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Credit spreads in the European green bond market: A daily analysis of the COVID-19 pandemic impact

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Abstract

Financial crises and economic downturns provide a unique opportunity to investigate the behavior of investors and financial instruments and shed light in the market's anticipation of future economic growth. In view of the current crisis, we examine how the COVID-19 pandemic affected the European green bond market. Using daily data from Thomson Reuter's Refinitiv, we conducted event studies on corporate credit spread changes over the period from January 1 to December 31, 2020. Our results reveal that green bonds' credit spreads increased significantly after the start of the coronavirus outbreak. However, as the fear of the pandemic eased in response to positive news about the vaccines, green bonds' credit spreads fell below conventional bonds. Overall, green bonds showed a higher risk exposure and lower resilience to distress while profiting during an upside. Our paper provides the first evidence about the impact of the COVID-19 pandemic and the announcement of vaccines' effectiveness on the European corporate green bond market. Our results suggest several key points that are relevant to both investors and issuers under the unprecedented conditions created by the pandemic.

KEYWORDS
COVID-19 pandemic, credit spread, financial innovation, green bonds, sustainable investment

1 | INTRODUCTION

While climate-change-related shocks appear inevitable, governments worldwide are trying to reduce the severity of the associated disruptions to the economy and financial markets through timely and stringent mitigating actions. Against this background, the financial system plays a crucial role in accelerating the necessary transition from a capitalist and closed economy focused on maximizing short-term profits, to a circular and sharing economy, focused on resource preservation, respect for the environment, and consumer safety (Polzin et al., 2017). This transition process certainly requires that large flows of capital be reoriented toward more sustainable investments that integrate Environmental, Social, and Governance (ESG) requirements in decision-making while ensuring the financial system's stability. This is necessary if the European Union is to achieve the objectives set by the 2015 Paris Climate Agreement and the 17 Sustainable Development Goals (SDGs) of the UN 2030 Agenda. In this changing context, green bonds represent a promising financial innovation that fosters the massive reallocation of financial resources needed to transform Europe's economy into a greener and more resilient economy (Flammer, 2021).

Green bonds are fixed-income securities whose proceeds are exclusively used to finance new and existing eligible projects that contribute to environmental sustainability. Their structures, financial risks, and return characteristics are otherwise analog to conventional bonds (Flammer, 2021). The green bonds usually undergo a third-party verification to establish that the proceeds are effectively funding projects intended to generate climate or other environmental benefits. Since the European Investment Bank (EIB) pioneered the Green Bonds market by issuing the world's first Climate Awareness Bond (CAB) in late 2007, more than USD269.5 billion have been allocated globally.[1]

The United States had the largest issuance of green bonds by country, with a total value of USD51.1 billion, followed by Germany with USD40.2 billion, and France with USD32.1 billion. China and the Netherlands issued USD17.2 billion and USD17 billion in green bonds, respectively, rounding out the top five. Looking at market share, green bonds currently account for 50% of the total sustainable bond market and 5% of the overall bond market, which indicates their very high potential for growth over the next few years. However, the COVID-19 pandemic introduced considerable uncertainty about the future of green bonds. Since it began to proliferate in early 2020, the pandemic has shaken global financial markets, caused immense turmoil, and had unprecedented effects that will ripple for years (Ji et al., 2020). Most of the global bond market suffered from higher price volatility and lower trading liquidity as the coronavirus crisis emerged and intensified. The credit spreads (i.e., the difference in yields [in basis points] between a government bond and a corporate bond with the same maturity) have widened at a great speed and reached record levels. The coronavirus outbreak had an immediate impact on the cumulative sustainable (green, social, and sustainability) bond issuance, which dropped by 14% in the earliest days of the crisis compared with the first quarter of 2019, and by 32% compared with the fourth quarter of 2019.[2]

The outbreak of COVID-19 has negatively impacted on the global economy and caused a massive shock in financial markets. At the same time, it has led to a growing focus on sustainability and a greater awareness of ESG risks. Corporates and investors alike have recognized the importance of "greenifying" their portfolios, which are heavily dominated by the utility, financial, and real estate sectors, and instead of looking for more responsible investment strategies, including those involving green bonds. In the third quarter of 2020, four high-profile auto companies issued debut green bonds to help finance their transitions away from Internal Combustion Engine (ICE) vehicles to electric vehicles (EVs). For example, on September 16, 2020, the Volkswagen Group—the World's second-biggest carmaker—issued their first green bonds, worth USD2.4 billion, to finance the development of an extensive EV program. The fact that green bonds are a growing subset of the ESG investment universe, alongside the contentious issue of pricing difference with conventional bonds (i.e., green bond premium; Larcker & Watts, 2020), has presented an opportunity to study the pricing dynamic of green bonds during the COVID-19 pandemic.

In line with the theoretical paradigm posited by Zerbib (2019), investors are willing to accept lower yields to hold green assets rather than conventional ones with equal risk to affirm their green commitment (Fama & French, 2007). According to Löffler et al. (2021), this would justify the existence of a "greenium" (i.e., a green bond premium) that makes green bonds a cheaper source of financing for the issuer than other bonds (Gianfrate & Peri, 2019). However, the recent findings from Larcker and Watts (2020) and Flammer (2021) reveal no pricing difference between green and conventional bonds, confirming that the green projects can generate competitive returns.

