CEO_comp_Perf), transparency (GRI_Transp), sustainability external audit (CSR_ext_audit), audit committee independence (Audit_com_Ind), and Refinitiv corporate governance rating (Governance). All the dependent variables are defined in Table III-1.

5.2.3. Control variables

Following the previous studies that examine the relationship between corporate governance and firms' environmental decisions (e.g., Shive and Forster, 2020; Atif *et al.*, 2021; Bardos *et al.,* 2020), this research controls for a series of firms characteristics that may affect RE policies. These variables are as follows: firm size (Size_Firm), firm value (Tobin's Q), debt ratio (DebtRatio), ROA, and cash-to-asset ratio (CashtoASSET). The study also controls the governance characteristics of firms based on the board meeting (Board_meeting) and the board size (Board_size). In addition, it uses the year, industry, and country dummy variables to control the year, industry, and country fixed effects. Please see Table III-1 for the details and definition of these variables.

5.3. Model specification

To capture the impact of corporate governance mechanisms on RE consumption, we adopt a panel model with fixed effects as our basic estimation model, following many empirical studies that examine the relationship between corporate governance variables and corporate policies (Bernile *et al.*, 2018; Jo and Harjoto, 2012; Atif *et al.*, 2021; Zhang *et al.*, 2021). We specify the reference model as follows:

$$(III-1): \quad RE\_Used_{it} = \alpha + \beta_{Gov} GOV_{it} + \gamma_c \sum Control\_variables_{it} + \rho_1 \sum FirmEffects_{it} + \rho_2 \sum YearEffects_t + \varepsilon_{it}$$

where the dependent variable RE_Used_{it} is the share of RE used over the total energy consumption of the firm *i* in a given year *t*. GOV is a vector of corporate governance mechanisms (board independence, board gender diversity, CSR/sustainability committee, CEO compensation policies, audit committee independence, etc.). Control_variables is a vector of control variables. FirmEffects control for firm fixed effects, and YearEffects control for year fixed effects (see Jo and Harjoto, 2012; Atif *et al.*, 2021). β_{Gov} is the coefficient of interest. We expect a positive impact of appropriate governance mechanisms on RE consumption, which means positive betas.

In Table III-2, we present the means, the medians, and the standard deviation of the main variables. As can be seen, 65.03% of our sample firms use RE (the mean of Renew_Dummy is 0.6503), and only 19.18% produce RE (the mean of RE_Prod_Dummy is 0.1918). On average, RE consumption to the total energy use ratio is 9.69% (we take into account of the sample firms that do not use RE, so have 0%). 75.45% of the firms have a sustainability committee, 30.96% have an ESG performance-based compensation policy, and 39.05% link CEO compensation to financial performance. Table III-1 summarizes the variables and their definition. In Table III-2, we report the summary statistics. Figures III-1 and III-2 illustrate the evolution of RE consumption since 2002. Figure III-4 presents the repartition of RE consumption by industry (industry 2-digit SIC code) since 2002, and Figure III-5 RE use by country. Figures III-3 and III-6 present RE users and RE producers by year and by country, respectively.

Table III-1.
Variables and measurement

Notation	Variable name	Measurement	Source
RE_Used	Renewable energy consumption	Total consumption of energy generated from primary renewable energy sources divided by total energy use	Refinitiv ESG
Renew_Dummy	Renewable Energy Use	A dummy variable equals one if the firm uses renewable energy, and zero otherwise	Refinitiv ESG
RE_Prod_Dummy	Renewable Energy Production dummy	A dummy variable equals one if the firm produces renewable energy, and zero otherwise	Refinitiv ESG
TotCO2toRevenues	CO_2 emissions	The ratio of total CO_2 emissions divided by the book value of total sales (revenues).	Refinitiv ESG and Compustat
Environmental perf	Environmental performance	Refinitiv ESG environmental rating	Refinitiv ESG
Governance	Corporate governance rating	Refinitiv ESG corporate governance rating	Refinitiv ESG
CSR_committee	CSR/sustainability committee	A dummy variable equals one if the firm has a CSR/ sustainability committee or team, and zero otherwise	Refinitiv ESG
ESG_Comp	ESG performance-based compensation	A dummy variable equals one if the firm has an ESG-related compensation policy, and zero otherwise	Refinitiv ESG
CEO_comp_Perf	Financial performance-based compensation policy	A dummy variable equals one if the CEO's compensation is linked to total shareholder return, and zero otherwise	Refinitiv ESG
Gender_diversity	Board gender diversity	Percentage or proportion of females on the board (a number between 0 and 1).	Refinitiv ESG
Board_indep	Board Independence (a number between 0 and 1)	Percentage or proportion of strictly independent board members (not employed by the company; not representing or employed by a majority shareholder; not served on the board for more than ten years; not a reference)	Refinitiv ESG
CEO duality	CEO-Chairman Separation	A dummy variable equals one if the CEO simultaneously chairs the board or the chairman of the board has been the CEO of the company, and zero otherwise	Refinitiv ESG
Board_size	Board size	The logarithms of the total number of board members at the end of the fiscal year	Refinitiv ESG
Board_meeting	Number of Board Meetings	The logarithm of the number of board meetings in the year	Refinitiv ESG
GRI_Transp	GRI Report Guidelines (transparency)	A dummy variable equals one if the firm publishes a separate CSR/sustainability report or publishes a section in its annual report on CSR/sustainability, and if the firm's CSR/sustainability report is published following the GRI guidelines, and zero otherwise	Refinitiv ESG
CSR_ext_audit	CSR Sustainability External Audit	A dummy variable equals one if the company has an external auditor of its sustainability report, and zero otherwise	Refinitiv ESG
Audit_com_Ind	Audit Committee Independence	Percentage of independent board members on the audit committee as stipulated by the company	Refinitiv ESG
QTobin	Tobin’s Q (firm value)	The ratio of the company’s market capitalization to the book value of the equity	Compustat
CashtoASSET	Cash-to-asset ratio	The book value of the firm’s total cash to the book value of total assets	Compustat
Size_Firm	Firm size	The logarithm of the book value of the total assets	Compustat
DebtRatio	Debt ratio	The ratio of the book value of the long-term debt to the book value of the total equity	Compustat
ROA	Return on assets (ROA)	The ratio of the earnings before interest and taxes (EBIT) to the book value of the total assets	Compustat

Source (s): Authors own work

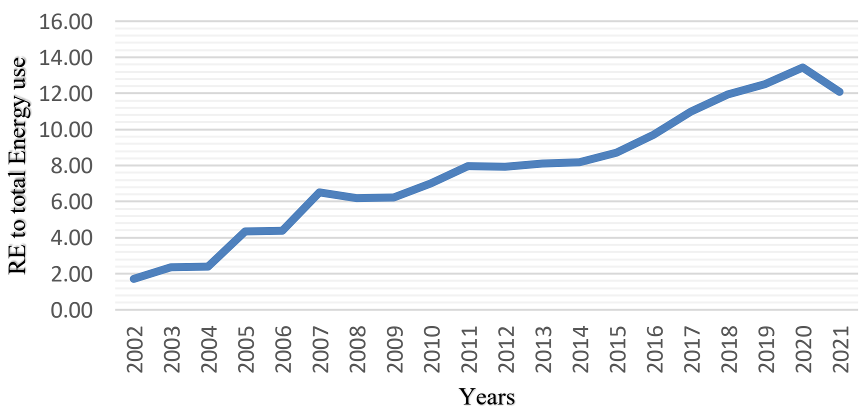
Table III-2.
Summary statistics

Variable	Obs	Median	Mean	Std. dev.	Min	Max
RE_Used	23,716	0	0.0969	0.2168	0	0.9999
CSR_committee	23,716	1	0.7545	0.4303	0	1
ESG_Comp	23,716	0	0.3096	0.4623	0	1
CEO_comp_Perf	23,716	0	0.3905	0.4878	0	1
Gender_diversity	23,537	0.5228	0.5239	0.3016	0.0703	1
Board_indep	23,715	0.7581	0.5289	0.3257	0.0661	0.8558
CEO duality	22,948	0	0.4710	0.3131	0	1
Board_size	23,673	2.3025	2.3274	0.3255	0	3.6636
Board_meeting	19,898	0.4182	0.4829	0.2429	0.0450	1
GRI_Transp	16,070	1	0.9706	0.1688	0	1
CSR_ext_audit	15,519	1	0.7215	0.4482	0	1
Audit_com_Ind	21,780	0.7072	0.5079	0.2722	0.0001	0.7165
Size_Firm	23,713	9.8649	10.3574	2.6440	2.6714	19.75
QTobin	23,545	1.6434	4.7387	31.7187	0.00001	962.23
DebtRatio	21,008	0.4386	0.9287	5.5063	0	421.73
ROA	23,548	0.0703	0.0795	0.0808	-1.9559	1.0277
CashtoASSET	23,460	0.0760	0.0999	0.0882	0	0.9447
Renew_Dummy	23,716	1	0.6503	0.4768	0	1
RE_Prod_Dummy	23,716	0	0.1918	0.3937	0	1
TotCO2toRevenus	21,257	0.5472	0.5286	0.1095	0	0.7003
Environmental rating	23,714	0.8513	0.7629	0.2085	0.0880	0.9748
Governance rating	23,715	0.5910	0.5429	0.3089	0.0105	0.9850

Note (s): This Table reports the mean, the median, the standard deviation, the minimum, and the maximum, for the sample firms. The sample includes all firm-year observations from 2002 to 2021. The entire sample firms are up to 3,896, with a maximum observation of up to 23,716. Accounting data are obtained from Compustat. All other data (RE use, corporate board, and corporate governance) are from Refinitiv ESG. ROA is the ratio of the earnings before interest and taxes (EBIT) to the book value of total assets. Tobin's Q is the ratio of the company's market capitalization to the book value of equity. The debt ratio is the ratio of the book value of long-term debt to the book value of total equity. CO_2 emission is the ratio of CO_2 emissions (expressed in tons) divided by the total revenues (sales).

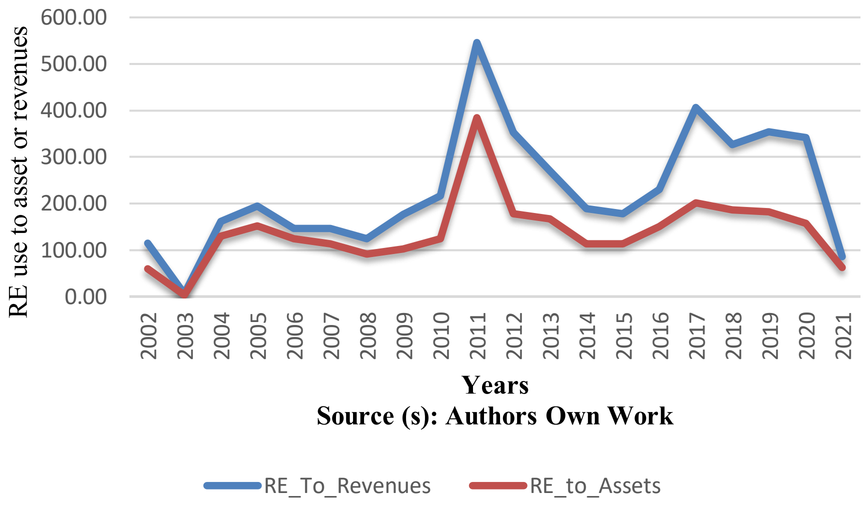
Source (s): Authors own work

Fig 1. Renewable Energy to Total Energy use (in %)



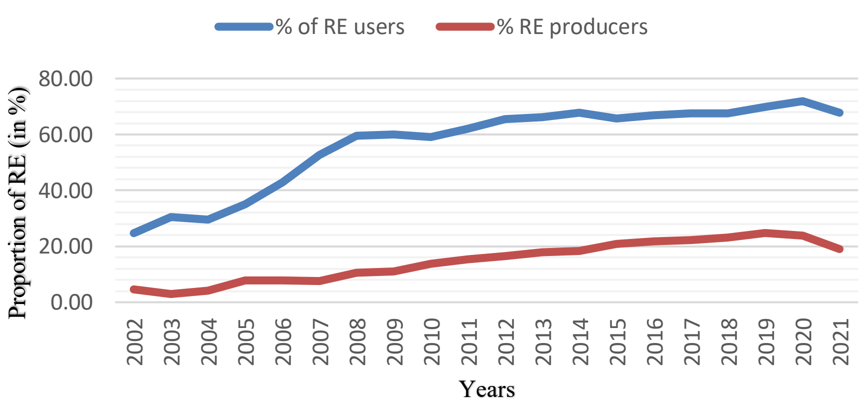
Source (s): Authors Own Work

Fig 2. Renewable consumption by year



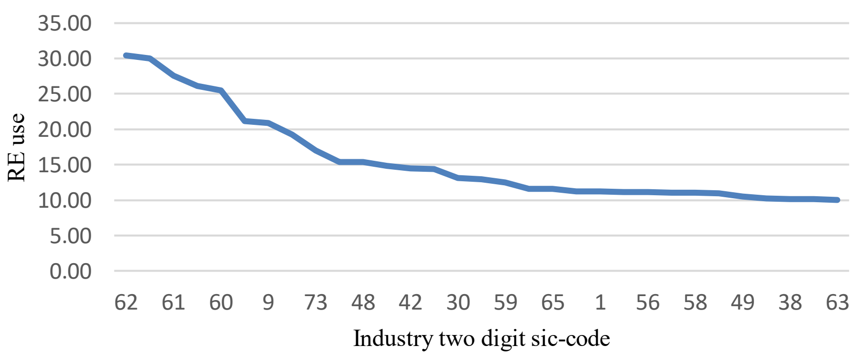
Source (s): Authors Own Work

Fig 3. Proportion of RE users and RE producers by year



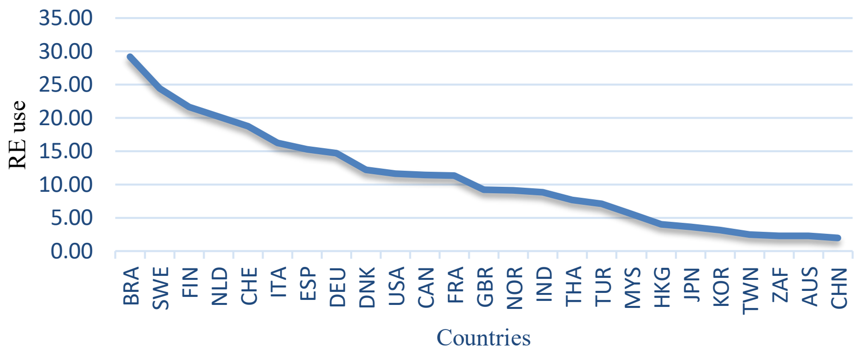
Sources (s): Authors Own Work

Fig 4. Renewable Energy to total Energy use by industry (%)



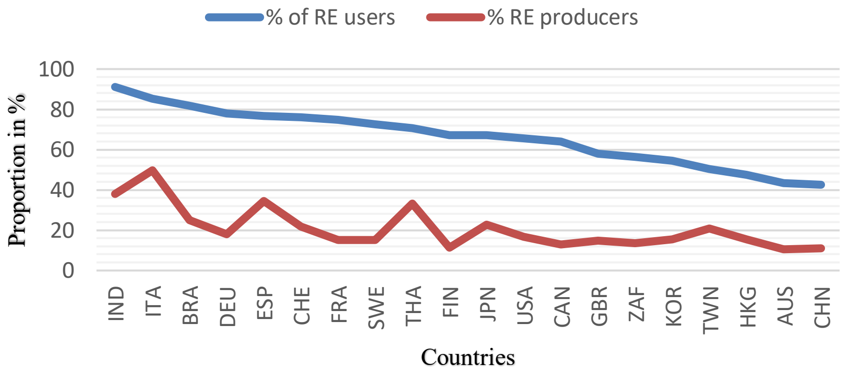
Source (s): Authors Own Work

Fig 5. Renewable Energy to total Energy use by country (in%)



Source (s): Authors Own Work

Fig 6. Proportion of RE users and RE producers by country



Source (s): Authors Own Work

6. Empirical results

In this section, we present our empirical results and the robustness tests.

6.1. Results of the baseline specification

We examine whether RE consumption in year *t* is influenced by the specific governance mechanism of year *t*, using several specifications. Table III-3 shows the results of the baseline regressions using the panel model with firm and year fixed effects. The regression in Column 1 includes all governance variables, while the regressions in Columns 2 to 9 include only one governance mechanism. The results suggest that, except audit committee independence (Audit_com_Ind), which is not significant in any model, all governance mechanisms examined affect (positively) RE consumption. Thus, our results provide empirical evidence for our hypotheses that well-governed firms tend to use more RE.

6.1.1. Board characteristics and RE consumption

To test the relationship between board characteristics and RE consumption, we start with model 1, which incorporates all governance variables. We also consider models 8 to 9, in which we replace governance variables with board gender diversity and board independence, respectively. To test H1.a, we combine model 1 with model 8. Table III-3 reports that female directors have a significantly positive impact on the use of RE (columns 1 and 8). These findings support H1.a. In model 1, the coefficient associated with Gender_diversity is 0.0290 and significant at 1% level (column 1), and in model 8, the estimate is 0.0204 and also significant at 1%. A one-percentage-point increase in the percentage of female directors leads to an increase in RE use of between 2.04 and 2.90 percentage points. These results support the findings of Atif *et al.* (2021) and Zhang *et al.* (2021).

We found a similar result for H1.b. As shown in model 1, board independence has a significantly positive effect on RE consumption (coefficient is 0.0269, and significant at 1% level). Model 9 also provides a similar result (coefficient is 0.0076, and significant at a 5% level). Indeed, all of the specifications suggest that board independence results in a tendency to use more RE. In model 1, a one-percentage-point increase in the percentage of strictly independent board members leads to an increase in RE consumption by 2.69 percentage points, while in model 9, it leads to an increase in RE consumption by 0.76 percentage points only. These findings confirm H1.b and support Atif *et al.* (2021) and Zhang *et al.* (2021) that firms with less independent boards tend to use less RE.