The main purpose of this study is to investigate whether corporate green bonds were more resilient relative to conventional bonds in the rampant debt market sell-off following the outbreak of COVID-19. In particular, we empirically analyze the respective credit spreads of green bonds and conventional ones during the first year of the pandemic. During a period of extreme financial turmoil, credit spreads can serve as a crucial indicator of the degree of tensions in the financial markets (Gilchrist & Zakrajšek, 2012). In such a dynamic scenario, fluctuations in corporate bond credit spreads could reflect a default-risk factor that captures compensation demanded by investors—above and beyond expected losses—for bearing exposure to corporate credit risk.

We assume that the COVID-19 pandemic represents an unprecedented economic shock with a variable impact on the different geographical areas of the world depending on the exposure to the pandemic and the effects of the lockdown measures. First, the COVID-19 crisis led governments to impose lockdown measures to contain the spread of the virus, which served as an unexpected shock to global bond markets and numerous other financial markets around the world. Second, unlike the 2008 global financial shock, the COVID-19 pandemic is an exogenous shock originating from a public health crisis and whose devastating consequences are producing severe damage to the real economy and extraordinary volatility on the financial markets. Third, the pandemic resulted in a bond markets crash. Credit spreads on corporate bonds—investment grade and high yield alike—widened above their historical average; liquidity conditions deteriorated substantially for a wide range of bonds, while transaction costs increased sharply. Acharya and Steffen (2020) showed that firms with high credit ratings, and especially those operating in industries heavily affected by lockdown measures, increased their bond issuance activities. Moreover, since the COVID-19 breakdown, they drew down their bank credit lines as a precaution.

To this end, we examine the relation between the credit spreads of green bonds and the COVID-19 pandemic by using European daily data from Thomson Reuter's Refinitiv and conducting a Difference-in-Difference (DID) analysis inside the period spanning from January 1 to December 31, 2020. In a similar vein of Albuquerque et al. (2020), we estimate a DID regression of daily corporate credit spreads with a COVID-19 event date of February 24, when the financial markets decline accelerated. We include a second event date of November 9, when Pfizer and BioNTech announced their experimental COVID-19 vaccine was more than 90% effective in preventing COVID-19, which was a watershed moment in fighting the coronavirus pandemic. We controlled for the second event to understand how credit spreads reacted to the positive shock resulting from the announcement of vaccine efficacy. We added day, country, sector, issuer, and rating fixed effects to control for any other unobservable effects and clustered the standard errors by bonds and day. Finally, since the ESG scores are priced by the markets and affect the cost of both capital and debt, we controlled for the ESG rating of the issuing companies.

As discussed in detail below, the results show that green bonds generate an extra aggregate credit spread between 0.132% and 0.243% from February 24 to March 31 relative to conventional bonds. From the investors' point of view, this means that, if green bonds tend to exhibit lower yields relative to their conventional counterparts under ordinary market conditions (Löffler et al., 2021), then in periods of heightened market volatility, corporate green bonds behave like high beta securities: offering higher risk premiums compared with conventional bonds as compensation for the uncertain profitability and a higher risk of default. We find further support for green bond underperformance—given the stronger run-up in their credit spread—when running the robustness tests.

Next, we find that the green bond credit spreads narrowed on optimism about Pfizer–BioNTech's COVID-19 vaccine, paying a lower premium compared with conventional ones from November 9, 2020, until the end of December. Several distinct periods can be identified in the behavior of corporate credit spreads of both green and conventional bonds during the global outbreak of COVID-19. When the virus led to the first crisis in China (the Wuhan lockdown on January 23, 2020), corporate credit spreads remained stable. Only after February 24, when 11 municipalities in Northern Italy entered lockdown, did the green bonds' credit spreads start to rise, surpassing conventional bonds and reaching their peak in mid-March 2020. Green bonds' credit spreads fell below the conventional ones in October and retreated significantly after November 9, when US-based Pfizer and Germany's BioNTech revealed positive results from trials of their vaccine.

We can deduce that the promising developments on the vaccine front have investors' optimism on the impending end of the COVID-19 pandemic and a possible return to normalcy. Investors—concerned about the broader impact of the coronavirus outbreak—showed renewed confidence in the green bond market over the conventional bond market, giving green bonds issuers the financing needed to recover after the COVID-19 crisis and triggering a pull-back in green bonds' credit spreads. Furthermore, the COVID-19 pandemic highlighted the substantial negative impact of humans on the environment. Hence, it may have led to increased investor beliefs that consumer demand for green products and services will increase in the long run and that green investment will have a positive impact on the economic recovery in the post-COVID world.

Green bonds' credit spreads decreased further in the following month until December 31, 2020, showing greater capacity to profit from upturns. Overall, our results reveal that green bonds showed a higher risk exposure and a lower resilience to distress than conventional bonds during the COVID-19 crisis, while profiting more of any upside. At the onset of the pandemic, green bonds performed worse than conventional bonds, just to rebound with greater force as the fear of the pandemic eased after the vaccine announcement.

This study makes several contributions to the literature. First, it adds to the growing literature on the financial and economic consequences of the COVID-19 shock by providing novel evidence on the behavior of green bonds' credit spreads in a comprehensive sample of European issuers. The limited research conducted so far has focused on the effects of the COVID-19 pandemic on bond markets pricing (Bi & Marsh, 2020; Nozawa & Qiu, 2021).

However, very little is known about the green bond markets. An exception is the recent article by Naeem et al. (2021), who analyzed the level of efficiency of the green and traditional bond markets before and during the Coronavirus crisis by examining the presence of asymmetric multifractality. Taking the outbreak of the COVID-19 pandemic as an exogenous shock, our paper uses the event study method and econometric models to investigate the impact of COVID-19 and the announcement of the vaccine's effectiveness on Europe's green bond market for the first time, as well as analyzed the underlying reasons behind these impacts.

Second, we contribute to the growing literature that studies the green bond market Zerbib (2019). Since this literature focuses mainly on the pricing of green bonds in the market for municipal and sovereign green bonds, there is a lack of studies examining corporate green bonds. The sole exceptions are the recent studies by Tang and Zhang (2020) and Flammer (2021). They found evidence that the stock market responds positively to the issuance announcement of corporate green bonds, especially for first-time issuers and bonds certified by third parties. Our study complements this body of research by examining whether previous studies' findings about a green bond premium—defined as the yield differential between a green bond and an otherwise identical conventional bond, persisted during the COVID-19 pandemic and after the announcement of the vaccine's effectiveness.

Finally, this paper contributes to the recent debate on whether firms with higher ESG ratings are relatively more resilient during crisis periods (Albuquerque et al., 2020; Ding et al., 2021; Lins et al., 2017). Specifically, we estimate the relation between ESG and credit spreads' behavior during the COVID-19 crisis. Our findings indicate that firms with high ESG scores have higher resilience to adverse shocks (like COVID-19).

The remainder of the paper is organized as follows. In Section 2, we describe our testable prediction. In Section 3, we present our data, summary statistics, and methodology. In Section 4, we show the baseline results, and in Section 5, we add some robustness tests to the main outcomes. Section 6 concludes the paper.

2 | TESTABLE PREDICTIONS

The COVID-19 outbreak revealed the malfunctions in the debt market that pose a threat to firms' survival. As the uncertainty about the economy's future persists companies that are highly leveraged or are not highly profitable experience difficulty refinancing expiring bonds and loans, or they only service these at a much higher financial cost. With much less or no incoming revenues in the wake of pandemic-fighting lockdowns and fewer options to deal with this shortfall, even companies that were profitable and had healthy balance sheets before the virus outbreak can quickly run into financial trouble. As it usually happens during periods of market distress, the COVID-19 shock negatively affected investors' attitudes toward risk, triggering sell-offs in financial markets. This tendency had an immediate impact on corporate bond markets in Europe, changing the valuation of assets.

According to the literature on sustainable and responsible investments (SRI), investors with a preference for environmental and social stocks are more loyal and less sensitive to sustainable funds' performance than to conventional mutual funds' performance (Albuquerque et al., 2020; Bollen, 2007; Renneboog et al., 2011). Furthermore, investors with a longer investment horizon prefer to hold high ESG firms and behave more patiently when incurring a loss (Starks et al., 2017). In line with this literature, we expect green bonds credit spreads to be more stable than conventional bonds during the market turmoil, reflecting a more stable and committed investor base.

Following the segmented capital markets model developed by Heinkel et al. (2001), polluting firms are held by a subset of investors. Since those investors who are sensitive to the environment choose not to hold them, polluting firms have a less diversified investor base and carry higher systematic risk than green firms with greater valuations. In their empirical study, Tang and Zhang (2020) find evidence that green bond issuance helps firms enlarge their investor base and attract investors with a green mandate and socially responsible funds by signaling firms' dedication to sustainable development.

Furthermore, as investing in green bonds reduces portfolio downside risk for investors holding dirty energy stocks or international equity indices (Kuang, 2021), they can be a safe haven asset during the COVID-19 pandemic, delivering less when economic conditions are improving, in exchange for a stronger resilience during downturns. On the basis of the above arguments, the escape from the market due to the COVID-19 crisis should be less effective for sustainability-oriented investors. Then the credit spreads of green bonds should not increase as much relative to the credit spreads of conventional bonds. Hence, we hypothesize the following:

H1a: *Credit spreads of green bonds increase less compared with conventional bonds after February 24, when 11 municipalities in Northern Italy entered lockdown.*

On the other hand, some investors prefer to hold assets with a low environmental impact and avoid low sustainability investments not because they care about the environment per se, but because they rationally view such investments as a way to maximize profits (Hartzmark & Sussman, 2019; Nilsson, 2008) or reduce risk (Gangi et al., 2020; Godfrey et al., 2009). Empirical evidence from Larcker and Watts (2020) and Flammer (2021) confirm that green bonds provide investors with at least the same risk-return trade-off as conventional bonds. Investors might therefore be attracted to green bonds for solely financial reasons.