6.1.2. CSR/sustainability committee and RE consumption

To test the validity of H2, we consider models 1 and 2 reported in Table III-3. The first set is based on model 1 (column 1), where GOV (corporate governance) is a vector of all governance mechanisms we examined (board independence, board gender diversity, CSR committee, CEO compensation, audit committee independence, and so on). The second step is based on model 2, in which GOV corresponds to the CSR committee only (column 2). The results show that the existence of a CSR committee in the firm has a significantly positive impact (at the 1% level) on RE consumption across the two regressions, which supports hypothesis H2. The economic significance is also high. The existence of a sustainability committee in the firm leads to an increase in RE consumption of between 2.13 (model 1) and 2.77 (model 2) percentage points. Thus, there is consistent evidence that the CSR committee has a significantly positive impact on the use of RE by firms.

Table III-3.
Corporate governance mechanisms and RE consumption (fixed effects)

	Dependant variable: RE_Used (the ratio of RE divided by total energy use)								
Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CSR_committee	0.0213***	0.0277***							
	(2.82)	(14.80)							
ESG_Comp	0.0156***		0.0209***						
	(2.84)		(10.31)						
CEO_comp_Perf	0.0357***			0.0160***					
	(5.93)			(9.21)					
GRI_Transp	0.0222**				0.0350***				
	(2.01)				(4.43)				
CSR_ext_audit	0.0517***					0.0727***			
	(8.23)					(15.70)			
Audit_com_Ind	-0.0026						-0.0042		
	(-0.19)						(-0.84)		
Gender_diversity	0.0290***							0.0204***	
	(2.64)							(5.86)	
Board_indep	0.0269***								0.0076**
	(2.83)								(2.51)
Board_size	0.0155	-0.0023	-0018	-0.0031	-0.0008	0.0136	-0.0035	-0.0032	-0.0018
	(1.34)	(-0.60)	(-0.46)	(-0.80)	(-0.09)	(1.54)	(-0.88)	(-0.83)	(-0.48)
Board_meeting	0.0147	-0.0001	-0.0006	-0.0006	0.0123	0.0159*	0.0002	-0.0002	-0.0001
	(1.26)	(-0.03)	(-0.17)	(-0.17)	(1.32)	(1.82)	(0.04)	(-0.07)	(-0.03)
Size_Firm	0.0524***	0.0343***	0.0374***	0.0367***	0.0671***	0.0624***	0.0392***	0.0381***	0.0389***
	(11.52)	(25.46)	(28.25)	(27.39)	(17.98)	(18.38)	(29.33)	(28.89)	(29.43)
QTobin*100	0.05**	0.02***	0.02***	0.0152***	0.0462***	0.0454***	0.0162***	0.0159***	0.0162***
	(2.46)	(3.78)	(3.90)	(3.85)	(3.66)	(3.52)	(4.04)	(4.01)	(4.08)
DebtRatio*100	-0.08	-0.01	-0.004	-0.0047	-0.0266	-0.0227	-0.005	-0.0051	-0.0049
	(-0.81)	(-1.00)	(-0.96)	(-1.04)	(-0.66)	(-0.58)	(-1.08)	(-1.13)	(-1.09)
ROA	-0.0074	-0.026***	-0.028***	-0.029***	-0.0369	-0.0183	-0.030***	-0.030***	-0.031***
	(-0.22)	(-4.39)	(-4.79)	(-4.98)	(-1.40)	(-0.72)	(-4.92)	(-5.17)	(-5.30)
CashtoASSET	0.0236	0.0141*	0.0167**	0.0159**	0.0281	0.0483*	0.0185**	0.0170**	0.0165**
	(0.69)	(1.75)	(2.04)	(1.97)	(1.02)	(1.89)	(2.21)	(2.10)	(2.03)
Constant	-0.622***	-0.274***	-0.295***	-0.287***	-0.636***	-0.635***	-0.294***	-0.303***	-0.309***
	(-11.33)	(-20.18)	(-21.87)	(-21.16)	(-14.74)	(-16.56)	(-21.07)	(-22.52)	(-22.84)
Firm effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	10,906	17,471	17,471	17,471	12,165	11,022	16,418	17,471	17,471
Firms	2,333	3,512	3,512	3,512	2,534	2,266	3,301	3,512	3,512
Adj. R-sq	0.1514	0.1313	0.1284	0.1278	0.132	0.1681	0.1249	0.125	0.125

Note (s): Table III-3 presents the results of the relationship between corporate governance mechanisms and RE consumption using a panel model with fixed effects. The dependent variable is RE consumption, proxied by the ratio of RE divided by total energy use. The coefficients appear first, and the z statistics are in parentheses. In the regression of column 1, we use all governance mechanisms (board independence, board gender diversity, CSR committee, CEO compensation, audit committee independence, etc.), while in the regressions of columns 2 to 9, we use only one governance mechanism. All regressions include constant, firm, and year fixed effects. The sample includes all firm-year observations from 2002–2021. The symbols ∗, ∗∗, and ∗∗∗ indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels. R^2 are in decimals (not in percentage).

Source (s): Authors own work

6.1.3. CEO compensation and RE consumption

We test the relationship between CEO compensation policies and RE consumption using models 1, 3, and 4 (Table III-3). All of these specifications suggest that the two types of CEO compensation policies we examined have a significantly positive impact on the use of RE. In model 1 (column 1), where GOV includes all internal governance mechanisms, ESG performance-based compensation policy (ESG_Comp) is positively and significantly associated with RE consumption (the coefficient is 0.0156, at 1% level). Financial performance-based compensation policy (CEO_comp_Perf) is also positive and significant at a 1% level (coefficient is 0.0357). In model 3, GOV corresponds to ESG performance-based compensation policy only (column 3), and in model 4, GOV corresponds to financial performance-based compensation policy only (column 4). Both ESG performance-related compensation (coefficient is 0.0209, at a 1% level) and financial performance-based compensation policy (coefficient is 0.0160, at a 1% level) have a significantly positive impact on the use of RE. These findings support H3a, and H3b.

The estimates are also economically significant. In model 1, when CEO compensation is linked to the firm's ESG performance, RE consumption increases by 1.56 percentage points; when CEO compensation is tied to financial performance, RE consumption increases by 3.57 percentage points. Although ESG performance-based compensation positively affects RE consumption in model 1, the impact is less than that of model 3. In model 3, as GOV includes only ESG-related compensation, the increase of RE use by 2.09 percentage points is associated with ESG performance-based compensation. The effect of ESG-related compensation is more pronounced in the absence of other governance mechanisms, possibly due to these mechanisms' potential impact on RE use. Contrariwise, in the presence of other governance mechanisms, the positive effect of financial performance-based compensation policy on RE use is more pronounced. Although CEO compensation linked to financial performance positively affects RE usage in model 4, the impact is lower than that of model 1. In model 4, when GOV includes only the financial performance-based compensation policy, RE use increases significantly by 1.60 percentage points compared to 3.57 in model 1. This difference is possible since, in the absence of other governance mechanisms, CEOs tend to make more trade-offs between financial and ESG performance to choose RE consumption that optimizes their compensation. Also, the presence of other governance mechanisms may positively impact the firm's returns and limit financial performance concerns for managers who can then consider ESG performance as a source of profitability.

6.1.4. Other internal governance mechanisms and RE consumption

We complete our analysis by examining other internal governance mechanisms on RE consumption. The results show that these mechanisms are also crucial for the company's environmental strategy. The variables studied are transparency (adoption of GRI Report Guidelines), CSR/sustainability external audit (CSR_ext_audit), and audit committee independence (Audit_com_Ind). The adoption of GRI Report Guidelines is widely used as a proxy for transparency since, following the GRI framework, firms must report positive and negative information regarding their operations (Hussain *et al.*, 2018). Table III-3 presents the estimates from the regressions. In models 1 and 5, the adoption of GRI Report Guidelines (GRI_Transp) has a positive impact on RE use. On average, firms that publish a sustainability report following the GRI guidelines use 2.22% to 3.50% RE more than firms that do not publish sustainability reports (model 1 and model 5). The CSR/sustainability external audit also has a significantly positive impact on RE consumption. Having an external auditor of the firm's sustainability reports increases RE use by between 5.17 and 7.27 percentage points (model 1 and model 6). Finally, the audit committee independence has no significant impact on RE use (models 1 and 7). The percentage of independent board members on the audit committee does not affect RE use.

6.2. Robustness tests

This section tests the robustness of our results. First, we estimated the model using the lagged values of the explanatory variables instead of contemporary ones, following the literature (Jo and Harjoto, 2012; Atif *et al.*, 2021). Second, we employed logit regressions using an alternative measure of RE consumption. Finally, we exclude the dummy explanatory variables from the model and perform a system GMM. Overall, the findings confirm the positive effect of good governance on RE use.

6.2.1. Lagged explanatory variables

We consider another specification of our baseline estimation method, using one-year lagged explanatory variables instead of the contemporary ones. This specification is based on the argument that corporate governance can affect firm decisions, including RE use with lag (Jo and Harjoto, 2012; Atif *et al.*, 2021; Opoku *et al.*, 2021). Using lagged variables mitigates the endogeneity concerns in all the regressions (e.g., simultaneity effects), as the governance mechanisms require time to influence corporate policies, including RE consumption (Jo and Harjoto, 2012; Atif *et al.*, 2021). With this new specification, we estimate the same panel data model with fixed effects, using the share of RE to total energy as the dependent variable.

Table III-4 reports the estimates from the regressions using the fixed effects to examine whether RE consumption in period t is influenced by the firm's specific governance mechanism of period $t-1$. The results summarized in models 1 to 9 confirm our previous findings. As in the baseline model, the lagged audit committee independence has no significant impact on RE consumption (columns 1 and 7). On the other hand, the lag of other governance variables (sustainability committee, ESG performance-based compensation, financial performance-based compensation policy, transparency, CSR/sustainability external audit, gender diversity) has a significantly positive impact on RE consumption (columns 1 to 6 and column 8). The only exception is that the lag of board independence has no significant effect on RE use (columns 9), in contrast with the previous results in Table III-3. Indeed, while the lagged board independence has no impact on RE use, its contemporaneous values have a significantly positive effect.

Table III-4.
Robustness tests using a panel model with fixed effects and the lagged explanatory variables

	Dependant variable: RE_Used (the ratio of RE divided by total energy use)								
Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CSR_committee	0.0226***	0.0264***							
	(2.71)	(12.15)							
ESG_Comp	0.0196***		0.0218***						
	(3.23)		(9.51)						
CEO_comp_Perf	0.0220***			0.0153***					
	(3.24)			(7.73)					
GRI_Transp	0.0343***				0.0402***				
	(2.98)				(4.82)				
CSR_ext_audit	0.0416***					0.0709***			
	(6.16)					(14.23)			
Audit_com_Ind	0.0049						-0.0043		
	(0.33)						(-0.77)		
Gender_diversity	0.0355***							0.0228***	
	(2.86)							(5.75)	
Board_indep	0.0116								0.0021
	(1.13)								(0.63)
Board_size	0.0128	0.0004	0.0008	-0.0002	-0.0001	0.0105	0.0009	-0.0004	0.0011
	(1.00)	(0.10)	(0.18)	(-0.06)	(-0.02)	(1.07)	(0.20)	(-0.10)	(0.26)
Board_meeting	0.0033	0.0022	0.0016	0.0019	0.0069	0.0141	0.0016	0.0018	0.0018
	(0.25)	(0.54)	(0.39)	(0.47)	(0.65)	(1.45)	(0.37)	(0.44)	(0.44)
Size_Firm	0.0462***	0.0360***	0.0383***	0.038***	0.0577***	0.0572***	0.0404***	0.039***	0.040***
	(9.01)	(23.33)	(25.33)	(24.88)	(13.87)	(15.48)	(26.41)	(25.76)	(26.41)
QTobin*100	0.03	0.01**	0.013**	0.013**	0.04**	0.03*	0.013**	0.013**	0.014**
	(1.26)	(2.21)	(2.33)	(2.33)	(2.17)	(1.84)	(2.43)	(2.39)	(2.48)
DebtRatio*100	-0.10	-0.008	-0.01	-0.01	-0.09	-0.039	-0.010	-0.009	-0.01
	(-0.93)	(-0.54)	(-0.68)	(-0.64)	(-1.33)	(-0.93)	(-0.66)	(-0.62)	(-0.66)
ROA	0.060	-0.0164**	-0.017**	-0.018**	0.0470	0.046	-0.018**	-0.019***	-0.02***
	(1.48)	(-2.26)	(-2.36)	(-2.58)	(1.44)	(1.52)	(-2.33)	(-2.67)	(-2.80)
CashtoASSET	-0.0404	-0.0030	-0.0015	-0.0009	-0.0372	0.0017	0.0003	-0.0027	-0.0029
	(-1.05)	(-0.32)	(-0.16)	(-0.10)	(-1.20)	(0.06)	(0.03)	(-0.29)	(-0.31)
Constant	-0.482***	-0.291***	-0.306***	-0.305***	-0.542***	-0.546***	-0.311***	-0.317***	-0.319***
	(-8.76)	(-20.83)	(-22.09)	(-21.88)	(-12.35)	(-14.33)	(-21.81)	(-22.93)	(-22.85)
Firms effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	7,551	13,845	13,845	13,845	9,785	8,937	13,138	13,832	13,845
Firms	1,700	2,917	2,917	2,917	2,127	1,928	2,787	2,917	2,917
Adj. R-sq	0.1375	0.1293	0.1275	0.1265	0.1244	0.1578	0.1242	0.125	0.1241

Note (s): Table III-4 presents the results of the robustness tests using a panel model with fixed effects and the lagged explanatory variables (lag 1). The dependent variable is RE consumption, measured by the ratio of RE divided by total energy use. The coefficients appear first, and the z statistics are in parentheses. In the regression of column 1, we use a vector of all corporate governance mechanisms (board independence, board gender diversity, CSR committee, CEO compensation, audit committee independence, and so on), while in the regressions of columns 2 to 9, we use only one governance mechanism. All regressions include constant, firm, and year fixed effects. The sample includes all firm-year observations from 2002–2021. The symbols *, **, and *** indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels. R^2 are in decimals (not in percentage).

Source (s): Authors own work

Table III-5.
Robustness tests using logit regression

Dependant variable: Renew_Dummy (renewable energy consumption dummy)									
Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CSR_committee	0.4020***	1.671***							
	(5.82)	(67.48)							
ESG_Comp	0.0946*		0.751***						
	(1.81)		(30.70)						
CEO_comp_Perf	0.2860***			0.5118***					
	(5.05)			(21.39)					
GRI_Transp	1.2290***				1.3277***				
	(12.14)				(16.44)				
CSR_ext_audit	0.5364***					1.234***			
	(10.09)					(30.68)			
Audit_com_Ind	-0.724***						-0.400***		
	(-6.10)						(-7.63)		
Gender_diversity	0.5686***							1.603***	
	(6.10)							(38.10)	
Board_indep	0.3106***								0.4794***
	(2.80)								(10.67)
Board_size	0.6244	0.9028***	1.146***	1.1447***	0.9312***	0.6601***	1.220***	0.9192***	1.2125***
	(7.61)	(21.16)	(27.93)	(27.96)	(14.76)	(10.00)	(28.51)	(21.98)	(29.62)
Board_meeting	-0.261***	-0.123**	-0.129***	-0.101**	0.0837	-0.1323	-0.0415	-0.114**	-0.0432
	(-2.55)	(-2.41)	(-2.66)	(-2.09)	(1.03)	(-1.61)	(-0.83)	(-2.33)	(-0.90)
Size_Firm	0.139***	0.235***	0.3438***	0.356***	0.1317***	0.1496***	0.337***	0.368***	0.341***
	(11.93)	(45.08)	(67.85)	(67.76)	(16.20)	(16.84)	(62.12)	(70.43)	(63.85)
QTobin	0.0021	0.0018**	0.0028***	0.0028***	0.0034**	0.0020	0.0027***	0.0025***	0.0025***
	(1.45)	(2.58)	(4.04)	(4.06)	(2.13)	(1.46)	(4.02)	(3.87)	(3.87)
DebtRatio	0.0079	-0.0004	-0.0011	-0.0011	0.0041	0.0073	-0.0009	-0.001	-0.0009
	(0.72)	(-0.37)	(-0.83)	(-0.83)	(0.82)	(1.17)	(-0.82)	(-1.03)	(-0.78)
ROA	1.097***	1.626***	1.814***	1.822***	1.796***	0.5219**	1.881***	1.418***	1.819***
	(3.72)	(13.33)	(15.50)	(15.52)	(7.57)	(2.26)	(15.90)	(12.19)	(15.75)
CashtoASSET	0.2451	-1.202***	-1.186***	-1.19***	-0.967***	-0.249	-1.35***	-0.997***	-1.397***
	(0.86)	(-10.53)	(-11.05)	(-11.14)	(-4.78)	(-1.18)	(-12.04)	(-9.24)	(-12.97)
Industry	-0.0004	-0.005***	-0.009***	-0.011***	-0.0014	-0.004***	-0.011***	-0.013***	-0.011***
	(-0.40)	(-9.67)	(-17.86)	(-20.81)	(-1.51)	(-4.34)	(-20.37)	(-23.97)	(-20.93)
Country	-0.007***	-0.007***	-0.009***	-0.012***	-0.006***	-0.009***	-0.009***	-0.011***	-0.012***
	(-7.36)	(-18.54)	(-25.22)	(-30.53)	(-9.06)	(-13.53)	(-23.83)	(-29.90)	(-28.96)
Constant	-2.023***	-2.896***	-2.88***	-2.86***	-1.44***	-0.921***	-2.23***	-3.559***	-2.682***
	(-10.35)	(-45.60)	(-46.41)	(-44.93)	(-11.77)	(-8.56)	(-32.38)	(-52.38)	(-39.39)
Obs.	10,906	17,471	17,471	17,471	12,165	11,022	16,418	17,471	17,471
Firms	2,333	3,512	3,512	3,512	2,534	2,266	3,301	3,512	3,512
Pseudo R2	0.0879	0.2382	0.1704	0.1621	0.0529	0.1288	0.1586	0.1813	0.1563

Note (s): Table III-5 presents the results of the relationship between corporate governance mechanisms and RE consumption, using the logit regression. The dependent variable is the RE consumption dummy, equal to one for a firm using RE in year t, and zero otherwise. The coefficients appear first, and the z statistics are in parentheses. In the regression of column 1, we use a vector of all corporate governance mechanisms (board independence, board gender diversity, CSR committee, CEO compensation, audit committee independence, and so on), while in the regressions of columns 2 to 9, we use only one governance mechanism. We control for the firm industry two-digit SIC codes and country of location. All regressions include a constant. The sample includes all firm-year observations from 2002–2021. The symbols ∗, ∗∗, and ∗∗∗ indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels. Pseudo R^2 are in decimals.