Since the green bond market is impacted by shocks occurring in other financial markets (Reboredo & Ugolini, 2020), the environment of uncertainty and fluctuation in global financial markets caused by the COVID-19 pandemic may have impacted the green bond market, at least in a short term, by potentially providing an incentive for investors—especially those driven by profit—to sell green bonds and focus on more traditional investment instruments. As stated by Zeidan (2020) "amidst a global crisis, the search for financial returns (or minimizing financial losses) takes precedence among all else, in financial markets."

According to the literature (Delmas & Burbano, 2011; Marquis et al., 2016), the significant market pressure to adopt environmentally friendly policies may feed greenwashing practices: corporate behaviors that present an obvious discrepancy between the claims about the company's environmental commitment and its environmental performances (Lyon & Montgomery, 2015).

Greenwashing is a widespread phenomenon, and green bond issuers could decide to engage in this practice to portray themselves as environmentally responsible without taking tangible actions. Due to a lack of unified standards for identifying a green bond and the limited legal enforcement for supervising green integrity, the green bond market is a conducive environment for greenwashing practices.[3] Moreover, the COVID-19 pandemic has increased general awareness about the urgency of the climate-change crisis and the need to address environmental and sustainability challenges. As a result, there is increasing market pressure on companies to go green (Severo et al., 2021). The changing landscape triggered by COVID-19 might have encouraged firms to engage in greenwashing practices to appear socially and ecologically more sustainable and gain legitimacy from the public (Zeidan, 2020). Since greenwashing negatively affects firm performance (Du, 2015; Price & Sun, 2017) and the intention to invest (Gatti et al., 2021), we might expect that investors will be more willing to sell green bonds than conventional ones due to the potential risk of greenwashing.

Finally, green assets are susceptible to oil market volatility and oil price fluctuations; therefore, when the crude oil market experiences high volatility regimes, the incentives and interests of green investments decrease (Dutta et al., 2020). The coronavirus pandemic has negatively impacted the oil industry, reducing the global demand for crude oil and triggering an oil trade war between Saudi Arabia and Russia—the major oil-producing nations (Bourghelle et al., 2021). The high levels of oil price volatility due to the pandemic may have influenced green bonds' credit spreads (Lee et al., 2021). On the basis of these considerations, we expect green bonds' credit spreads to be less stable than those of conventional bonds during the market turmoil. Accordingly, we developed the following alternative hypothesis:

H1b: *Credit spreads of green bonds increased more compared with conventional bonds after February 24, when 11 municipalities in Northern Italy entered lockdown.*

Investor sentiment (i.e., the optimism or pessimism that an investor has about the financial market in the future)[4] can be affected by published news and witnessing an event (Broadstock & Cheng, 2019). Therefore, if the outbreak of the COVID-19 pandemic led to a massive sell-off of global financial assets, the surprising success rate of a coronavirus vaccine trial from Pfizer and BioNTech may represent a game change for the dynamics of the world economy, giving a material reason to change the overall financial market outlook.

In response to the worsening COVID-19 pandemic, the European Commission and the European Central Bank (ECB) took a series of monetary and fiscal policies designed to first mitigate and contain the economic repercussions of the coronavirus crisis, and then to support the economic recovery (see Table 1). Among these interventions, the European Commission announced the "Next Generation EU" (NG-EU) project in July 2020—a €750 billion package funded through the issue of bonds on the financial markets by the European Commission on behalf of the EU (see Arce Hortigüela et al., 2020). The package offers financial support to all the Member States—especially those most affected by the pandemic—through a mixture of grants and loans to finance urgent investments and reforms, particularly in the green and digital transitions. In the years to come, the NG-EU project will strongly support green-based spending and investments mainly through each Member State's Recovery and Resilience Plan (RRP).

All those initiatives may have played a strong role in the recovery of the green bond market. In light of the above, we hypothesize the following:

H2: *Credit spreads of green bonds decreased more than conventional bonds after the positive shock represented by the announcement of the vaccine's effectiveness on November 9, 2020.*

TABLE 1 This table reports the fiscal and monetary policies to support in the European Union during 2020 (COVID-19 pandemic)

	Date	Description
EU fiscal support measures		
Safety net	April 9, 2020	The Eurogroup puts forward €500 billion support package
	April 23, 2020	The European Council endorsed the support package agreement
	May 8, 2020	The Eurogroup agrees deal on emergency financial support to euro area countries
	May 15, 2020	The credit line was made operational by the ESM Board of Governors
Protecting workers and jobs		A temporary loan-based instrument (SURE) of up to €100 billion to protect workers and jobs, supported by guarantees from EU member states
	May 15, 2020	The European Council reaches political agreement on safety net for jobs and workers (SURE)
	May 19, 2020	The EU implements the temporary scheme to support workers (SURE)
	September 25, 2020	The European Council approves €87.4 billion in financial support for member states under SURE
Loan guarantees		€25 billion in government guarantees to the European Investment Bank (EIB) to support up to €200 billion to finance to companies, especially SMEs
	May 15, 2020	The Eurogroup discusses priorities for the EU recovery
	May 26, 2020	President Centeno welcomes EIB agreement on safety net for businesses. Adoption June 1
Fiscal rules flexibility	March 23, 2020	The Finance ministers agree to ease EU fiscal rules in COVID-19 fallout. The aim is to suspend the fiscal adjustment requirements for countries that are not at their medium-term objective
Temporary flexibility in the state aide rules	May 8, 2020	The European Commission adopted a second amendment to extend the scope of the state aid temporary framework to recapitalization and subordinated debt measures to further support the economy in the context of the coronavirus outbreak through September 2021
Next Generation EU (NGEU) recovery package	April 23, 2020	The EU leaders work on a recovery fund
	May 27, 2020	The European Council discuss Commission's proposal for MFF and recovery fund

TABLE 1 (Continued)

	Date	Description
	July 17–21, 2020	The EU leaders agreed a deal on the recovery package and the European budget for 2021–2027
	November 10, 2020	Political agreement reached in negotiations on EU's long-term budget and recovery plan
	December 17, 2020	Long-term EU budget 2021–2027 adopted
	December 18, 2020	The Council and the Parliament reach a provisional agreement on the Recovery and Resilience Facility
ECB monetary policy measures		
Increasing banks' lending capacity	March 12, 2020	The ECB Banking Supervision provides temporary capital and operational relief in reaction to coronavirus
	March 20, 2020	The ECB Banking Supervision provides further flexibility to banks in reaction to coronavirus
	March 27, 2020	The ECB asks banks not to pay dividends until at least October 2020
Ensuring short-term concerns do not prevent lending	March 12, 2020	The ECB announces measures to support bank liquidity conditions and money market activity
Supporting access to credit for firms and households	March 12, 2020	The ECB announces easing of conditions for targeted longer-term refinancing operations (TLTRO III)
	April 7, 2020	The ECB announces package of temporary collateral easing measures
	April 30, 2020	The ECB recalibrates TLTRO-III to further support real economy
	April 30, 2020	The ECB announces new pandemic emergency longer-term refinancing operations (PELTROs)
	December 10, 2020	The ECB prolongs support via TLTRO-III for banks that lend to the real economy
	December 10, 2020	The ECB extends PELTROs
Other MP to absorb the shock of the COVID-19	March 18, 2020	The ECB announces €750 billion Pandemic Emergency Purchase Program (PEPP)
	June 4, 2020	Monetary policy decisions: (1) The PEPP increased by €600 billion to a total of €1,350 billion (2) The horizon for the PEPP will be extended to at least the end of June 2021 (3) The maturing principal payments from securities purchased under the PEPP will be reinvested until at least the end of 2022

(Continues)

TABLE 1 (Continued)

Date	Description
	(4) Net purchases under the asset purchase program (APP) will continue at a monthly pace of €20 billion, together with the purchases under the additional €120 billion temporary envelope until the end of the year (5) Reinvestments of the principal payments from maturing securities purchased under the APP will continue, in full

Source: European Central Bank, European Council, Eurogroup, European Parliament, and European Commission.

3 | DATA AND SAMPLE

3.1 | Data

To compile a complete corporate bonds database (both conventional and green) in Europe, we extracted all corporate bonds in the Thomson Reuter's Refinitiv fixed-income database. We excluded bonds whose issuer's sector is "Government" and "Supranational." Moreover, we excluded bonds whose issuer is not located in Europe and whose currency is different from the euro. Finally, we only included bonds that are labeled as "plain vanilla fixed coupon bond." The above criteria yielded 7935 corporate bonds (209 green bonds and 7726 conventional bonds) listed from January 1 to December 31, 2020. Thomson Reuter's Refinitiv contains information including the amount, maturity, credit rating, issuer, and collateral presence for each bond. We used the same database to collect daily green credit spread and conventional credit spread data.

A possible drawback of using bonds is the stale price problem and, in particular, the possibility of infrequent trading among corporate bonds. The stale price problem has been deeply studied in the financial markets literature, among others, Diaz and Skinner (2001), Qian (2011), and Zitzewitz (2006). This literature has focused on the fact that investors can take advantage of mutual funds that calculate their NAVs using stale closing prices by trading based on recent market movements. Notably, the stale price problem is usually linked to exchange traded fund (ETF) or mutual funds (Qian, 2011). Diaz and Skinner (2001) tested arbitrage-free pricing models, showing that the structure of errors produced by standard statistical yield curve models indicates that the liquidity problem remains, even with careful data selection. The authors found evidence that the errors due to illiquidity are modest and controlling bonds by rating category produces no significant bias in the estimations of the yield curve. Moreover, Galliani et al. (2014) investigated the liquidity of the European fixed-income market using a large sample of government, corporate, and covered bonds.

The evidence that corporate bonds may suffer from the stale price problem shows that an important driver of bond liquidity is the size of the bond issue and the importance of rating (they suggest that regulators create incentives for plain vanilla issues). Taking these considerations into account, we tried to solve this issue by considering the corporate bonds that are more liquid. We only included bonds that are "plain vanilla fixed coupon bonds," and for which there is information on rating, in line with the suggestions of Diaz and Skinner (2001) and Galliani et al. (2014).

Finally, Table 2 defines all variables used in the paper. The sample size varies across regression specifications because not all variables were available for all firm-daily observations.