Source (s): Authors own work

6.2.2. Logit model using RE consumption dummy

Since the proportion of RE consumption to total energy use can neither be negative nor above 100%, a nonlinear relationship between this dependent variable and the explanatory variables is probable (Opoku *et al.*, 2021). To consider this possibility, we test the robustness of our results using a logit model and an alternative measure of RE consumption. Zhang *et al.* (2021) argue that the choice of using RE is more important than the actual values used by a firm since the first step is always the hardest. Therefore, to represent this choice, we employ a dummy variable that equals one for the firm using RE in year *t*, and zero otherwise. We control for the firm industry two-digit SIC codes and country of location. Including country-of-location effects allows accounting for potential differences in country-level policies toward green energy across the world. Table III-5 reports the results. Except for audit committee independence, our results confirm that corporate governance mechanisms positively affect the choice to use RE. Indeed, board gender diversity, board independence, CSR/sustainability committee, ESG-based compensation, CEO compensation linked to financial performance, adoption of GRI Report Guidelines, and CSR sustainability external audit, result in a higher probability of using RE. In contrast, audit committee independence results in a significantly lower probability of using RE (columns 1 and 7). Therefore, most of our findings are robust to this new specification.

6.2.3. Identification strategy and the system GMM estimation

The relationship between corporate governance and RE consumption faces concerns about the potential endogeneity of corporate governance mechanisms (O'Connor and Rafferty, 2012; Jo and Harjoto, 2012). In this section, we employ the dynamic system GMM to address the endogeneity concerns. The system GMM simultaneously estimates the equation in both differences and levels. This approach uses all the available information in the dataset, so is more efficient than other GMM estimators (Blundell and Bond, 1998). Our reference model to capture the impact of corporate governance on RE consumption can be rewritten in the general form as follows:

$$(III-2a): \qquad Y_{i,t} = \alpha_0 + \beta X_{i,t} + \varepsilon_{i,t}$$

where the dependent variable $Y_{i,t}$ is the share of RE used, $X_{i,t}$ is a vector of explanatory variables (including corporate governance mechanisms, and the control variables). Since the system GMM estimators are designed for panel analysis with some endogenous regressors, and the dynamic process with current realizations of the dependent variable influenced by the past ones (Roodman, 2009), the general model of the data-generating process (III-2a) is like:

$$(III-2b): \qquad Y_{i,t} = \alpha Y_{i,t-1} + \beta X_{i,t} + \varepsilon_{i,t}$$

which can be rewritten as: $(III-2c)$: $\quad \Delta Y_{i,t} = (\alpha-1)Y_{i,t-1} + \beta X_{i,t} + \varepsilon_{i,t}$

$$with \qquad \varepsilon_{i,t} = \mu_i + v_{i,t} \qquad , \qquad E(\mu_i) = E(v_{i,t}) = E(\mu_i v_{i,t}) = 0$$

So, the model can be considered equally as for the level or increase of Y (Roodman, 2009). The disturbance term has two orthogonal components: the fixed effects μ_i, and the idiosyncratic shocks, $v_{i,t}$. The first-difference transform gives its name "difference GMM". The general form is as follows:

$$(III-2d): \qquad \Delta Y_{i,t} = \alpha \Delta Y_{i,t-1} + \beta \Delta X_{i,t} + \Delta v_{i,t}$$

The final step is to estimate equations (III-2b) and (III-2d) simultaneously (Blundell and Bond, 1998). By doing this, we obtain a system comprising both equations in levels and first differences. The system GMM is expressed as follows:

$$(III-3): \qquad \begin{cases} Y_{i,t} = \alpha Y_{i,t-1} + \beta X_{i,t} + \varepsilon_{i,t} \\ \Delta Y_{i,t} = \alpha \Delta Y_{i,t-1} + \beta \Delta X_{i,t} + \Delta v_{i,t} \end{cases}$$

The first difference in the regression equation (III-2d) eliminates any possible bias that may result from the fixed effects but the lagged dependent variable is still potentially endogenous, because the $Y_{i,t-1}$ term in $\Delta Y_{i,t-1} = Y_{i,t-1} - Y_{i,t-2}$ is correlated with the $v_{i,t-1}$ in $\Delta v_{i,t} = v_{i,t} - v_{i,t-1}$ (Arellano and Bond, 1991). Likewise, any predetermined variables in X that are not strictly exogenous become potentially endogenous because they, too, may be related to $v_{i,t-1}$ (Roodman, 2009). The system GMM estimation technique relies on the "internal" instruments based on lags of the instrumented variables. Arellano and Bond (1991) propose to use the lagged values of the explanatory variables as instruments in the regression equation since the lags of the regressors are orthogonal to the error and available as instruments. As documented by Roodman (2009), instrumenting with $Y_{i,t-2}$ seems preferable for maximizing sample size in both the levels and the difference estimator. In the differenced case, $Y_{i,t-2}$ is mathematically related to $\Delta Y_{i,t-1} = Y_{i,t-1} - Y_{i,t-2}$ but not to the error term $\Delta v_{i,t} = v_{i,t} - v_{i,t-1}$.

To estimate the system GMM, we follow the literature (O'Connor and Rafferty, 2012; Opoku et al., 2021; Roodman, 2009) and use the lags 1 and 2 of RE to total energy use ratio as instruments of the dependent variable. For the explanatory variables, we use lags 1 to 4 as instruments. We test the validity of the instruments using the Hansen (1982) test for overidentifying, and the Arellano-Bond (1991) serial correlation test. As mentioned by Roodman (2009), the first-difference transform has a weakness. For instance, the system GMM cannot be used with dummy variables, which could disappear in the difference GMM: any dummy that is 0 or 1 for almost all individuals might cause bias since the Arellano-Bond instruments for these variables are set to zero (Roodman, 2009). To circumvent this problem, we exclude all dummy variables from the model and use only non-dummy variables. Next, we employ Refinitiv ESG corporate governance rating as a measure of firm internal governance in place of individual governance mechanisms. The governance score from Refinitiv covers nearly 100 items grouped into three categories: CSR strategy, management, and shareholders' concerns. Refinitiv corporate governance ratings cover the agency problem and corporate social responsibility concerns, and are available for all years, since 2022.

Table III-6.
The System GMM estimation

Dependant variable: RE_Used (the ratio of RE divided by total energy use)					
Parameter	(1)	(2)	(3)	(4)	(5)
L1. RE_Used	0.3242***	0.3498***	0.3447***	0.3747***	0.4179***
	(13.65)	(14.25)	(14.39)	(15.23)	(17.94)
Corpgov_score					0.0490***
					(6.52)
Audit_com_Ind	-0.0285**	-0.0214**			
	(-2.01)	(-2.16)	-	-	-
Gender_diversity	0.0475***		0.0518***		
	(5.25)	-	(6.07)	-	-
Board_indep	0.0119*			0.0146**	
	(1.92)	-	-	(2.58)	-
Board_size	0.0215***	0.0286***	0.0170**	0.0278***	
	(2.61)	(3.59)	(2.13)	(3.59)	-
Board_meeting	0.0053	0.0196	0.0069	0.0104	
	(0.40)	(1.54)	(0.63)	(0.96)	-
Size_Firm	0.0050***	0.0032***	0.0041***	0.0024***	0.0048***
	(4.51)	(3.25)	(4.16)	(2.79)	(6.65)
QTobin*100	0.0168	0.0157	0.0162	0.0201	0.0032*
	(1.13)	(1.22)	(1.07)	(1.58)	(1.75)
DebtRatio*100	-0.0339	-0.0376	-0.0421	-0.0169	0.0042
	(-0.84)	(-1.09)	(-1.05)	(-0.52)	(0.09)
ROA	0.0059	0.0248	-0.0015	0.0202	0.0012
	(0.34)	(1.39)	(-0.09)	(1.18)	(0.09)
CashtoASSET	0.0483**	0.0153	0.0371**	0.0048	0.0133
	(2.39)	(0.80)	(2.00)	(0.29)	(0.97)
Arellano-Bond test for AR2	-1.55	-1.48	-1.38	-1.26	-0.63
	(0.122)	(0.139)	(0.167)	(0.207)	(0.530)
Hansen overidentification test	244.65***	231.34***	243.41***	235.37***	291.15***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Nb. Obs	5392	5426	5818	5828	8014
Firms	1253	1264	1311	1313	1654

Table III-6 presents the robustness test using the system GMM. The dependent variable is RE consumption, measured by the ratio of RE divided by total energy use. L1 indicates the first lag of the variable. The coefficients appear first, and the z statistics are in parentheses. In the regression of column 1, we use the vector of all governance mechanisms, except corporate governance score, while in the regressions of columns 2 to 5, we use only one governance mechanism. Regression in column 5 uses only the Refinitiv corporate governance rating. All regressions include a constant and the time effects. The sample includes all firm-year observations from 2002–2021. Corporate governance ratings are in decimal and obtained from the Refinitiv ESG database. We use the lags 1 to 2 of the dependent variables and the lags 1 to 4 of the explanatory variables, as instruments. We report the Arellano-Bond (1991) test statistics for AR(2), and the Hansen overidentification Chi 2 statistic test (p-values are in parentheses). The symbols *, **, and *** indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels.

Source (s): Authors own work

Table III-6 presents the results of the robustness test using the system GMM. In general, our results remain robust. In column 5, Refinitv corporate governance rating (corpgov_score) significantly impacts RE use. A one-percentage-point increase in the percentage of corporate governance rating leads to an increase in RE consumption of 4.90 percentage points. Except for audit committee independence, which again has a significantly negative impact on RE consumption as in the logit model, our results from the system GMM estimations show the positive relationship between corporate governance mechanisms and RE use. These findings support the argument that stronger governance enhances corporate environmental protection initiatives.

7. Further analysis

In the previous sections, we show that corporate governance mechanisms positively impact RE consumption. This section examines the interaction between RE consumption and the decision to produce RE. It also examines the relationship between RE use and firm environmental performance, as well as the impact of RE use on the firm financial performance. The energy transition is possible only if the adoption of RE does not negatively affect the firm financial performance.

7.1. Interaction between RE consumption and RE production

The previous studies are limited to RE consumption (Atif *et al.*, 2021; Zhang *et al.*, 2021). However, Atif *et al.* (2021) highlight the importance of considering RE production and recommend to identify whether firms that use RE produce part or all of that energy themselves. Their recommendation may help better understand if energy transition requires appropriate governance mechanisms. Indeed, in this section, we examine whether there is interdependence between the decision to use and the decision to produce RE. Specifically, we explore whether firms with appropriate governance mechanisms are more likely to produce and use RE than others. As RE use depends on its availability, one can argue that firms may consume more RE if they produce themselves. Then, the decision to use RE may depend on RE production. The two decisions are dummy variables as the firms can decide to use (produce) or not RE. The general model is as follows:

$$(III-4): \qquad \text{RE\_used}_{i,t} = \alpha + \beta \text{RE\_product}_{it} + \gamma X_{i,t} + \varepsilon_{it}$$

where, the dependent variable RE_used (the decision to use RE) is a dummy variable that takes the value of 1 if the firm i uses RE in year t, and 0 otherwise. RE_product (the decision to produce RE) is a dummy variable that equals 1 if the firm i produces RE in the year t, and 0 otherwise. X is a vector of control variables.

However, this specification suffers from endogeneity. For instance, some firms may decide to use RE because they produce themselves. Alternatively, others may choose to produce RE because they decide to use it too. On the other hand, other variables, such as corporate governance mechanisms, and unobservables that are difficult to take into account, can affect both the decision to produce and the decision to use RE. The two decisions are potentially interrelated. In addition, the model has the particularity to incorporate two endogenous dummy variables: a dummy dependent variable (RE use), and a dummy explanatory variable (RE production). Thus, employing a regular probit/logit or the instrumental variable probit approach is not appropriate. The bivariate probit model is recommended (Greene, 1996; Holm and Arendt, 2013). The model can be rewritten as follows:

$$(III-5): \quad \begin{cases} \text{RE\_used}^*_{it} = \gamma_1 X_{i,t} + \varepsilon_{1it} \\ \text{RE\_product}^*_{it} = \gamma_2 X_{i,t} + \varepsilon_{2it} \end{cases}$$

where, RE_usedt*, and RE_product* are latent variables. The random error terms ε between the two equations follow a bivariate normal distribution and are assumed to be correlated (with correlation ρ). Unobserved latent variables determine the two outcomes. The observed binary outcomes are:

$$(III-6): \text{RE\_used}_{i,t} = \begin{cases} 1 \; if \; \text{RE\_used}^*_{it} > 0 \\ 0, otherwise \end{cases} \quad and, \quad \text{RE\_product}_{it} = \begin{cases} 1 \; if \; \text{RE\_product}^*_{it} > 0 \\ 0, otherwise \end{cases}$$

The bivariate probit model applies when the decisions are binary and correlated. So, it is assumed that there are some correlations between the decisions of RE consumption and RE production. Since the decisions to be explained are correlated, this correlation will influence the choice of managers. The correlation between the two dependent variables is tested under the null hypothesis H0: ρ = 0. Thus, a bivariate probit is more relevant and accurate than two regular probit models.

Table III-7 reports the results. We control for industry and country-of-location effects. We present both the bivariate probit results and the regular probit results, for comparison. The bivariate probit model estimation (columns 1 and 2) shows that firms with appropriate governance mechanisms have a significantly higher probability of producing, and a higher likelihood of using RE than other firms. Except for board meetings, the coefficient associated with each governance mechanism is positive and significant at 1% or 5% for both RE use and RE production. Board gender diversity, board independence, sustainability committee, ESG performance-based compensation, and financial performance-based compensation, are associated with a higher probability of producing and a higher probability of using RE. The regular probit estimates (columns 3, and 4) show the same patterns (while these results are less reliable). In addition, column 3 reports a significantly positive relationship between the decision to produce RE (RE_Prod_Dummy) and the decision to use RE (RE_used_Dummy). RE producers have a higher probability of using RE than other firms.

Table III-7.
Interaction between RE use and RE production (bivariate probit)

	Bivariate Probit regression		Probit regression		Recursive Bivariate Probit	
	RE_used_Dummy (1)	RE_Prod_Dummy (2)	RE_used_Dummy (3)	RE_Prod_Dummy (4)	RE_used_Dummy (5)	RE_Prod_Dummy (6)
RE_Prod_Dummy	-	-	1.2933***	-	2.1189***	-
			(44.53)		(66.60)	
CSR_committee	0.9184***	0.6492***	0.8540***	0.6389***	0.1815***	0.0862*
	(60.68)	(29.16)	(55.11)	(28.55)	(4.88)	(1.86)
ESG_Comp	0.2081***	0.2729***	0.1664***	0.2616***	-0.0654**	0.1872***
	(12.78)	(13.09)	(9.90)	(12.37)	(-2.49)	(6.16)
CEO_comp_Perf	0.0796***	0.0509**	0.0768***	0.0475**	0.0457	0.0736**
	(4.85)	(2.25)	(4.56)	(2.07)	(1.60)	(2.22)
Gender_diversity	0.6754***	0.3739***	0.6534***	0.3610***	0.3683***	-0.1603***
	(25.09)	(10.31)	(23.65)	(9.90)	(7.82)	(-2.97)
Board_indep	0.0648***	0.1126***	0.0484**	0.1182***	0.0063	-0.0165
	(2.99)	(3.96)	(2.17)	(4.11)	(0.17)	(-0.40)
GRI_Transp	-	-	-	-	-	0.6117***
						(8.08)
CSR_ext_audit	-	-	-	-	-	0.3290***
						(11.33)
Audit_com_Ind	-	-	-	-	-	-0.3043***
						(-6.32)
CEO_Duality	-	-	-	-	-	0.0289
						(0.48)
Board_size	0.3323***	0.2796***	0.2924***	0.2923***	0.0510	0.3101***
	(13.32)	(8.85)	(11.36)	(9.12)	(1.24)	(6.67)
Board_meeting	-0.0723**	0.0692*	-0.0980***	0.0707*	-0.1166**	0.0829
	(-2.40)	(1.77)	(-3.16)	(1.80)	(-2.29)	(1.43)
Size_Firm	0.1380***	0.1106***	0.1249***	0.1074***	0.0185***	0.0313***
	(38.70)	(24.94)	(33.81)	(24.16)	(3.26)	(4.86)
QTobin*100	0.1198***	0.1193**	0.0917*	0.1339***	-0.0362	0.1262**
	(2.92)	(2.60)	(2.15)	(2.98)	(-0.65)	(2.33)
DebtRatio*100	-0.1112	-0.1272	-0.084	-0.1238	0.0350	-0.0684
	(-1.04)	(-0.77)	(-0.84)	(-0.78)	(0.08)	(-0.16)
ROA	0.7612***	-0.1973**	0.8245***	-0.1275	0.6564***	-0.4628***
	(11.27)	(-2.03)	(11.98)	(-1.36)	(4.51)	(-2.88)
CashtoASSET	-0.2498***	-0.7569***	-0.1808**	-0.5589***	0.5981***	-0.4686***
	(-3.73)	(-7.28)	(-2.66)	(-5.58)	(4.04)	(-2.81)
Industry effects	Yes	Yes	Yes	Yes	Yes	Yes
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Rho (ρ)	0.5947*** (LR test of rho=0: chi2(1) = 2578.17)		-	-	-0.99*** (LR test of rho=0: chi2(1) = 211.012)	
Wald chi2 (LR for probit)	12842.56***		16775.98***	4417.38***	4942.51	
Nb. Obs	17,413				10,900	

Note (s): Table III-7 presents the results of the bivariate probit estimations in columns (1) and (2). The results of the regular probit are in columns (3) and (4). The first dependent variable is the RE consumption dummy (RE_used_Dummy), which is equal to 1 if the firm uses RE in year t, and 0 otherwise. The second dependent variable is the RE production dummy (RE_Prod_Dummy), which is equal to 1 if the firm produces RE in the year t, and 0 otherwise. The coefficients appear first, and the z statistics (LR test for Rho) are in parentheses. In the regressions, we employ all corporate governance mechanisms. The sample includes all firm-year observations from 2002–2021. The symbols ∗, ∗∗, and ∗∗∗ indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels.