3.2 | Summary statistics

Table 3 provides a categorization of corporate green and conventional bonds by industries. Industries are partitioned according to The Refinitiv Business Classifications (TRBCs) codes. As can be seen, corporate green bonds are more common in the financials, utilities, and oil and gas (energy) sectors where the environment is likely core to the firm's operations (similar to Flammer, 2021). Table 4 shows a breakdown by country. Notably, green bonds are especially prevalent in the Netherlands, France, Germany, and Italy, in line with Flammer (2021).

Table 5 presents corporate and conventional bonds by rating. The more significant parts of both green and conventional issued bonds have an investment-grade rating. In contrast, a residual part is classified as high yield (especially for green bonds, which in relative terms, represent about 3.3% (180/5481) of the total investment-grade bonds, while representing approximately 1.5% (8/546) of total high-yield bonds). Our econometric analyses did not include

TABLE 2 Variables, definitions, and sources

Variable	Definition	Source
Ln Credit Spread	The Credit Spread is the natural logarithm of the difference in yields (in basis points) between a government bond and a corporate bond with the same maturity	Thomson Reuter's Refinitiv
ESG	ASSET4 ESG Company Rating	Thomson Reuter's Refinitiv
Green	Dummy variable that equals one if in the Thomson Reuter's Refinitiv database the bonds are labeled as "green bonds" (more precisely, bonds for which the filed "Green Bonds" is "Yes")	Thomson Reuter's Refinitiv
Post-COVID	Dummy variable that equals one from February 24 to March 31, 2020, and zero from January 1 to February 23, 2020 (Albuquerque et al., 2020; Ramelli & Wagner, 2020)	
Postvaccine	Dummy variable that equals one from November 9 to December 31, 2020, and zero from October 1 to November 8, 2020	
Sector	We use the Refinitiv Business Classification (TRBC) as our industry classification	Thomson Reuter's Refinitiv
Rating	The rating data are from Moody's Investors Service historical database. In Moody's Investors Service's rating system, securities are assigned a rating from Aaa to C, with Aaa being the highest quality and C the lowest quality	Thomson Reuter's Refinitiv
Collateral	Dummy variable that equals one if collateral was pledged at bond origination, zero otherwise	Thomson Reuter's Refinitiv
Amount Issued	The natural logarithm of the total amount issue of bonds	Thomson Reuter's Refinitiv

Abbreviation: ESG, Environmental, Social, and Governance.

TABLE 3 Corporate conventional and green bonds by industry

Industry	No. green bonds	No. conventional bonds	Total
Financials			
Banking	76	4755	4831
Financial	50	1661	1711
Mortgage banking	12	122	134
Real estate	0	33	33
Industrials			
Service	1	188	189
Utility	35	89	124
Telecommunications	1	117	118
Oil and gas	10	55	65
Automotive manufacturer	2	61	63
Chemicals	2	55	57
Beverage/bottling	0	56	56
Transportation	3	49	52
Gas utility	3	41	44
Conglomerate/diversified Mfg	1	38	39
Electronics	2	33	35
Cable/media	0	35	35
Pharmaceuticals	0	30	30
Containers	2	18	20
Others	9	290	299
Total	209	7726	7935

Note: This table reports the number of corporate conventional and green bonds by industry, using all corporate conventional and green bonds during 2020 listed in euro. Industries are partitioned according to The Refinitiv Business Classifications (TRBCs) codes.

bonds that lacked rating information. We were left with 6027 bonds (188 green, 5839 conventional), of which 5481 were investment grade (180 green and 5301 conventional).

In Table 6, we present the summary statistics with delineations between green and conventional bonds. Corporate green bonds have relatively large average issuance amounts compared with conventional ones. The average green bonds issuance amount during the COVID-19 outbreak (Vaccine Announcement) is 700 (706) million euros, while the conventional ones are 245 (253) million euros.[5] The average bond with collateral is about 20% for green bonds and 26% for conventional ones. Interestingly, the average ESG score of the issuer for both green and traditional bonds is quite similar: 77 for green bonds and 78 for conventional bonds. Finally, we evidence that the average Ln Credit Spread is lower for a green bond than that for the conventional one (96 b.p. green and 109 b.p. conventional).[6]

TABLE 4 Corporate conventional and green bonds by European countries

Country	Green bonds	Conventional bonds	Total
Austria	5	420	425
Belgium	2	123	125
Bulgaria	0	1	1
Croatia	0	4	4
Cyprus	0	1	1
Czech Republic	0	24	24
Denmark	2	51	53
Estonia	0	5	5
Finland	4	140	144
France	26	1055	1081
Germany	57	3423	3480
Greece	0	4	4
Hungary	0	2	2
Ireland	2	105	107
Italy	15	311	326
Latvia	1	0	1
Luxembourg	8	254	262
Netherlands	56	728	784
Poland	0	22	22
Portugal	1	28	29
Slovakia	0	50	50
Spain	12	289	301
Sweden	9	173	182
United Kingdom	9	513	522
Total	209	7726	7935

Note: This table reports the number of corporate conventional and green bonds by country, using all corporate bonds during 2020 listed in euro.