Source (s): Authors own work

From the bivariate probit results, the correlation estimated (ρ) between the two dependent variables (the decision to use RE, and the decision to produce RE) is positive and significant (Rho=ρ= 0.5947; p-value=0). Thus, the null hypothesis, H0: ρ = 0, is rejected at the 1% level.

Since rho (ρ) is significantly different from zero, there is some covariance of error terms between the probability of producing and the probability of using RE. This indicates the interdependence of the two decisions, i.e., the decision to produce implies the decision to use RE, and vice versa.

Finally, we estimated the recursive bivariate probit model (rbiprobit). The rbiprobit is a system of two probit equations that allows the error terms to be correlated, and the binary dependent variable in one equation to be an endogenous regressor in the other equation (Filippini *et al.*, 2018). The rbiprobit accounts for the recursive nature of the model in contrast to the bivariate probit. It estimates the effect of the binary endogenous variable on the binary outcome variable, and is a suitable alternative to the bivariate probit. In our study, we assume that RE production is the binary endogenous regressor in the equation of RE consumption. The model to be estimated is as follows:

$$(III-7): \quad \begin{cases} \text{RE\_used}^*_{i,t} = \beta\ \text{RE\_product}^*_{i,t} + \gamma_1 X_{1i,t} + \varepsilon_{1i,t} \\ \text{RE\_product}^*_{i,t} = \gamma_2 X_{2i,t} + \varepsilon_{2i,t} \end{cases}$$

With

$$(III-8): \quad \text{RE\_used}_{i,t} = \begin{cases} 1\ if\ \text{RE\_used}^*_{i,t} > 0 \\ 0, otherwise \end{cases} \quad and, \quad \text{RE\_product}_{it} = \begin{cases} 1\ if\ \text{RE\_product}^*_{i,t} > 0 \\ 0, otherwise \end{cases}$$

where RE_usedt* and, RE_product* are latent continuous variables (representing the probabilities of using RE and producing RE, respectively) for which only the binary variables RE_usedt and RE_product are observables. X_{1i} and X_{2i} are other explanatory variables, specifically, the corporate governance and the control variables. The estimates are, at best, weakly identified if $X_{1i} = X_{2i}$ (Han and Lee, 2019). In consequence, we have specified the model so that these vectors of variables are not identical (see Table III-7, columns 5 and 6).

If the coefficient β is significant, this indicates a correlation between the two binary dependent variables (Filippini *et al.*, 2018). The results are presented in columns 5 and 6. As can be seen, RE production has a significantly positive impact on RE use (columns 5). The coefficient associated with the RE production dummy is 2.1189 and significant at a 1% level. This confirms the bivariate probit results, and indicates that RE producers are more likely to use RE than other firms. In addition, the coefficients associated with the corporate governance variables are smaller than those estimated in the bivariate and the regular probit model. This effect may be due to the positive association between the governance variables and RE production, as shown in column 6.

The interpretation of the correlation parameter in the rbiprobit is not the same as in the bivariate probit regression. Filippini *et al.* (2018) documented that the correlation parameter in bivariate probit is a weighted average of the correlation from rbiprobit and the coefficient associated with the endogenous binary variable. The rbiprobit correlation parameter does not capture the correlation between the binary dependent variables. Once the effect of the endogenous binary variable is considered, the correlation between the error terms is not necessarily of the same sign as the endogenous relationship. Thus, in our regressions, since the bivariate probit delivers a positive significant coefficient of correlation, it is consistent that the rbiprobit yields a positive significant parameter associated with the RE production (endogenous binary variable).

Overall, the results indicate that appropriate governance mechanisms are necessary for RE transition, as they are both determinants of the decision to produce and the decision to use RE by the firms. This implies that the energy transition requires, first of all, establishing appropriate governance mechanisms within companies.

7.2. RE consumption and financial performance

The relationship between the firm environmental and financial performance remains unclear (Daugaard, 2020). One group of studies found a negative effect (Renneboog *et al.*, 2008; Cortez *et al.*, 2012), while another documented a positive relationship between firm environmental and financial performance (Daugaard, 2020; Lee *et al.*, 2015). Still, others reported an insignificant impact of environmental performance on financial performance (Humphrey and Lee, 2011; Bauer *et al.*, 2007). In this section, we investigate whether RE use impacts the firm's financial performance, measured by firm value and operating performance. We consider RE consumption a strategy to improve the firm's environmental performance. Similarly to our baseline method, we estimated a panel model with fixed effects. Our main explanatory variable is RE use, measured as the ratio of RE to the total energy used. We control for firm size, debt ratio, and cash-to-asset ratio. We do not incorporate any governance mechanism in our model since they are determinants of RE use, our main explanatory variable. All regressions include firm and year fixed effects.

First, we examine the impact of RE consumption on the firm operating performance (profitability). We proxy the operating performance by the return on assets (ROA), which we define as the ratio of the earnings before interest and taxes to the book value of total assets (see, e.g., Bardos *et al.,* 2020; Atif *et al.*, 2021). The results are reported in Table III-8. As presented in column (3), we find no significant effect of RE use on firm operating performance (ROA). That is, RE consumption has no impact on firm profitability. This finding supports the studies that found an insignificant effect of environmental performance on financial performance (Humphrey and Lee, 2011; Bauer *et al.*, 2007).

Table III-8.
RE consumption and firm outcomes

	Dependant variables			
	TotCO2toRevenus	Environmental performance	ROA	Tobin's Q
	(1)	(2)	(3)	(4)
RE_Used	-0.0103***	0.1033***	0.0055	1.4047**
	(-3.34)	(9.18)	(1.31)	(1.99)
Size_Firm	-0.0032***	0.0554***	0.0170***	-1.3002***
	(-4.60)	(47.13)	(11.93)	(-3.28)
QTobin*100	-0.0013	0.0096	-	-
	(-0.25)	(1.30)		
DebtRatio*100	0.0014	-0.013**	-0.0053***	0.3579**
	(0.13)	(-1.99)	(-2.68)	(2.28)
ROA	0.0668***	0.0026	-	-
	(6.99)	(0.32)		
CashtoASSET	0.0179**	-0.0459***	-0.0545***	2.0913
	(2.23)	(-4.05)	(-3.23)	(1.16)
Constant	0.5343***	-0.3869***	-0.0819***	12.0142***
	(14.64)	(-18.05)	(-5.63)	(3.64)
Firm effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
Obs	18,616	20,594	20,605	20,609
Firms	3,467	3,805	3,805	3,807
Adj. R2	0.1245	0.3323	0.1567	0.1784

Note (s): Table III-8 presents the results of the impact of RE consumption on firms' outcomes. The dependent variables are firm-level CO_2 emission to total sales (TotCO2toRevenus) in column 1, environmental performance in column 2, ROA in column 3, and Tobin's Q in column 4. The coefficients appear first, and the z statistics are in parentheses. The relevant explanatory variable is RE consumption, measured by the ratio of RE divided by total energy use. All regressions include constant, firm, and year fixed effects. The sample includes all firm-year observations from 2002–2021. The symbols *, **, and *** indicate, respectively, that the estimate is significant at the 10%, 5%, and 1% levels. We estimate the panel regressions with fixed effects, using vce (robust) and clustered options of Stata. Adjusted R^2 are in decimals (not in percentage).

Source (s): Authors own work

Next, we employ firm value as a measure of financial performance. The proxy of firm value is Tobin's Q, calculated as the ratio of the firm's market capitalization to the book value of equity (see, e.g., Bardos *et al.,* 2020; Flammer, 2021). As can be seen in column 4 (Table III-8), we find a significantly positive impact of RE consumption on firm value, indicating a positive stock market reaction to initiatives aimed at improving the firm's environmental performance. This supports studies that report a positive relationship between the firm environmental and financial performance (Lee *et al.*, 2015). It also indicates that investors view RE use as a competitive advantage and anticipate the firm's future financial performance. RE consumption is beneficial for society and the current shareholders.

7.3. RE consumption and environmental performance

The previous sections show that appropriate governance mechanisms foster RE consumption. It is widely believed that using RE helps reduce environmental pollution. This section examines this relationship using firm CO_2 emissions to total revenues as a proxy for pollution. We also analyze the impact of RE use on firm environmental performance measured by Refinitiv environmental rating. Similarly to our baseline method, we estimated a panel model with fixed effects. Our primary explanatory variable is RE consumption, measured as the ratio of RE to the total energy used.

Unsurprisingly, RE consumption negatively impacts CO_2 emissions (column 1 of Table III-8). A one-percentage-point increase in RE to total energy use ratio leads to a decrease in total CO_2 emissions to total sales ratio of about 1.03 percentage points. These findings support the widespread view that RE use contributes to CO_2 emission reduction. Furthermore, RE use is positively associated with firm environmental performance. A one-percentage-point increase in the RE to total energy use ratio leads to an increase in the environmental performance of about 10.33 percentage points. Therefore, firms can consider RE consumption as a strategy to combat climate change.

8. Discussion and implications

The results of this study reveal that appropriate governance mechanisms positively impact RE consumption. These include the existence of a sustainability committee, ESG-performance-based compensation policy, financial performance-based compensation, sustainability external audit, transparency, board gender diversity, and board independence. The study also shows that the decision to use RE implies the decision to produce RE by the firms, and vice versa. Firms with appropriate governance mechanisms are more likely to produce and use RE than others. Finally, while RE use positively affects firm value and environmental performance, we find no significant impact on actual profitability. The findings that the board gender diversity and board independence have a significantly positive effect on RE consumption confirm the results of Atif *et al.* (2021) and Zhang *et al.* (2021). They also confirm the theoretical argument that firms with more female directors may be more likely to address the challenge of climate change by promoting energy transition. Specifically, they support that women's presence on boards encourages firms to adopt environmentally friendly practices (Nadeem *et al.,* 2017). The results also align with Haque (2017), who states that board independence positively affects carbon reduction initiatives. They confirm that the decisions of independent boards are more likely to favor the interests of broader stakeholders (Zhang *et al.*, 2021) and support the argument that governance tools like board independence, a sustainability committee, and managerial incentives complement one another to enhance the firm's environmental performance (García-Sánchez et *al.,* 2019b). Thus, the interdependence observed between the decision to use and the decision to produce RE suggests that well-governed firms produce RE to reduce their carbon footprint, not only for sale. The appropriate governance mechanisms within firms play an essential role in environmental decision-making, including those relating to the energy transition.

The positive relationship observed between the existence of sustainability committees and RE use implies that sustainability committees are more likely to advocate using RE, which may improve the firm's environmental performance. This finding aligns with the view that the sustainability committee conveys a firm's commitment toward environmental issues (Dixon-Fowler *et al.*, 2017). By advocating CO_2 reduction initiatives and climate change strategies, the sustainability committee will pressure the firm to adopt RE. The positive impact of financial performance-based compensation on RE use supports the results of Karim *et al.* (2018) that a firm's environmental performance is positively linked with equity-based compensation, and those of Haque and Ntim (2020) that executive compensation has a positive effect on carbon performance. Finally, the findings are consistent with Haque (2017) that the ESG-based compensation policy seems necessary to motivate executives to address environmental concerns. Specifically, they confirm that firms can use an ESG-based compensation policy to motivate employees to develop energy-efficient products and implement RE projects. They also confirm that adopting CSR contracting is an effective tool for energy transition (Hong *et al.*, 2016; Flammer *et al.*, 2019). Thus, linking CEO compensation to firm ESG performance may result in clean and RE use, and help reduce pollution. Incentive-based mechanisms may persuade executives to undertake climate protection initiatives and facilitate energy transition.

The study extends the existing governance literature by providing novel empirical evidence that multiple governance mechanisms have a significantly positive impact on the RE transition. The results are in line with the previous studies that corporate governance affects firms' policies. In that regard, Bernile *et al.* (2018) show some preliminary evidence that diversity in corporate boards affects firms' policies, that these boards monitor and advise. The findings support diverse theoretical and empirical backgrounds, as governance mechanisms moderate environmental decisions and alleviate problems associated with groupthink (Adams *et al.*, 2021; Flammer *et al.*, 2019; Haque, 2017; Gillan *et al.*, 2021). For instance, Shive and Forster (2020) document that corporate governance tools allowing increased oversight can help reduce environmental pollution. Liao et *al.* (2015) defend strongly that the firm's climate policy may be influenced by the interactions between the corporate board, individual board members, and stakeholder constituents, in addition to an objective assessment of the severity of the agency problem. Thus, corporate governance provides a structure that sets goals that serve the interests of shareholders and society (García-Sánchez *et al.*, 2019a). Effective governance mechanisms are necessary for the RE transition and environmental efficiency.

Overall, the findings suggest that RE transition requires, first of all, establishing appropriate governance mechanisms within firms. The present study contributes to the achievement of three of the 17 U.N SDGs, specifically, Goal 7 on access to affordable and clean energy, goal 12 on responsible production and consumption, and Goal 13 on climate action. The findings have many implications for academic research and policymaking. From a theoretical perspective, the study contributes to the literature on corporate governance by identifying governance mechanisms that positively affect RE use as well as RE development. It offers new insights for managers and policymakers on how to use governance tools to combat climate change. The main policy implication is that corporate governance is beneficial in terms of environmental protection. The study shows the importance of corporate governance both for the development and the use of RE, and therefore pollution reduction. Given specific governance mechanisms in the firm increase RE adoption, policymakers aiming to combat climate change should encourage firms to adopt these mechanisms. This implies that governments and firm leaders must exercise attention and precaution when developing RE and environmental quality policies. Firms should consider appropriate governance tools to address climate change concerns. The governmental authorities should direct green subsidies mainly to well-governed firms. Finally, we find that RE use increases the firm market value without impacting its current profitability. Indeed, investors view RE use as a competitive advantage and anticipate the firm's future financial performance. An effective governance mechanism is beneficial in terms of RE consumption, and in turn, RE use results in a higher stock market valuation. Thus, firms have an interest in communicating their use of RE in order to send a positive signal to investors, attract green investors, and raise funds at a lower cost. This signal seems credible since RE use is related to firm-level CO_2 emission reduction.

9. Conclusion

We examine the impact of corporate governance on RE consumption, and explore the interdependence between the decision to use and the decision to produce RE by firms. Following Ferrell *et al.* (2016), we argue that well-governed firms are more likely to promote efforts to help protect the environment. We postulate that corporate governance mechanisms are important factors that affect firm environmental decisions, such as CO_2 emission reduction initiatives and RE use.

First, we examine how corporate governance mechanisms affect RE consumption. Using the panel model with fixed effects, we find that the appropriate governance mechanisms positively impact RE consumption. These include the existence of a sustainability committee, ESG-based compensation policy, financial performance-based compensation, sustainability external audit, transparency, board gender diversity, and board independence. However, audit committee independence has no significant impact on RE use. Indeed, the percentage of independent board members on the audit committee does not affect firm-level RE use. These results remain robust to various specifications, including using an alternative measure of RE consumption. In sum, our findings reveal that the better the corporate governance, the more the firm invests in environmental CSR activities, including RE use.

In the second part of our study, we explore the relationship between RE consumption and RE production. Using a bivariate probit regression, we find that, in general, corporate governance mechanisms have a significantly positive impact on both the decision to produce and the decision to use RE. Firms with appropriate governance mechanisms are more likely to produce and use RE. We also find a significantly positive correlation between the probability of using and the probability of producing RE. This indicates the interdependence of the two decisions, i.e., the decision to produce implies the decision to use RE, and vice versa. Overall, the findings suggest that inappropriate governance mechanisms may constitute an obstacle to the RE transition. The study implies that RE transition requires, first of all, establishing appropriate governance mechanisms within companies.

Furthermore, we document that RE consumption is significantly and negatively associated with firm-level pollution, as measured by the total CO_2 emissions to total sales. These findings support the view that RE consumption contributes to firm-level CO_2 emission reduction. In addition, RE consumption is positively associated with the firm's environmental performance. Finally, while RE consumption has a significantly positive impact on firm value, we find no significant effect on the firm profitability as measured by the return on assets. This indicates that the investors view RE use as a competitive advantage, and then anticipate the company's future financial performance in terms of profitability. Indeed, RE use is a strategy to combat climate change that is in the interest of the shareholders.

This study extends the existing governance literature by providing novel empirical evidence that multiple governance mechanisms have a significantly positive impact on the RE transition. The results are in line with the previous studies that show that corporate governance affects firms' policies. The main policy implication of this study is that corporate governance is beneficial in terms of environmental protection. The study shows the importance of corporate governance both for the development and the use of RE, and therefore pollution reduction. In addition, RE use positively affects firm value. As a result, firms should consider governance tools to address climate change concerns. Given specific governance mechanisms in the firm increase RE adoption, policymakers aiming to combat climate change and its impacts should encourage firms to adopt these mechanisms.

Our study is limited to RE use, and the interaction between RE use and RE production by the firms. Future research, benefiting from more data, should examine the impact of government policies, such as green subsidies, on adopting RE. Other governance mechanisms, such as the presence of a poison pill or golden parachute at the firm, should also be considered.

References

Adams, R.B., Ragunathan, V. and Tumarkin, R. (2021), "Death by committee? An analysis of corporate board (sub-) committees", *Journal of Financial Economics*, Vol. 141 No. 3, pp. 1119–1146, doi: 10.1016/j.jfineco.2021.05.032.

Almagtome, A., Khaghaany, M. and Önce, S. (2020), "Corporate Governance Quality, Stakeholders' Pressure, and Sustainable Development: An Integrated Approach", *International Journal of Mathematical, Engineering and Management Sciences* Vol. 5 No. 6, doi: 10.33889/ijmems.2020.5.6.082.

Arellano, M. and Bond, S. (1991), "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", *The Review of Economic Studies*, Vol. 58 No. 2, pp. 277–297, doi: 10.2307/2297968.

Atif, M., Hossain, M., Alam, M.S. and Goergen, M. (2021), “Does board gender diversity affect renewable energy consumption?”, *Journal of Corporate Finance*, Vol. 66, p. 101665, doi: 10.1016/j.jcorpfin.2020.101665.

Balachandran, B. and Nguyen, J.H. (2018), “Does carbon risk matter in firm dividend policy? Evidence from a quasi-natural experiment in an imputation environment”, *Journal of Banking & Finance*, Vol. 96, pp. 249–267, doi: 10.1016/j.jbankfin.2018.09.015.

Bardos, K.S., Ertugrul, M. and Gao, L.S. (2020), “Corporate social responsibility, product market perception, and firm value”, *Journal of Corporate Finance*, Vol. 62, p. 101588, doi: 10.1016/j.jcorpfin.2020.101588.

Bauer, R., Derwall, J. and Otten, R. (2007), “The Ethical Mutual Fund Performance Debate: New Evidence from Canada”, *Journal of Business Ethics*, Vol. 70 No. 2, pp. 111–124, doi: 10.1007/s10551-006-9099-0.

Ben-Amar, W., Chang, M. and McIlkenny, P. (2017), “Board Gender Diversity and Corporate Response to Sustainability Initiatives: Evidence from the Carbon Disclosure Project”, *Journal of Business Ethics*, Vol. 142 No. 2, pp. 369–383, doi: 10.1007/s10551-015-2759-1.

Bernile, G., Bhagwat, V. and Yonker, S. (2018), “Board diversity, firm risk, and corporate policies”, *Journal of Financial Economics*, Vol. 127 No. 3, pp. 588–612, doi: 10.1016/j.jfineco.2017.12.009.

Bernstein, A., Gustafson, M.T. and Lewis, R. (2019), “Disaster on the horizon: The price effect of sea level rise”, *Journal of Financial Economics*, Vol. 134 No. 2, pp. 253–272, doi: 10.1016/j.jfineco.2019.03.013.

Bildirici, M.E. and Gökmenoğlu, S.M. (2017), “Environmental pollution, hydropower energy consumption and economic growth: Evidence from G7 countries”, *Renewable and Sustainable Energy Reviews*, Vol. 75, pp. 68–85, doi: 10.1016/j.rser.2016.10.052.

Blundell, R. and Bond, S. (1998), “Initial conditions and moment restrictions in dynamic panel data models”, *Journal of Econometrics*, Vol. 87 No. 1, pp. 115–143, doi: 10.1016/S0304-4076(98)00009-8.

Cardillo, G., Onali, E. and Torluccio, G. (2021), “Does gender diversity on banks’ boards matter? Evidence from public bailouts”, *Journal of Corporate Finance*, Vol. 71, p. 101560, doi: 10.1016/j.jcorpfin.2020.101560.

Chams, N. and García-Blandón, J. (2019), “Sustainable or not sustainable? The role of the board of directors”, *Journal of Cleaner Production*, Vol. 226, pp. 1067–1081, doi: 10.1016/j.jclepro.2019.04.118.

Chang, L., Saydaliev, H.B., Meo, M.S. and Mohsin, M. (2022), “How renewable energy matter for environmental sustainability: Evidence from top-10 wind energy consumer countries of European Union”, *Sustainable Energy, Grids and Networks*, Vol. 31, p. 100716, doi: 10.1016/j.segan.2022.100716.

Choi, D., Gao, Z. and Jiang, W. (2020), “Attention to Global Warming”, *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1112–1145, doi: 10.1093/rfs/hhz086.

Cortez, M.C., Silva, F. and Areal, N. (2012), “Socially Responsible Investing in the Global Market: The Performance of Us and European Funds”, *International Journal of Finance & Economics*, Vol. 17 No. 3, pp. 254–271, doi: 10.1002/ijfe.454.

Daugaard, D. (2020), “Emerging new themes in environmental, social and governance investing: a systematic literature review”, *Accounting & Finance*, Vol. 60 No. 2, pp. 1501–1530, doi: 10.1111/acfi.12479.

Destek, M.A. and Aslan, A. (2020), “Disaggregated renewable energy consumption and environmental pollution nexus in G-7 countries”, *Renewable Energy*, Vol. 151, pp. 1298–1306, doi: 10.1016/j.renene.2019.11.138.

Dixon-Fowler, H.R., Ellstrand, A.E. and Johnson, J.L. (2017), “The Role of Board Environmental Committees in Corporate Environmental Performance”, *Journal of Business Ethics*, Vol. 140 No. 3, pp. 423–438, doi: 10.1007/s10551-015-2664-7.

Dmytriyev, S.D., Freeman, R.E. and Hörisch, J. (2021), “The Relationship between Stakeholder Theory and Corporate Social Responsibility: Differences, Similarities, and Implications for Social Issues in Management”, *Journal of Management Studies*, Vol. 58 No. 6, pp. 1441–1470, doi: 10.1111/joms.12684.

Dogan, E., Chishti, M.Z., Karimi Alavijeh, N. and Tzeremes, P. (2022), “The roles of technology and Kyoto Protocol in energy transition towards COP26 targets: Evidence from the novel GMM-PVAR approach for G-7 countries”, *Technological Forecasting and Social Change*, Vol. 181, p. 121756, doi: 10.1016/j.techfore.2022.121756.

Eberhardt-Toth, E. (2017), “Who should be on a board corporate social responsibility committee?”, *Journal of Cleaner Production*, Vol. 140, pp. 1926–1935, doi: 10.1016/j.jclepro.2016.08.127.

Fama, E.F. and Jensen, M.C. (1983), “Separation of Ownership and Control”, *The Journal of Law & Economics*, Vol. 26(2) No. 2, pp. 301–325.

Ferrell, A., Liang, H. and Renneboog, L. (2016), “Socially responsible firms”, *Journal of Financial Economics*, Vol. 122 No. 3, pp. 585–606, doi: 10.1016/j.jfineco.2015.12.003.

Filippini, M., Greene, W.H., Kumar, N. and Martinez-Cruz, A.L. (2018), "A note on the different interpretation of the correlation parameters in the Bivariate Probit and the Recursive Bivariate Probit", *Economics Letters*, Vol. 167, pp. 104–107, doi: 10.1016/j.econlet.2018.03.018.

Flammer, C. (2021), "Corporate green bonds", *Journal of Financial Economics*, Vol. 142 No. 2, pp. 499–516, doi: 10.1016/j.jfineco.2021.01.010.

Flammer, C., Hong, B. and Minor, D. (2019), "Corporate governance and the rise of integrating corporate social responsibility criteria in executive compensation: Effectiveness and implications for firm outcomes", *Strategic Management Journal*, Vol. 40 No. 7, pp. 1097–1122, doi: 10.1002/smj.3018.

García Lara, J.M., García Osma, B., Mora, A. and Scapin, M. (2017), "The monitoring role of female directors over accounting quality", *Journal of Corporate Finance*, Vol. 45, pp. 651–668, doi: 10.1016/j.jcorpfin.2017.05.016.

García-Sánchez, I.-M., Gómez-Miranda, M.E., David, F. and Rodríguez-Ariza, L. (2019a), "Board independence and GRI-IFC performance standards: The mediating effect of the CSR committee", *Journal of Cleaner Production*, Vol. 225, pp. 554–562, doi: 10.1016/j.jclepro.2019.03.337.

García-Sánchez, I.-M., Hussain, N. and Martínez-Ferrero, J. (2019b), "An empirical analysis of the complementarities and substitutions between effects of ceo ability and corporate governance on socially responsible performance", *Journal of Cleaner Production*, Vol. 215, pp. 1288–1300, doi: 10.1016/j.jclepro.2019.01.130.

Gillan, S.L., Koch, A. and Starks, L.T. (2021), "Firms and social responsibility: A review of ESG and CSR research in corporate finance", *Journal of Corporate Finance*, Vol. 66, p. 101889, doi: 10.1016/j.jcorpfin.2021.101889.

Greene, W.H. (1996), "Marginal Effects in the Bivariate Probit Model", SSRN Scholarly Paper, Rochester, NY, 1 June. Accessed: October, 2022

Han, S. and Lee, S. (2019), "Estimation in a generalization of bivariate probit models with dummy endogenous regressors", *Journal of Applied Econometrics*, Vol. 34 No. 6, pp. 994–1015, doi: 10.1002/jae.2727.

Hansen, L.P. (1982), "Large Sample Properties of Generalized Method of Moments Estimators", *Econometrica*, Vol. 50 No. 4, pp. 1029–1054, doi: 10.2307/1912775.

Haque, F. (2017), "The effects of board characteristics and sustainable compensation policy on carbon performance of U.K. firms", *The British Accounting Review*, Vol. 49 No. 3, pp. 347–364, doi: 10.1016/j.bar.2017.01.001.

Haque, F. and Ntim, C.G. (2020), “Executive Compensation, Sustainable Compensation Policy, Carbon Performance and Market Value”, *British Journal of Management*, Vol. 31 No. 3, pp. 525–546, doi: 10.1111/1467-8551.12395.

Holm, A. and Arendt, J.N. (2013), “Evaluating the performance of simple estimators for probit models with two dummy endogenous regressors”, *Journal of Statistical Computation and Simulation*, Taylor & Francis, Vol. 83 No. 6, pp. 1156–1178, doi: 10.1080/00949655.2011.652631.

Hong, B., Li, Z. and Minor, D. (2016), “Corporate Governance and Executive Compensation for Corporate Social Responsibility”, *Journal of Business Ethics*, Vol. 136 No. 1, pp. 199–213, doi: 10.1007/s10551-015-2962-0.

Humphrey, J.E. and Lee, D.D. (2011), “Australian Socially Responsible Funds: Performance, Risk and Screening Intensity”, *Journal of Business Ethics*, Vol. 102 No. 4, pp. 519–535, doi: 10.1007/s10551-011-0836-7.

Hussain, N., Rigoni, U. and Orij, R.P. (2018), “Corporate Governance and Sustainability Performance: Analysis of Triple Bottom Line Performance”, *Journal of Business Ethics*, Vol. 149 No. 2, pp. 411–432, doi: 10.1007/s10551-016-3099-5.

Jensen, C. and Meckling, H. (1976), “Theory of the firm: Managerial behavior, agency costs and ownership structure”, *Journal of Financial Economics*, Vol. 3 No. 4, pp. 305–360, doi: 10.1016/0304-405X(76)90026-X.

Jian, M. and Lee, K.-W. (2015), “CEO compensation and corporate social responsibility”, *Journal of Multinational Financial Management*, Vol. 29, pp. 46–65, doi: 10.1016/j.mulfin.2014.11.004.

Jo, H. and Harjoto, M.A. (2012), “The Causal Effect of Corporate Governance on Corporate Social Responsibility”, *Journal of Business Ethics*, Vol. 106 No. 1, pp. 53–72, doi: 10.1007/s10551-011-1052-1.

Karim, K., Lee, E. and Suh, S. (2018), “Corporate social responsibility and CEO compensation structure”, *Advances in Accounting*, Vol. 40, pp. 27–41, doi: 10.1016/j.adiac.2017.11.002.

Krueger, P., Sautner, Z. and Starks, L.T. (2020), “The Importance of Climate Risks for Institutional Investors”, *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1067–1111, doi: 10.1093/rfs/hhz137.

Lee, K.-H., Min, B. and Yook, K.-H. (2015), “The impacts of carbon (CO2) emissions and environmental research and development (R&D) investment on firm performance”, *International Journal of Production Economics*, Vol. 167, pp. 1–11, doi: 10.1016/j.ijpe.2015.05.018.

Liao, L., Luo, L. and Tang, Q. (2015), "Gender diversity, board independence, environmental committee and greenhouse gas disclosure", *The British Accounting Review*, Vol. 47 No. 4, pp. 409–424, doi: 10.1016/j.bar.2014.01.002.

Liu, C. (2018), "Are women greener? Corporate gender diversity and environmental violations", *Journal of Corporate Finance*, Vol. 52, pp. 118–142, doi: 10.1016/j.jcorpfin.2018.08.004.

Manning, B., Braam, G. and Reimsbach, D. (2019), "Corporate governance and sustainable business conduct—Effects of board monitoring effectiveness and stakeholder engagement on corporate sustainability performance and disclosure choices", *Corporate Social Responsibility and Environmental Management*, Vol. 26(2) No. 2, pp. 351–366, doi: 10.1002/csr.1687.

Naciti, V. (2019), "Corporate governance and board of directors: The effect of a board composition on firm sustainability performance", *Journal of Cleaner Production*, Vol. 237, p. 117727, doi: 10.1016/j.jclepro.2019.117727.

Nadeem, M., Zaman, R. and Saleem, I. (2017), "Boardroom gender diversity and corporate sustainability practices: Evidence from Australian Securities Exchange listed firms", *Journal of Cleaner Production*, Vol. 149, pp. 874–885, doi: 10.1016/j.jclepro.2017.02.141.

Nguyen, T.H.H., Elmagrhi, M.H., Ntim, C.G. and Wu, Y. (2021), "Environmental performance, sustainability, governance and financial performance: Evidence from heavily polluting industries in China", *Business Strategy and the Environment*, Vol. 30 No. 5, pp. 2313–2331, doi: 10.1002/bse.2748.

Nuber, C. and Velte, P. (2021), "Board gender diversity and carbon emissions: European evidence on curvilinear relationships and critical mass", *Business Strategy and the Environment*, Vol. 30 No. 4, pp. 1958–1992, doi: 10.1002/bse.2727.

O'Connor, M. and Rafferty, M. (2012), "Corporate Governance and Innovation", *Journal of Financial and Quantitative Analysis*, Vol. 47 No. 2, pp. 397–413, doi: 10.1017/S002210901200004X.

Opoku, E.E.O., Kufuor, N.K. and Manu, S.A. (2021), "Gender, electricity access, renewable energy consumption and energy efficiency", *Technological Forecasting and Social Change*, Vol. 173, p. 121121, doi: 10.1016/j.techfore.2021.121121.

Orazalin, N.S., Ntim, C.G. and Malagila, J.K. (2023), "Board Sustainability Committees, Climate Change Initiatives, Carbon Performance, and Market Value", *British Journal of Management*, doi: 10.1111/1467-8551.12715.

Pearl-Martinez, R. and Stephens, J.C. (2016), "Toward a gender diverse workforce in the renewable energy transition", *Sustainability: Science, Practice and Policy*, Vol. 12 No. 1, pp. 8–15, doi: 10.1080/15487733.2016.11908149.

Rekker, S.A.C., Benson, K.L. and Faff, R.W. (2014), "Corporate social responsibility and CEO compensation revisited: Do disaggregation, market stress, gender matter?", *Journal of Economics and Business*, Vol. 72, pp. 84–103, doi: 10.1016/j.jeconbus.2013.11.001.

Renneboog, L., Ter Horst, J. and Zhang, C. (2008), "The price of ethics and stakeholder governance: The performance of socially responsible mutual funds", *Journal of Corporate Finance*, Vol. 14 No. 3, pp. 302–322, doi: 10.1016/j.jcorpfin.2008.03.009.

Roodman, D. (2009), "How to do Xtabond2: An Introduction to Difference and System GMM in Stata", *The Stata Journal*, Vol. 9 No. 1, pp. 86–136, doi: 10.1177/1536867X0900900106.

Scherer, A.G. and Voegtlin, C. (2020), "Corporate Governance for Responsible Innovation: Approaches to Corporate Governance and Their Implications for Sustainable Development", *Academy of Management Perspectives*, Vol. 34 No. 2, pp. 182–208, doi: 10.5465/amp.2017.0175.

Shive, S.A. and Forster, M.M. (2020), "Corporate Governance and Pollution Externalities of Public and Private Firms", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1296–1330, doi: 10.1093/rfs/hhz079.

Suchman, M.C. (1995), "Managing Legitimacy: Strategic and Institutional Approaches", *Academy of Management Review*, Academy of Management, Vol. 20(3) No. 3, pp. 571–610, doi: 10.5465/amr.1995.9508080331.

Ullah, F., Jiang, P., Ntim, C.G., Shahab, Y. and Jiang, X. (2022), "Female Directors' Foreign Experience and Environmental and Sustainable Performance", *Asia-Pacific Journal of Financial Studies*, Vol. 51 No. 2, pp. 169–193, doi: 10.1111/ajfs.12369.

Wang, L. (2022), "Research on the dynamic relationship between China's renewable energy consumption and carbon emissions based on ARDL model", *Resources Policy*, Vol. 77, p. 102764, doi: 10.1016/j.resourpol.2022.102764.

Yu, J., Saydaliev, H.B., Liu, Z., Nazar, R. and Ali, S. (2022), "The asymmetric nexus of solar energy and environmental quality: Evidence from Top-10 solar energy-consuming countries", *Energy*, Vol. 247, p. 123381, doi: 10.1016/j.energy.2022.123381.

Zhang, D., Zhang, Z., Ji, Q., Lucey, B. and Liu, J. (2021), "Board characteristics, external governance and the use of renewable energy: International evidence", *Journal of International Financial Markets, Institutions and Money*, Vol. 72, p. 101317, doi: 10.1016/j.intfin.2021.101317.

Zhu, Y., Taylor, D. and Wang, Z. (2022), "The role of renewable energy in reducing residential fossil energy-related CO2 emissions: Evidence from rural China", *Journal of Cleaner Production*, Vol. 366, p. 132891, doi: 10.1016/j.jclepro.2022.132891.

Footnotes

1. Posted on August 29, 2022, by LA PRESSE CANADIENNE. Accessed: October, 2022.
2. The 2030 Agenda for Sustainable Development. United Nations.
3. COP26: Together for our planet. Climate actions. United Nations.
4. Climate Bulletins. Copernicus Climate Change Service.

Appendix III-A1.

Sample description

Country	# firms	RewtoTotEn (%)	RE_ To_Revenus	RE_ to_Assets	% of RE users	% of RE producers
USA	824	11.62	244.75	166.73	0.6554	0.1684
GBR	386	9.18	179.32	138.64	0.5799	0.1496
JPN	324	3.60	0.68	0.46	0.6730	0.2272
CHN	218	1.97	6.35	4.29	0.4258	0.1106
AUS	152	2.27	82.54	43.43	0.4345	0.1052
DEU	145	14.73	731.12	514.58	0.7793	0.1809
FRA	124	11.37	838.59	289.00	0.7486	0.1529
HKG	109	4.03	23.08	8.21	0.4754	0.1557
TWN	109	2.45	1.46	0.87	0.5029	0.2095
SWE	105	24.39	105.29	94.02	0.7273	0.1509
CHE	90	18.80	253.56	154.77	0.7599	0.2171
ZAF	89	2.30	182.60	175.20	0.5630	0.1348
CAN	86	11.39	830.47	457.77	0.6395	0.1288
KOR	85	3.17	0.27	0.19	0.5446	0.1554
IND	82	8.86	8.64	6.88	0.9112	0.3807
ITA	76	16.21	710.78	366.61	0.8543	0.4975
BRA	75	29.20	1207.15	395.51	0.8191	0.2511
ESP	61	15.26	534.49	242.85	0.7668	0.3445
FIN	56	21.66	1213.79	986.05	0.6734	0.1127
THA	53	7.69	78.13	23.87	0.7054	0.3333
NOR	49	9.17	90.76	71.34	0.5285	0.1901
TUR	49	7.08	542.57	318.40	0.6100	0.1750
NLD	47	20.23	386.58	201.28	0.7927	0.1102
DNK	43	12.23	20.01	13.61	0.5352	0.1055
MYS	43	5.60	36.27	28.24	0.6079	0.2291
SGP	38	3.36	141.60	76.78	0.6229	0.1829
MEX	34	14.60	135.36	64.73	0.7817	0.2183
RUS	33	2.43	397.67	308.66	0.5000	0.2159
IRL	29	13.80	379.82	229.66	0.6776	0.0984
AUT	26	9.31	285.16	164.55	0.6951	0.1768
BEL	25	21.24	241.43	162.96	0.8182	0.1932
CHL	24	8.91	777.68	380.14	0.6866	0.3881
IDN	24	4.04	14.95	7.30	0.8000	0.1786
POL	24	8.01	88.87	48.62	0.5164	0.3197
LUX	22	14.10	775.14	651.86	0.7097	0.1720
PHL	19	0.22	0.04	0.02	0.7263	0.2842
NZL	18	4.89	170.34	136.95	0.4286	0.0714
ARG	16	4.79	2.38	2.01	0.5882	0.3137
GRC	16	4.07	344.73	242.83	0.5490	0.3627
PER	15	16.30	7312.08	2172.82	0.6275	0.3137
PRT	15	23.54	1098.90	513.97	0.8681	0.4615
COL	13	11.58	122.87	81.22	0.8082	0.5342
BMU	12	5.34	5.05	3.64	0.3043	0.0000
ISR	7	4.26	23.38	7.45	0.5714	0.1837
ARE	6	1.06	0.73	0.95	0.8235	0.0588
Total	**3,896**	**9.69**	**290.80**	**164.98**	**0.6504**	**0.1918**

Source (s): Authors own work

CONCLUSION

Climate change is a costly negative externality imposed on society, and a risk factor for firms and institutional funds. To combat climate change, technological and financial innovations are essential. The present thesis aims to show how stronger corporate governance and green bond financing may favor the low-carbon economic transition. It includes three essays. It postulates that the transition toward a low-carbon economy depends on technological innovation related to climate change, which in turn depends on the quality of firm internal governance and the availability of financial resources. Agency costs and financial market frictions affect corporate investment and financial decisions and, hence, firm environmental policies. By limiting agency conflicts, effective governance favors efficiency, facilitates access to external financing, and may encourage green innovation and the transition toward a low-carbon economy.

In essay 1, we investigate the long-run financial and environmental performance of corporate green bond issuers, worldwide. A methodological challenge arose when evaluating the long-term stock market performance of green bond issuers since the estimation of long-run abnormal returns has been controversial. Several approaches have been proposed, and each has its advantages and shortcomings. We follow the financial literature and employ two different techniques: we adopt an event-time approach and conduct robustness tests using the calendar-time method. In contrast with the earlier long-run event studies, the results reveal that multiple-time issuers and issuers operating in industries where the natural environment is financially material perform financially in the long term relative to the control firms. However, this stock market performance is not due to the better operating performance of the issuers. The study also documents that corporate green bond issuers reduce their CO_2 emissions, and improve their resource use efficiency and environmental performance, in the long run. Green bond issuers are also the most eco-innovative. Thus, our results invalidate the greenwashing hypothesis and support the signaling view of corporate green bond funding. In sum, issuing corporate green bonds appears to be beneficial for the existing shareholders and society.

This study has multiple theoretical and practical implications. The continuation of positive abnormal performance from the announcement period into the post-event period suggests that the stock market underreacts to the information contained in the announcement of corporate green bond issuances. Markets are not efficient since some cautious investors may take time to react to green bond issuances, considering the possibilities of greenwashing. A green bond issuance leads to a positive valuation of the firm, while issuing a conventional bond to finance environmental projects may have a negative impact on the firm's stock market valuation. At the firm level, managers have an interest in issuing green bonds to finance their environmental projects to send a positive signal to investors and other stakeholders such as customers or environmentalists. This action is in the interest of the firm's current shareholders. Otherwise, issuing a conventional bond or equity to finance green projects would send a negative signal to the financial markets, which is not in the interest of current shareholders. This study also supports the need to develop the green bond market. The main challenge is to improve credibility in the green bond market by minimizing the possibilities of greenwashing. Policymakers can play this role by providing a robust legal framework or governance tools that discourage issuing green bonds for greenwashing. These actions will contribute to making the green bond market more efficient and allow green projects to be financed more easily.

Essay 2 examines the impact of corporate governance on green innovation, worldwide. We adopt Tobin's q model of investment to conceptualize the relationship between corporate governance and investment in green R&D. We argue that agency costs and financial market frictions affect investment decisions of corporations and are fundamental factors in innovation and R&D activities. We analyzed the causal effect by using the system-GMM. The results reveal that the better the corporate governance, the more the firm invests in green R&D activities and develops green products. In addition, an increase in the score of each dimension (strategy, management, and shareholder) of corporate governance results in an increase in the probability of green product innovation. Finally, green innovation is positively related to firm environmental performance, including emission reduction and resource use efficiency. Overall, our results suggest that stronger governance fosters innovation that is beneficial for society. The findings provide implications to support managers and policymakers on how to improve sustainability through corporate governance. Understanding the impact of corporate governance on green innovation may help firms combat climate change, a crucial societal concern. Governance mechanisms will help resolve agency problems, favor external financing, and, in turn, encourage green innovation and the transition toward a low-carbon economy.

As the energy sector is responsible for most global emissions, developing clean energy is crucial to combat climate change. Essay 3 examines the relationship between corporate governance and renewable energy transition. We postulate that corporate governance mechanisms are important factors that affect firm environmental decisions, such as CO_2 emission reduction initiatives and RE use. The study adopts an econometric framework of a panel model, followed by the robustness check using alternative methods, including logit regressions. The bivariate probit model is employed to analyze the interaction between the decision to use and the decision to produce RE. The results reveal that appropriate governance mechanisms positively impact RE consumption. These include the existence of a sustainability committee, ESG-based compensation policy, financial performance-based compensation, sustainability external audit, transparency, board gender diversity, and board independence. We also find the interdependence between the decision to produce and the decision to use RE, i.e., the decision to produce implies the decision to use RE, and vice versa. That is, firms with appropriate governance mechanisms are more likely to produce and use RE than others. Finally, while RE use positively impacts firm market value and environmental performance, we find no significant effect on current profitability. This indicates that the investors view RE use as a competitive advantage and then anticipate the company's future financial performance in terms of profitability. Indeed, RE use is a strategy to combat climate change that is in the interest of the current shareholders.

Overall, the findings suggest that the transition toward a low-carbon economy requires, first of all, establishing appropriate governance mechanisms within companies. The main policy implication is that corporate governance is beneficial in terms of environmental protection and stock market performance. As a result, firms should consider governance tools to address climate change concerns. Given that specific corporate governance mechanisms in the firm promote RE transition, policymakers aiming to combat climate change and its impacts should encourage firms to adopt these mechanisms.

Like similar studies, this research has limitations that might form the basis for future research. The main issue in essay 1 is the potential endogenization of green bond issuances. The real problem is that it is very difficult or even impossible to identify all external and internal events as well as all other factors that can affect firms over the sample period.

Moreover, if one managed to identify all these events and factors, the question would be how to analyze them all in a single study. Nevertheless, the objective of our research is to examine the impact of corporate green bond funding on the firm financial and environmental performance, not to analyze the effect of all factors and events. Therefore, the matching approach remains an effective methodological answer to these concerns. However, the matching method may also have limitations, although it was widely adopted in the literature. Hence, another approach (e.g., a quasi-experimental) to confirm the results can be an avenue for future research. It would also be interesting to pursue the analysis by examining the determining factors of green bond issuances. In essay 2, since green R&D is a new form of investment, the results are based on relatively few observations. As more data become available, future research could provide larger-scale evidence and a more refined characterization of the long-term implications of green R&D investments. Future research, benefiting from more data, should also examine the impact of government policies, such as green subsidies, on adopting RE. Other governance mechanisms, such as the presence of a poison pill or golden parachute at the firm, should also be considered.

BIBLIOGRAPHY

Adams, R.B., Ragunathan, V. and Tumarkin, R. (2021), "Death by committee? An analysis of corporate board (sub-) committees", *Journal of Financial Economics*, Vol. 141 No. 3, pp. 1119–1146, doi: 10.1016/j.jfineco.2021.05.032.

Akerlof, G.A. (1970), "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism", *The Quarterly Journal of Economics*, Vol. 84 No. 3, pp. 488–500, doi: 10.2307/1879431.

Akey, P. and Appel, I. (2021), "The Limits of Limited Liability: Evidence from Industrial Pollution", *The Journal of Finance*, Vol. 76 No. 1, pp. 5–55, doi: 10.1111/jofi.12978.

Albort-Morant, G., Leal-Millán, A. and Cepeda-Carrión, G. (2016), "The antecedents of green innovation performance: A model of learning and capabilities", *Journal of Business Research*, Vol. 69 No. 11, pp. 4912–4917, doi: 10.1016/j.jbusres.2016.04.052.

Albuquerque, R., Koskinen, Y. and Zhang, C. (2019), "Corporate Social Responsibility and Firm Risk: Theory and Empirical Evidence", *Management Science*, INFORMS, Vol. 65 No. 10, pp. 4451–4469, doi: 10.1287/mnsc.2018.3043.

Almagtome, A., Khaghaany, M. and Önce, S. (2020), "Corporate Governance Quality, Stakeholders' Pressure, and Sustainable Development: An Integrated Approach", *International Journal of Mathematical, Engineering and Management Sciences* Vol. 5 No. 6, doi: 10.33889/ijmems.2020.5.6.082.

Alok, S., Kumar, N. and Wermers, R. (2020), "Do Fund Managers Misestimate Climatic Disaster Risk", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1146–1183, doi: 10.1093/rfs/hhz143.

Amore, M.D. and Bennedsen, M. (2016), "Corporate governance and green innovation", *Journal of Environmental Economics and Management*, Vol. 75, pp. 54–72, doi: 10.1016/j.jeem.2015.11.003.

Andersson, M., Bolton, P. and Samama, F. (2016), "Hedging Climate Risk", *Financial Analysts Journal*, Routledge, Vol. 72 No. 3, pp. 13–32, doi: 10.2469/faj.v72.n3.4.

Arellano, M. and Bond, S. (1991), "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", *The Review of Economic Studies*, Vol. 58 No. 2, pp. 277–297, doi: 10.2307/2297968.

Arellano, M. and Bover, O. (1995), "Another look at the instrumental variable estimation of error-components models", *Journal of Econometrics*, Vol. 68 No. 1, pp. 29–51, doi: 10.1016/0304-4076(94)01642-D.

Asni, N. and Agustia, D. (2022), "Does corporate governance induce green innovation? An emerging market evidence", *Corporate Governance: The International Journal of Business in Society*, Vol. 22 No. 7, pp. 1375–1389, doi: 10.1108/CG-10-2021-0389.

Atanasov, V.A. and Black, B.S. (2016), "Shock-Based Causal Inference in Corporate Finance and Accounting Research", *Critical Finance Review*, Vol.5, pp.207-304, doi:10.2139/ssrn.1718555.

Atanassov, J. (2013), "Do Hostile Takeovers Stifle Innovation? Evidence from Antitakeover Legislation and Corporate Patenting", *The Journal of Finance*, Vol. 68 No. 3, pp. 1097–1131, doi: 10.1111/jofi.12019.

Atif, M., Hossain, M., Alam, M.S. and Goergen, M. (2021), "Does board gender diversity affect renewable energy consumption?", *Journal of Corporate Finance*, Vol. 66, p. 101665, doi: 10.1016/j.jcorpfin.2020.101665.

Bachelet, M.J., Becchetti, L. and Manfredonia, S. (2019), "The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification", *Sustainability*, Multidisciplinary Digital Publishing Institute, Vol. 11 No. 4, p. 1098, doi: 10.3390/su11041098.

Balachandran, B. and Nguyen, J.H. (2018), "Does carbon risk matter in firm dividend policy? Evidence from a quasi-natural experiment in an imputation environment", *Journal of Banking & Finance*, Vol. 96, pp. 249–267, doi: 10.1016/j.jbankfin.2018.09.015.

Baldauf, M., Garlappi, L. and Yannelis, C. (2020), "Does Climate Change Affect Real Estate Prices? Only If You Believe In It", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1256–1295, doi: 10.1093/rfs/hhz073.

Balvers, R., Du, D. and Zhao, X. (2017), "Temperature shocks and the cost of equity capital: Implications for climate change perceptions", *Journal of Banking & Finance*, Vol. 77, pp. 18–34, doi: 10.1016/j.jbankfin.2016.12.013.

Bansal, R., Kiku, D. and Ochoa, M. (2017), "Price of Long-Run Temperature Shifts in Capital Markets", Working Paper, National Bureau of Economic Research, August, doi: 10.3386/w22529.

Barber, B.M. and Lyon, J.D. (1997), "Detecting long-run abnormal stock returns: The empirical power and specification of test statistics", *Journal of Financial Economics*, Vol. 43 No. 3, pp. 341–372, doi: 10.1016/S0304-405X(96)00890-2.

Bardos, K.S., Ertugrul, M. and Gao, L.S. (2020), "Corporate social responsibility, product market perception, and firm value", *Journal of Corporate Finance*, Vol. 62, p. 101588, doi: 10.1016/j.jcorpfin.2020.101588.

Barnett, M., Brock, W. and Hansen, L.P. (2020), "Pricing Uncertainty Induced by Climate Change", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1024–1066, doi: 10.1093/rfs/hhz144.

Barry, C.B. and Mihov, V.T. (2015), "Debt financing, venture capital, and the performance of initial public offerings", *Journal of Banking & Finance*, Vol. 58, pp. 144–165, doi: 10.1016/j.jbankfin.2015.04.001.

Bartram, S.M., Hou, K. and Kim, S. (2022), "Real effects of climate policy: Financial constraints and spillovers", *Journal of Financial Economics*, Vol. 143 No. 2, pp. 668–696, doi: 10.1016/j.jfineco.2021.06.015.

Bauer, R., Derwall, J. and Otten, R. (2007), "The Ethical Mutual Fund Performance Debate: New Evidence from Canada", *Journal of Business Ethics*, Vol. 70 No. 2, pp. 111–124, doi: 10.1007/s10551-006-9099-0.

Baulkaran, V. (2019), "Stock market reaction to green bond issuance", *Journal of Asset Management*, Vol. 20 No. 5, pp. 331–340, doi: 10.1057/s41260-018-00105-1.

Bebchuk, L., Cohen, A. and Ferrell, A. (2009), "What Matters in Corporate Governance?", *The Review of Financial Studies*, Vol. 22 No. 2, pp. 783–827, doi: 10.1093/rfs/hhn099.

Beck, U. (2015), "Emancipatory catastrophism: What does it mean to climate change and risk society?", *Current Sociology*, SAGE Publications Ltd, Vol. 63 No. 1, pp. 75–88, doi: 10.1177/0011392114559951.

Becker-Blease, J.R. (2011), "Governance and innovation", *Journal of Corporate Finance*, Vol. 17 No. 4, pp. 947–958, doi: 10.1016/j.jcorpfin.2011.04.003.

Ben-Amar, W., Chang, M. and McIlkenny, P. (2017), "Board Gender Diversity and Corporate Response to Sustainability Initiatives: Evidence from the Carbon Disclosure Project", *Journal of Business Ethics*, Vol. 142 No. 2, pp. 369–383, doi: 10.1007/s10551-015-2759-1.

Bernile, G., Bhagwat, V. and Yonker, S. (2018), "Board diversity, firm risk, and corporate policies", *Journal of Financial Economics*, Vol. 127 No. 3, pp. 588–612, doi: 10.1016/j.jfineco.2017.12.009.

Bernile, G., Bhagwat, V., Kecskés, A. and Nguyen, P.-A. (2021), "Are the risk attitudes of professional investors affected by personal catastrophic experiences?", *Financial Management*, Vol. 50 No. 2, pp. 455–486, doi: 10.1111/fima.12328.

Bernstein, A., Gustafson, M.T. and Lewis, R. (2019), "Disaster on the horizon: The price effect of sea level rise", *Journal of Financial Economics*, Vol. 134 No. 2, pp. 253–272, doi: 10.1016/j.jfineco.2019.03.013.

Bildirici, M.E. and Gökmenoğlu, S.M. (2017), "Environmental pollution, hydropower energy consumption and economic growth: Evidence from G7 countries", *Renewable and Sustainable Energy Reviews*, Vol. 75, pp. 68–85, doi: 10.1016/j.rser.2016.10.052.

Blundell, R. and Bond, S. (1998), "Initial conditions and moment restrictions in dynamic panel data models", *Journal of Econometrics*, Vol. 87 No. 1, pp. 115–143, doi: 10.1016/S0304-4076(98)00009-8.

Blundell, R., Bond, S., Devereux, M. and Schiantarelli, F. (1992), "Investment and Tobin's Q: Evidence from company panel data", *Journal of Econometrics*, Vol. 51 No. 1, pp. 233–257, doi: 10.1016/0304-4076(92)90037-R.

Cardillo, G., Onali, E. and Torluccio, G. (2021), "Does gender diversity on banks' boards matter? Evidence from public bailouts", *Journal of Corporate Finance*, Vol. 71, p. 101560, doi: 10.1016/j.jcorpfin.2020.101560.

Chakraborty, A., Gao, L.S. and Sheikh, S. (2019), "Managerial risk taking incentives, corporate social responsibility and firm risk", *Journal of Economics and Business*, Vol. 101, pp. 58–72, doi: 10.1016/j.jeconbus.2018.07.004.

Chams, N. and García-Blandón, J. (2019), "Sustainable or not sustainable? The role of the board of directors", *Journal of Cleaner Production*, Vol. 226, pp. 1067–1081, doi: 10.1016/j.jclepro.2019.04.118.

Chang, L., Saydaliev, H.B., Meo, M.S. and Mohsin, M. (2022), "How renewable energy matter for environmental sustainability: Evidence from top-10 wind energy consumer countries of European Union", *Sustainable Energy, Grids and Networks*, Vol. 31, p. 100716, doi: 10.1016/j.segan.2022.100716.

Chemmanur, T.J. and Tian, X. (2018), "Do Antitakeover Provisions Spur Corporate Innovation? A Regression Discontinuity Analysis", *Journal of Financial and Quantitative Analysis*, Vol. 53 No. 3, pp. 1163–1194, doi: 10.1017/S0022109018000029.

Chen, X., Yi, N., Zhang, L. and Li, D. (2018), "Does institutional pressure foster corporate green innovation? Evidence from China's top 100 companies", *Journal of Cleaner Production*, Vol. 188, pp. 304–311, doi: 10.1016/j.jclepro.2018.03.257.

Chen, Y.-S. and Chang, K.-C. (2013), "The nonlinear effect of green innovation on the corporate competitive advantage", *Quality & Quantity*, Vol. 47 No. 1, pp. 271–286, doi: 10.1007/s11135-011-9518-x.

Cheong, C. and Choi, J. (2020), "Green bonds: a survey", *Journal of Derivatives and Quantitative Studies*, Emerald Publishing Limited, Vol. 28 No. 4, pp. 175–189, doi: 10.1108/JDQS-09-2020-0024.

Choi, B.-K., Ahn, J.-Y. and Choi, M.-C. (2021), "Corporate Social Responsibility, CEO Compensation Structure, and Corporate Innovation Activities", *Sustainability*, Vol. 13 No. 23, p. 13039, doi: 10.3390/su132313039.

Choi, D., Gao, Z. and Jiang, W. (2020), "Attention to Global Warming", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1112–1145, doi: 10.1093/rfs/hhz086.

Cortez, M.C., Silva, F. and Areal, N. (2012), "Socially Responsible Investing in the Global Market: The Performance of Us and European Funds", *International Journal of Finance & Economics*, Vol. 17 No. 3, pp. 254–271, doi: 10.1002/ijfe.454.

Cui, H. and Leung, C.-M.S. (2020), "The long-run performance of acquiring firms in mergers and acquisitions: Does managerial ability matter?", *Journal of Contemporary Accounting & Economics*, Vol. 16 No. 1, p. 100185, doi: 10.1016/j.jcae.2020.100185.

Cui, X., Zhao, K., Zhou, Z. and Huang, P. (2021), "Examining the uncertainty of carbon emission changes: A systematic approach based on peak simulation and resilience assessment", *Environmental Impact Assessment Review*, Vol. 91, p. 106667, doi: 10.1016/j.eiar.2021.106667.

Dai, R., Liang, H. and Ng, L. (2021), "Socially responsible corporate customers", *Journal of Financial Economics*, Vol.142 No.2, pp.598–626, doi: 10.1016/j.jfineco.2020.01.003.

Daugaard, D. (2020), "Emerging new themes in environmental, social and governance investing: a systematic literature review", *Accounting & Finance*, Vol. 60 No. 2, pp. 1501–1530, doi: 10.1111/acfi.12479.

Dessaint, O. and Matray, A. (2017), "Do managers overreact to salient risks? Evidence from hurricane strikes", *Journal of Financial Economics*, Vol. 126 No. 1, pp. 97–121, doi: 10.1016/j.jfineco.2017.07.002.

Destek, M.A. and Aslan, A. (2020), "Disaggregated renewable energy consumption and environmental pollution nexus in G-7 countries", *Renewable Energy*, Vol. 151, pp. 1298–1306, doi: 10.1016/j.renene.2019.11.138.

Dichev, I.D. and Piotroski, J.D. (1999), "The Performance of Long-run Stock Returns Following Issues of Public and Private Debt", *Journal of Business Finance & Accounting*, Vol. 26 No. 9–10, pp. 1103–1132, doi: 10.1111/1468-5957.00288.

Dixon-Fowler, H.R., Ellstrand, A.E. and Johnson, J.L. (2017), "The Role of Board Environmental Committees in Corporate Environmental Performance", *Journal of Business Ethics*, Vol. 140 No. 3, pp. 423–438, doi: 10.1007/s10551-015-2664-7.

Dmytriyev, S.D., Freeman, R.E. and Hörisch, J. (2021), "The Relationship between Stakeholder Theory and Corporate Social Responsibility: Differences, Similarities, and Implications for Social Issues in Management", *Journal of Management Studies*, Vol. 58 No. 6, pp. 1441–1470, doi: 10.1111/joms.12684.

Dogan, E., Chishti, M.Z., Karimi Alavijeh, N. and Tzeremes, P. (2022), "The roles of technology and Kyoto Protocol in energy transition towards COP26 targets: Evidence from the novel GMM-PVAR approach for G-7 countries", *Technological Forecasting and Social Change*, Vol. 181, p. 121756, doi: 10.1016/j.techfore.2022.121756.

Dorfleitner, G., Utz, S. and Zhang, R. (2022), "The pricing of green bonds: external reviews and the shades of green", *Review of Managerial Science*, Vol. 16 No. 3, pp. 797–834, doi: 10.1007/s11846-021-00458-9.

Du, S. and Cao, J. (2023), "Non-family shareholder governance and green innovation of family firms: A socio-emotional wealth theory perspective", *International Review of Financial Analysis*, Vol. 90, p. 102857, doi: 10.1016/j.irfa.2023.102857.

Dutta, A. and Dutta, P. (2015), "Measuring long-run security price performance: a review", *Investment Management and Financial Innovations*, Vol. 12 No. 2.

Dutta, S. and Jog, V. (2009), "The long-term performance of acquiring firms: A re-examination of an anomaly", *Journal of Banking & Finance*, Vol. 33 No. 8, pp. 1400–1412, doi: 10.1016/j.jbankfin.2009.02.004.

Dyck, A., Lins, K.V., Roth, L. and Wagner, H.F. (2019), "Do institutional investors drive corporate social responsibility? International evidence", *Journal of Financial Economics*, Vol. 131 No. 3, pp. 693–714, doi: 10.1016/j.jfineco.2018.08.013.

Eberhardt-Toth, E. (2017), "Who should be on a board corporate social responsibility committee?", *Journal of Cleaner Production*, Vol. 140, pp. 1926–1935, doi: 10.1016/j.jclepro.2016.08.127.

Engle, R.F., Giglio, S., Kelly, B., Lee, H. and Stroebel, J. (2020), "Hedging Climate Change News", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1184–1216, doi: 10.1093/rfs/hhz072.

Fama, E.F. (1998), "Market efficiency, long-term returns, and behavioral finance", *Journal of Financial Economics*, Vol. 49 No. 3, pp. 283–306, doi: 10.1016/S0304-405X(98)00026-9.

Fama, E.F. and French, K.R. (2007), "Disagreement, tastes, and asset prices", *Journal of Financial Economics*, Vol. 83 No. 3, pp. 667–689, doi: 10.1016/j.jfineco.2006.01.003.

Fama, E.F. and Jensen, M.C. (1983), "Separation of Ownership and Control", *The Journal of Law & Economics*, Vol. 26(2) No. 2, pp. 301–325.

Fatica, S. and Panzica, R. (2021), "Green bonds as a tool against climate change?", *Business Strategy and the Environment*, Vol. 30 No. 5, pp. 2688–2701, doi: 10.1002/bse.2771.

Fazzari, S.M. and Athey, M.J. (1987), "Asymmetric Information, Financing Constraints, and Investment", *The Review of Economics and Statistics*, Vol. 69 No. 3, pp. 481–487, doi: 10.2307/1925536.

Febi, W., Schäfer, D., Stephan, A. and Sun, C. (2018), "The impact of liquidity risk on the yield spread of green bonds", *Finance Research Letters*, Vol. 27, pp. 53–59, doi: 10.1016/j.frl.2018.02.025.

Ferrell, A., Liang, H. and Renneboog, L. (2016), "Socially responsible firms", *Journal of Financial Economics*, Vol. 122 No. 3, pp. 585–606, doi: 10.1016/j.jfineco.2015.12.003.

Filippini, M., Greene, W.H., Kumar, N. and Martinez-Cruz, A.L. (2018), "A note on the different interpretation of the correlation parameters in the Bivariate Probit and the Recursive Bivariate Probit", *Economics Letters*, Vol. 167, pp. 104–107, doi: 10.1016/j.econlet.2018.03.018.

Flammer, C. (2021), "Corporate green bonds", *Journal of Financial Economics*, Vol. 142 No. 2, pp. 499–516, doi: 10.1016/j.jfineco.2021.01.010.

Flammer, C., Hong, B. and Minor, D. (2019), "Corporate governance and the rise of integrating corporate social responsibility criteria in executive compensation: Effectiveness and implications for firm outcomes", *Strategic Management Journal*, Vol. 40 No. 7, pp. 1097–1122, doi: 10.1002/smj.3018.

Fu, F. and Huang, S. (2016), "The Persistence of Long-Run Abnormal Returns Following Stock Repurchases and Offerings", *Management Science*, INFORMS, Vol. 62 No. 4, pp. 964–984, doi: 10.1287/mnsc.2015.2150.

Galbreath, J. (2019), "Drivers of Green Innovations: The Impact of Export Intensity, Women Leaders, and Absorptive Capacity", *Journal of Business Ethics*, Vol. 158 No. 1, pp. 47–61, doi: 10.1007/s10551-017-3715-z.

García Lara, J.M., García Osma, B., Mora, A. and Scapin, M. (2017), "The monitoring role of female directors over accounting quality", *Journal of Corporate Finance*, Vol. 45, pp. 651–668, doi: 10.1016/j.jcorpfin.2017.05.016.

García-Sánchez, I.-M., Gómez-Miranda, M.E., David, F. and Rodríguez-Ariza, L. (2019a), "Board independence and GRI-IFC performance standards: The mediating effect of the CSR committee", *Journal of Cleaner Production*, Vol. 225, pp. 554–562, doi: 10.1016/j.jclepro.2019.03.337.

García-Sánchez, I.-M., Hussain, N. and Martínez-Ferrero, J. (2019b), "An empirical analysis of the complementarities and substitutions between effects of ceo ability and corporate governance on socially responsible performance", *Journal of Cleaner Production*, Vol. 215, pp. 1288–1300, doi: 10.1016/j.jclepro.2019.01.130.

Gianfrate, G. and Peri, M. (2019), "The green advantage: Exploring the convenience of issuing green bonds", *Journal of Cleaner Production*, Vol. 219, pp. 127–135, doi: 10.1016/j.jclepro.2019.02.022.

Giglio, S., Maggiori, M., Rao, K., Stroebel, J. and Weber, A. (2021), "Climate Change and Long-Run Discount Rates: Evidence from Real Estate", *The Review of Financial Studies*, Vol. 34 No. 8, pp. 3527–3571, doi: 10.1093/rfs/hhab032.

Gilchrist, D., Yu, J. and Zhong, R. (2021), "The Limits of Green Finance: A Survey of Literature in the Context of Green Bonds and Green Loans", *Sustainability*, Multidisciplinary Digital Publishing Institute, Vol. 13 No. 2, p. 478, doi: 10.3390/su13020478.

Gillan, S.L., Koch, A. and Starks, L.T. (2021), "Firms and social responsibility: A review of ESG and CSR research in corporate finance", *Journal of Corporate Finance*, Vol. 66, p. 101889, doi: 10.1016/j.jcorpfin.2021.101889.

Gompers, P., Ishii, J. and Metrick, A. (2003), "Corporate Governance and Equity Prices", *The Quarterly Journal of Economics*, Vol. 118 No. 1, pp. 107–156, doi: 10.1162/00335530360535162.

Greene, W.H. (1996), "Marginal Effects in the Bivariate Probit Model", SSRN Scholarly Paper, Rochester, NY, 1 June. Accessed: October, 2022

Han, S. and Lee, S. (2019), "Estimation in a generalization of bivariate probit models with dummy endogenous regressors", *Journal of Applied Econometrics*, Vol. 34 No. 6, pp. 994–1015, doi: 10.1002/jae.2727.

Hansen, L.P. (1982), "Large Sample Properties of Generalized Method of Moments Estimators", *Econometrica*, Vol. 50 No. 4, pp. 1029–1054, doi: 10.2307/1912775.

Haque, F. (2017), "The effects of board characteristics and sustainable compensation policy on carbon performance of UK firms", *The British Accounting Review*, Vol. 49 No. 3, pp. 347–364, doi: 10.1016/j.bar.2017.01.001.

Haque, F. and Ntim, C.G. (2020), "Executive Compensation, Sustainable Compensation Policy, Carbon Performance and Market Value", *British Journal of Management*, Vol. 31 No. 3, pp. 525–546, doi: 10.1111/1467-8551.12395.

Harris, M. and Raviv, A. (1991), "The Theory of Capital Structure", *The Journal of Finance*, Vol. 46 No. 1, pp. 297–355, doi: 10.1111/j.1540-6261.1991.tb03753.x.

Hart, O. and Zingales, L. (2017), "Companies Should Maximize Shareholder Welfare Not Market Value", ECGI - Finance Working Paper No. 521/2017, Available at SSRN: http://dx.doi.org/10.2139/ssrn.3004794, doi: 10.2139/ssrn.3004794.

He, X. and Jiang, S. (2019), "Does gender diversity matter for green innovation?", *Business Strategy and the Environment*, Vol. 28 No. 7, pp. 1341–1356, doi: 10.1002/bse.2319.

Hennessy, C.A. (2004), "Tobin's Q, Debt Overhang, and Investment", *The Journal of Finance*, Vol. 59 No. 4, pp. 1717–1742, doi: 10.1111/j.1540-6261.2004.00677.x.

Hillier, D., Pindado, J., Queiroz, V. de and de la Torre, C. (2011), "The impact of country-level corporate governance on research and development", *Journal of International Business Studies*, Vol. 42 No. 1, pp. 76–98, doi: 10.1057/jibs.2010.46.

Holm, A. and Arendt, J.N. (2013), "Evaluating the performance of simple estimators for probit models with two dummy endogenous regressors", *Journal of Statistical Computation and Simulation*, Taylor & Francis, Vol. 83 No. 6, pp. 1156–1178, doi: 10.1080/00949655.2011.652631.

Hong, B., Li, Z. and Minor, D. (2016), "Corporate Governance and Executive Compensation for Corporate Social Responsibility", *Journal of Business Ethics*, Vol. 136 No. 1, pp. 199–213, doi: 10.1007/s10551-015-2962-0.

Hong, H., Karolyi, G.A. and Scheinkman, J.A. (2020), "Climate Finance", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1011–1023, doi: 10.1093/rfs/hhz146.

Hong, H., Li, F.W. and Xu, J. (2019), "Climate risks and market efficiency", *Journal of Econometrics*, Vol. 208 No. 1, pp. 265–281, doi: 10.1016/j.jeconom.2018.09.015.

Hosono, K., Tomiyama, M. and Miyagawa, T. (2004), "Corporate governance and research and development: Evidence from Japan", *Economics of Innovation and New Technology*, Vol. 13 No. 2, pp. 141–164, doi: 10.1080/10438590410001628125.

Howell, S.T. (2017), "Financing Innovation: Evidence from R&D Grants", *American Economic Review*, Vol. 107 No. 4, pp. 1136–1164, doi: 10.1257/aer.20150808.

Humphrey, J.E. and Lee, D.D. (2011), "Australian Socially Responsible Funds: Performance, Risk and Screening Intensity", *Journal of Business Ethics*, Vol. 102 No. 4, pp. 519–535, doi: 10.1007/s10551-011-0836-7.

Hussain, N., Rigoni, U. and Orij, R.P. (2018), "Corporate Governance and Sustainability Performance: Analysis of Triple Bottom Line Performance", *Journal of Business Ethics*, Vol. 149 No. 2, pp. 411–432, doi: 10.1007/s10551-016-3099-5.

Hutchinson, M. and Gul, F.A. (2004), "Investment opportunity set, corporate governance practices and firm performance", *Journal of Corporate Finance*, Vol. 10 No. 4, pp. 595–614, doi: 10.1016/S0929-1199(03)00022-1.

Jensen, M.C. (1986), "Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers", *The American Economic Review*, Vol. 76 No. 2, pp. 323–329.

Jensen, M.C. and Meckling, W.H. (1976), "Theory of the firm: Managerial behavior, agency costs and ownership structure", *Journal of Financial Economics*, Vol. 3 No. 4, pp. 305–360, doi: 10.1016/0304-405X(76)90026-X.

Jia, N., Huang, K.G. and Man Zhang, C. (2019), "Public Governance, Corporate Governance, and Firm Innovation: An Examination of State-Owned Enterprises", *Academy of Management Journal*, Vol. 62 No. 1, pp. 220–247, doi: 10.5465/amj.2016.0543.

Jian, M. and Lee, K.-W. (2015), "CEO compensation and corporate social responsibility", *Journal of Multinational Financial Management*, Vol. 29, pp. 46–65, doi: 10.1016/j.mulfin.2014.11.004.

Jo, H. and Harjoto, M.A. (2012), "The Causal Effect of Corporate Governance on Corporate Social Responsibility", *Journal of Business Ethics*, Vol. 106 No. 1, pp. 53–72, doi: 10.1007/s10551-011-1052-1.

Jo, H. and Na, H. (2012), "Does CSR Reduce Firm Risk? Evidence from Controversial Industry Sectors", *Journal of Business Ethics*, Vol. 110 No. 4, pp. 441–456, doi: 10.1007/s10551-012-1492-2.

Karim, K., Lee, E. and Suh, S. (2018), "Corporate social responsibility and CEO compensation structure", *Advances in Accounting*, Vol. 40, pp. 27–41, doi: 10.1016/j.adiac.2017.11.002.

Kim, Y.-B., An, H.T. and Kim, J.D. (2015), "The effect of carbon risk on the cost of equity capital", *Journal of Cleaner Production*, Vol. 93, pp. 279–287, doi: 10.1016/j.jclepro.2015.01.006.

Kothari, S.P. and Warner, J.B. (1997), "Measuring long-horizon security price performance", *Journal of Financial Economics*, Vol. 43 No. 3, pp. 301–339, doi: 10.1016/S0304-405X(96)00899-9.

Kothari, S.P. and Warner, J.B. (2007), "Econometrics of Event Studies", in Eckbo, B.E. (Ed.), *Handbook of Empirical Corporate Finance*, Elsevier, San Diego, pp. 3–36, doi: 10.1016/B978-0-444-53265-7.50015-9.

Krueger, P., Sautner, Z. and Starks, L.T. (2020), "The Importance of Climate Risks for Institutional Investors", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1067–1111, doi: 10.1093/rfs/hhz137.

La Rocca, M., La Rocca, T. and Cariola, A. (2011), "Capital Structure Decisions During a Firm's Life Cycle", *Small Business Economics*, Vol. 37 No. 1, pp. 107–130, doi: 10.1007/s11187-009-9229-z.

Larcker, D.F. and Watts, E.M. (2020), "Where's the greenium?", *Journal of Accounting and Economics*, Vol. 69 No. 2, p. 101312, doi: 10.1016/j.jacceco.2020.101312.

Lee, I. and Loughran, T. (1998), "Performance following convertible bond issuance", *Journal of Corporate Finance*, Vol. 4 No. 2, pp. 185–207, doi: 10.1016/S0929-1199(98)00007-8.

Lee, K.-H. and Min, B. (2015), "Green R&D for eco-innovation and its impact on carbon emissions and firm performance", *Journal of Cleaner Production*, Vol. 108, pp. 534–542, doi: 10.1016/j.jclepro.2015.05.114.

Lee, K.-H., Min, B. and Yook, K.-H. (2015), "The impacts of carbon (CO2) emissions and environmental research and development (R&D) investment on firm performance", *International Journal of Production Economics*, Vol. 167, pp. 1–11, doi: 10.1016/j.ijpe.2015.05.018.

Li, D., Zheng, M., Cao, C., Chen, X., Ren, S. and Huang, M. (2017), "The impact of legitimacy pressure and corporate profitability on green innovation: Evidence from China top 100", *Journal of Cleaner Production*, Vol. 141, pp. 41–49, doi: 10.1016/j.jclepro.2016.08.123.

Li, Y., Eddie, I. and Liu, J. (2014), "Carbon emissions and the cost of capital: Australian evidence", *Review of Accounting and Finance*, Vol. 13 No. 4, pp. 400–420, doi: 10.1108/RAF-08-2012-0074.

Liao, L., Luo, L. and Tang, Q. (2015), "Gender diversity, board independence, environmental committee and greenhouse gas disclosure", *The British Accounting Review*, Vol. 47 No. 4, pp. 409–424, doi: 10.1016/j.bar.2014.01.002.

Liao, Z., Zhang, M. and Wang, X. (2019), "Do female directors influence firms' environmental innovation? The moderating role of ownership type", *Corporate Social Responsibility and Environmental Management*, Vol. 26 No. 1, pp. 257–263, doi: 10.1002/csr.1677.

Lin, H., Zeng, S.X., Ma, H.Y., Qi, G.Y. and Tam, V.W.Y. (2014), "Can political capital drive corporate green innovation? Lessons from China", *Journal of Cleaner Production*, Vol. 64, pp. 63–72, doi: 10.1016/j.jclepro.2013.07.046.

Lins, K.V., Servaes, H. and Tamayo, A. (2017), "Social Capital, Trust, and Firm Performance: The Value of Corporate Social Responsibility during the Financial Crisis", *The Journal of Finance*, Vol. 72 No. 4, pp. 1785–1824, doi: 10.1111/jofi.12505.

Liu, C. (2018), "Are women greener? Corporate gender diversity and environmental violations", *Journal of Corporate Finance*, Vol. 52, pp. 118–142, doi: 10.1016/j.jcorpfin.2018.08.004.

Lu, J. and Herremans, I.M. (2019), "Board gender diversity and environmental performance: An industries perspective", *Business Strategy and the Environment*, Vol. 28 No. 7, pp. 1449–1464, doi: 10.1002/bse.2326.

Lyon, J.D., Barber, B.M. and Tsai, C.-L. (1999), "Improved Methods for Tests of Long-Run Abnormal Stock Returns", *The Journal of Finance*, Vol. 54 No. 1, pp. 165–201, doi: 10.1111/0022-1082.00101.

MacAskill, S., Roca, E., Liu, B., Stewart, R.A. and Sahin, O. (2021), "Is there a green premium in the green bond market? Systematic literature review revealing premium determinants", *Journal of Cleaner Production*, Vol. 280, p. 124491, doi: 10.1016/j.jclepro.2020.124491.

Malmendier, U., Moretti, E. and Peters, F.S. (2018), "Winning by Losing: Evidence on the Long-run Effects of Mergers", *The Review of Financial Studies*, Vol. 31 No. 8, pp. 3212–3264, doi: 10.1093/rfs/hhy009.

Manning, B., Braam, G. and Reimsbach, D. (2019), "Corporate governance and sustainable business conduct—Effects of board monitoring effectiveness and stakeholder engagement on corporate sustainability performance and disclosure choices", *Corporate Social Responsibility and Environmental Management*, Vol. 26(2) No. 2, pp. 351–366, doi: 10.1002/csr.1687.

Markus, A. and Swift, T. (2019), "Corporate governance and the impact to the R&D lab", *Journal of Strategy and Management*, Vol. 13 No. 1, pp. 91–110, doi: 10.1108/JSMA-06-2019-0100.

McLaughlin, R., Safieddine, A. and Vasudevan, G.K. (1998), "The Long-Run Performance of Convertible Debt Issuers", *Journal of Financial Research*, Vol. 21 No. 4, pp. 373–388, doi: 10.1111/j.1475-6803.1998.tb00692.x.

Mitchell, M.L. and Stafford, E. (2000), "Managerial Decisions and Long-Term Stock Price Performance", *The Journal of Business*, The University of Chicago Press, Vol. 73 No. 3, pp. 287–329, doi: 10.1086/209645.

Modigliani, F. and Miller, M.H. (1958), "The Cost of Capital, Corporation Finance and the Theory of Investment", *The American Economic Review*, American Economic Association, Vol. 48 No. 3, pp. 261–297.

Murfin, J. and Spiegel, M. (2020), "Is the Risk of Sea Level Rise Capitalized in Residential Real Estate?", *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1217–1255, doi: 10.1093/rfs/hhz134.

Myers, S.C. and Majluf, N.S. (1984), "Corporate financing and investment decisions when firms have information that investors do not have", *Journal of Financial Economics*, Vol. 13 No. 2, pp. 187–221, doi: 10.1016/0304-405X(84)90023-0.

Naciti, V. (2019), "Corporate governance and board of directors: The effect of a board composition on firm sustainability performance", *Journal of Cleaner Production*, Vol. 237, p. 117727, doi: 10.1016/j.jclepro.2019.117727.

Nadeem, M., Zaman, R. and Saleem, I. (2017), "Boardroom gender diversity and corporate sustainability practices: Evidence from Australian Securities Exchange listed firms", *Journal of Cleaner Production*, Vol. 149, pp. 874–885, doi: 10.1016/j.jclepro.2017.02.141.

Nguyen, T.H.H., Elmagrhi, M.H., Ntim, C.G. and Wu, Y. (2021), "Environmental performance, sustainability, governance and financial performance: Evidence from heavily polluting industries in China", *Business Strategy and the Environment*, Vol. 30 No. 5, pp. 2313–2331, doi: 10.1002/bse.2748.

Nordhaus, W. (2019), "Climate Change: The Ultimate Challenge for Economics", *American Economic Review*, Vol. 109 No. 6, pp. 1991–2014, doi: 10.1257/aer.109.6.1991.

Nordhaus, W.D. (1977), "Economic Growth and Climate: The Carbon Dioxide Problem", *The American Economic Review*, American Economic Association, Vol. 67 No. 1, pp. 341–346.

Nuber, C. and Velte, P. (2021), "Board gender diversity and carbon emissions: European evidence on curvilinear relationships and critical mass", *Business Strategy and the Environment*, Vol. 30 No. 4, pp. 1958–1992, doi: 10.1002/bse.2727.

O'Connor, M. and Rafferty, M. (2012), "Corporate Governance and Innovation", *Journal of Financial and Quantitative Analysis*, Vol. 47 No. 2, pp. 397–413, doi: 10.1017/S002210901200004X.

Opoku, E.E.O., Kufuor, N.K. and Manu, S.A. (2021), "Gender, electricity access, renewable energy consumption and energy efficiency", *Technological Forecasting and Social Change*, Vol. 173, p. 121121, doi: 10.1016/j.techfore.2021.121121.

Orazalin, N.S., Ntim, C.G. and Malagila, J.K. (2023), “Board Sustainability Committees, Climate Change Initiatives, Carbon Performance, and Market Value”, *British Journal of Management*, doi: 10.1111/1467-8551.12715.

Painter, M. (2020), “An inconvenient cost: The effects of climate change on municipal bonds”, *Journal of Financial Economics*, Vol. 135 No. 2, pp. 468–482, doi: 10.1016/j.jfineco.2019.06.006.

Paranque, B. and Revelli, C. (2019), “Ethico-economic analysis of impact finance: The case of Green Bonds”, *Research in International Business and Finance*, Vol. 47, pp. 57–66, doi: 10.1016/j.ribaf.2017.12.003.

Pástor, L., Stambaugh, R.F. and Taylor, L.A. (2021), “Sustainable investing in equilibrium”, *Journal of Financial Economics*, Vol. 142 No. 2, pp. 550–571, doi: 10.1016/j.jfineco.2020.12.011.

Pearl-Martinez, R. and Stephens, J.C. (2016), “Toward a gender diverse workforce in the renewable energy transition”, *Sustainability: Science, Practice and Policy*, Vol. 12 No. 1, pp. 8–15, doi: 10.1080/15487733.2016.11908149.

Rekker, S.A.C., Benson, K.L. and Faff, R.W. (2014), “Corporate social responsibility and CEO compensation revisited: Do disaggregation, market stress, gender matter?”, *Journal of Economics and Business*, Vol. 72, pp. 84–103, doi: 10.1016/j.jeconbus.2013.11.001.

Renneboog, L. and Vansteenkiste, C. (2019), “Failure and success in mergers and acquisitions”, *Journal of Corporate Finance*, Vol. 58, pp. 650–699, doi: 10.1016/j.jcorpfin.2019.07.010.

Renneboog, L., Ter Horst, J. and Zhang, C. (2008), “The price of ethics and stakeholder governance: The performance of socially responsible mutual funds”, *Journal of Corporate Finance*, Vol. 14 No. 3, pp. 302–322, doi: 10.1016/j.jcorpfin.2008.03.009.

Roodman, D. (2009), “How to do Xtabond2: An Introduction to Difference and System GMM in Stata”, *The Stata Journal*, Vol. 9 No. 1, pp. 86–136, doi: 10.1177/1536867X0900900106.

Ross, S.A. (1977), “The Determination of Financial Structure: The Incentive-Signalling Approach”, *The Bell Journal of Economics*, [RAND Corporation, Wiley], Vol. 8 No. 1, pp. 23–40, doi: 10.2307/3003485.

Sapra, H., Subramanian, A. and Subramanian, K.V. (2014), “Corporate Governance and Innovation: Theory and Evidence”, *Journal of Financial and Quantitative Analysis*, Vol. 49 No. 4, pp. 957–1003, doi: 10.1017/S002210901400060X.

Scherer, A.G. and Voegtlin, C. (2020), “Corporate Governance for Responsible Innovation: Approaches to Corporate Governance and Their Implications for Sustainable Development”, *Academy of Management Perspectives*, Vol. 34 No. 2, pp. 182–208, doi: 10.5465/amp.2017.0175.

Schoenmaker, D. and Schramade, W. (2018), *Principles of Sustainable Finance*, Oxford University Press, Oxford.

Servaes, H. and Tamayo, A. (2013), “The Impact of Corporate Social Responsibility on Firm Value: The Role of Customer Awareness”, *Management Science*, INFORMS, Vol. 59 No. 5, pp. 1045–1061, doi: 10.1287/mnsc.1120.1630.

Shive, S.A. and Forster, M.M. (2020), “Corporate Governance and Pollution Externalities of Public and Private Firms”, *The Review of Financial Studies*, Vol. 33 No. 3, pp. 1296–1330, doi: 10.1093/rfs/hhz079.

Singh, R., Gupta, C.P. and Chaudhary, P. (2023), “Dividend policy and corporate life cycle: a study of Indian companies”, *Managerial Finance*, Vol. ahead-of-print, doi: 10.1108/MF-01-2023-0053.

Spence, M. (1973), “Job Market Signaling”, *The Quarterly Journal of Economics*, Vol. 87 No. 3, pp. 355–374, doi: 10.2307/1882010.

Spiess, D.K. and Affleck-Graves, J. (1999), “The long-run performance of stock returns following debt offerings”, *Journal of Financial Economics*, Vol. 54 No. 1, pp. 45–73, doi: 10.1016/S0304-405X(99)00031-8.

Stein, J.C. (1988), “Takeover Threats and Managerial Myopia”, *Journal of Political Economy*, Vol. 96 No. 1, pp. 61–80, doi: 10.1086/261524.

Suchman, M.C. (1995), “Managing Legitimacy: Strategic and Institutional Approaches”, *Academy of Management Review*, Academy of Management, Vol. 20(3) No. 3, pp. 571–610, doi: 10.5465/amr.1995.9508080331.

Takalo, S.K., Tooranloo, H.S. and Shahabaldini parizi, Z. (2021), “Green innovation: A systematic literature review”, *Journal of Cleaner Production*, Vol. 279, p. 122474, doi: 10.1016/j.jclepro.2020.122474.

Tang, D.Y. and Zhang, Y. (2020), “Do shareholders benefit from green bonds?”, *Journal of Corporate Finance*, Vol. 61, p. 101427, doi: 10.1016/j.jcorpfin.2018.12.001.

Ullah, F., Jiang, P., Ntim, C.G., Shahab, Y. and Jiang, X. (2022), “Female Directors’ Foreign Experience and Environmental and Sustainable Performance”, *Asia-Pacific Journal of Financial Studies*, Vol. 51 No. 2, pp. 169–193, doi: 10.1111/ajfs.12369.

Usman, M., Javed, M. and Yin, J. (2020), “Board internationalization and green innovation”, *Economics Letters*, Vol. 197, p. 109625, doi: 10.1016/j.econlet.2020.109625.

Wang, L. (2022), “Research on the dynamic relationship between China’s renewable energy consumption and carbon emissions based on ARDL model”, *Resources Policy*, Vol. 77, p. 102764, doi: 10.1016/j.resourpol.2022.102764.

Xu, Q. and Kim, T. (2022), “Financial Constraints and Corporate Environmental Policies”, *The Review of Financial Studies*, Vol. 35 No. 2, pp. 576–635, doi: 10.1093/rfs/hhab056.

Yu, J., Saydaliev, H.B., Liu, Z., Nazar, R. and Ali, S. (2022), “The asymmetric nexus of solar energy and environmental quality: Evidence from Top-10 solar energy-consuming countries”, *Energy*, Vol. 247, p. 123381, doi: 10.1016/j.energy.2022.123381.

Zerbib, O.D. (2019), “The effect of pro-environmental preferences on bond prices: Evidence from green bonds”, *Journal of Banking & Finance*, Vol. 98, pp. 39–60, doi: 10.1016/j.jbankfin.2018.10.012.

Zhang, D., Zhang, Z., Ji, Q., Lucey, B. and Liu, J. (2021), “Board characteristics, external governance and the use of renewable energy: International evidence”, *Journal of International Financial Markets, Institutions and Money*, Vol. 72, p. 101317, doi: 10.1016/j.intfin.2021.101317.

Zhang, F. and Zhu, L. (2019), “Enhancing corporate sustainable development: Stakeholder pressures, organizational learning, and green innovation”, *Business Strategy and the Environment*, Vol. 28 No. 6, pp. 1012–1026, doi: 10.1002/bse.2298.

Zhu, Y., Taylor, D. and Wang, Z. (2022), “The role of renewable energy in reducing residential fossil energy-related CO2 emissions: Evidence from rural China”, *Journal of Cleaner Production*, Vol. 366, p. 132891, doi: 10.1016/j.jclepro.2022.132891.