3.3 | Empirical design

Our econometric approach is based on a DID design used to identify the effect of the COVID-19 pandemic and the vaccine announcement on the corporate green bonds credit spreads. This approach has been widely used to evaluate the impact of the COVID-19 pandemic in the empirical literature (Albuquerque et al., 2020; Brodeur et al., 2021). To understand the impact of the COVID-19 pandemic, we ran the following daily regression for the period from January 1, 2019 to March 31, 2020:

TABLE 5 Corporate conventional and green bonds by rating

Rating	Green bonds	Conventional bonds	Total
Investment grade (IG)			
Aaa	6	1053	1059
Aa1	1	498	499
Aa2	8	154	162
Aa3	12	481	493
A1	12	283	295
A2	12	760	772
A3	45	502	547
Baa1	43	547	590
Baa2	29	723	752
Baa3	12	300	312
Bonds with IG rating	180	5301	5481
High yield (HY)			
Ba1	1	68	69
Ba2	1	133	134
Ba3	0	65	65
B1	2	68	70
B2	2	70	72
B3	2	50	52
C	0	1	1
Ca	0	7	7
Caa1	0	42	42
Caa2	0	28	28
Caa3	0	6	6
Bonds with HY rating	8	538	546
Bonds with rating	188	5839	6027
Bonds without rating			
Withdrawn rating (WR)	2	134	136
No rating	19	1753	1772
Bonds without rating	21	1887	1908
Total	209	7726	7935

Note: This table reports the number of corporate conventional and green bonds by rating, using all corporate conventional and green bonds during 2020 listed in euro. Ratings are partitioned according to Moody's credit ratings classifications codes.

TABLE 6 This table reports the summary statistics (number of observations, mean, median, standard deviation (SD), min, and max) for all variables

	Bonds	Obs.	Mean	Median	SD	Min	Max
Panel A: COVID (January 1–March 31, 2020)							
Ln Credit Spread	Green	7188	4.565	4.458	0.498	3.493	6.461
	Conventional	255,511	4.694	4.520	0.952	0.693	14.075
Collateral	Green	7188	0.208	0.000	0.406	0.000	1.000
	Conventional	255,511	0.265	0.000	0.441	0.000	1.000
Amount Issued	Green	7188	20.368	20.208	0.435	18.599	21.307
	Conventional	255,511	19.317	20.208	1.752	11.124	22.511
ESG	Green	4698	77.188	79.480	11.360	28.160	93.960
	Conventional	143,194	78.437	83.320	12.223	24.360	93.960
Panel B: Vaccine (October 1–December 31, 2020)							
Ln Credit Spread	Green	9502	4.397	4.324	0.480	3.001	6.090
	Conventional	293,285	4.573	4.402	1.032	−2.303	17.424
Collateral	Green	9502	0.224	0.000	0.417	0.000	1.000
	Conventional	293,285	0.267	0.000	0.443	0.000	1.000
Amount Issued	Green	9502	20.376	20.208	0.428	18.599	21.307
	Conventional	293,285	19.351	20.208	1.736	11.124	22.693
ESG	Green	6206	77.423	79.480	11.191	28.160	93.960
	Conventional	170,187	78.278	83.250	12.263	24.360	93.960

Note: Panel A shows the summary statistics for the sample from January 1 to March 31, 2020, and Panel B for the sample from October 1 to December 31, 2020. Table 2 defines all variables used in the paper.

Abbreviation: ESG, Environmental, Social, and Governance.

$$\begin{aligned} \mathit{Credit\ Spread}_{i,t} = {} & \beta_0 + \beta_1 \mathit{Green}_i + \beta_2 \mathit{COVID}_t \\ & + \beta_3 \mathit{Green}_i \times \mathit{COVID}_t + \beta_4 \mathit{Collateral}_i + \beta_5 \mathit{Amount\ Issued}_i \\ & + \beta_6 \mathit{Time\ FE}_t + \beta_7 \mathit{Country\ FE}_c + \beta_8 \mathit{Issurer\ FE}_i \\ & + \beta_9 \mathit{Rating\ FE}_i + \epsilon_{i,t}, \end{aligned} \tag{1}$$

where the $\mathit{Credit\ Spread}_{i,t}$ variable is the natural logarithm of the daily credit spread of bond i on day t. Green_i is a dummy variable that equals one for bond i that is classified as "Green Bond" in the Thomson Reuter's Refinitiv fixed-income database and zero otherwise. COVID_t equals one from February 24 to April 30, 2020, and zero before this period. We also included a proxy for bond size calculated as the natural logarithm of the amount issued by the firm ($\mathit{Amount\ Issued}_i$) and the presence of collateral ($\mathit{Collateral}_i$). $\mathit{Time\ FE}_t$ represents day fixed effects, $\mathit{Country\ FE}_c$ is day country effects, $\mathit{Issurer\ FE}_i$ represents issuer fixed effects, $\mathit{Rating\ FE}_i$ is rating fixed effects, and $\epsilon_{i,t}$ represents an error term. In all specifications, we considered time, country, sector, issuer, and rating fixed effects to control for any other unobservable effects. Finally, we clustered the standard errors by bonds and day. We are also interested in understanding the impact of the vaccine announcement; thus, we estimated the following equation for the period from October 1 to December 31, 2020:

$$\begin{aligned} Credit\ Spread_{i,t} = \beta_0 &+ \beta_1 Green_i + \beta_2 Vaccine_t \\ &+ \beta_3 Green_i \times Vaccine_t + \beta_4 Collateral_i + \beta_5 Amount\ Issued_i \\ &+ \beta_6 Time\ FE_t + \beta_7 Country\ FE_c + \beta_8 Issurer\ FE_i \\ &+ \beta_9 Rating\ FE_i + \epsilon_{i,t}, \end{aligned} \tag{2}$$

where $Vaccine_t$ equals one from November 9 to December 31, 2020, and zero before this period. To understand our choice of events window for $COVID_t$ and $Vaccine_t$, consider Figure 1. Figure 1 shows the evolution of the natural logarithm of the credit spread for both the green and conventional bonds, with two dates highlighted: February 24 (Panel A) and November 9 (Panel B). These dates are used to identify the COVID-19 pandemic and vaccine shock in our DID setup. Following Albuquerque et al. (2020) and Ramelli and Wagner (2020), February 24 is the start of the "fever period" and also the first trading day after the first lockdown in Europe (11 municipalities in Northern Italy).

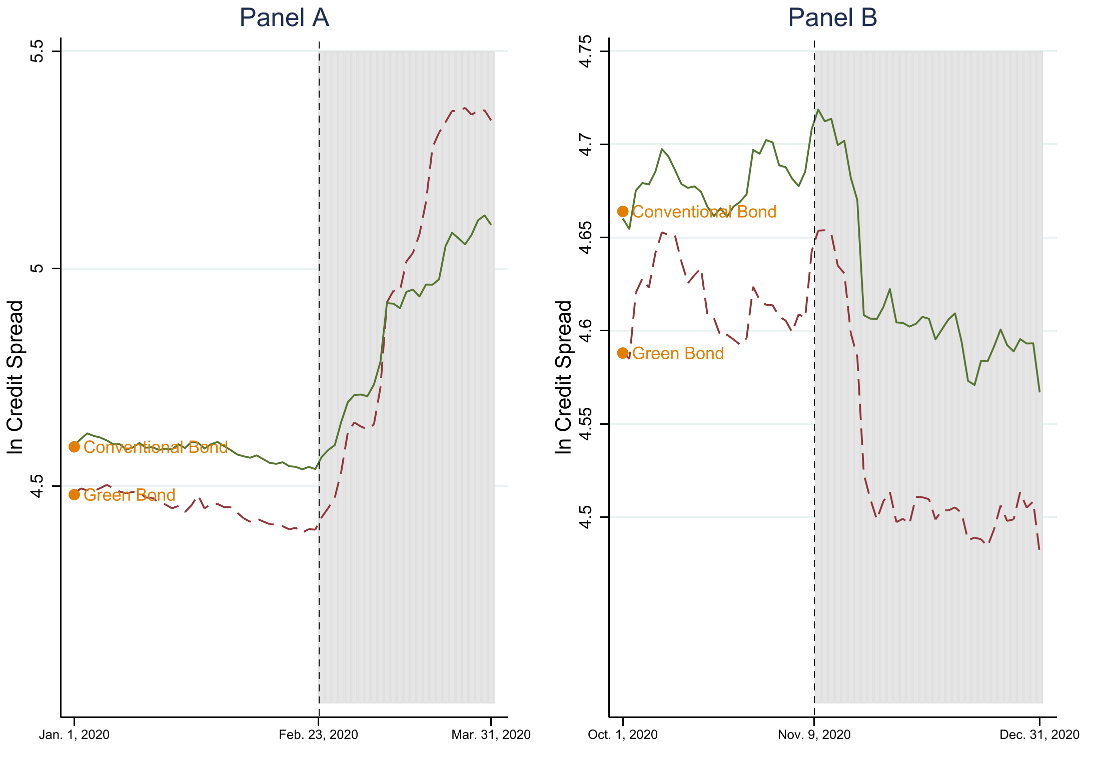

FIGURE 1 Evolution of green bond versus conventional bond. This figure shows the development of the natural logarithm of the Credit Spread (in basis point) during 2020 for both the Green bonds and Conventional ones. The Credit Spread is the difference in yields (in basis points) between a government bond and a corporate bond with the same maturity. Panel A shows the dynamics of the natural log of the credit spread (green vs conventional) during the COVID-19 outbreak. The vertical dashed line represented when the first lockdown in Europe started (COVID, February 23, 2020). Panel B shows the dynamics before and after the Vaccine Announcement. The vertical dashed line represents the day when Pfizer–BioNTech announced the efficacy of their COVID-19 vaccine (Vaccine, November 9, 2020)

Furthermore, for the second part of the analysis, we constructed a second event dummy to isolate the effect of the vaccine announcements on corporate green bonds' credit spread. November 9 is the day that Pfizer–BioNTech announced that their vaccine candidate against COVID-19 was found to be more than 90% effective in preventing COVID-19.[7] The key coefficient in both Equations (1) and (2) is β_3. If the coefficient of the DID term (β_3) is positive (negative) on credit spread, then we assume that the COVID-19 pandemic has contributed to increasing (decrease) the green bond credit spread relative to conventional ones.

4 | EMPIRICAL ANALYSIS

4.1 | Baseline results

Panel A in Table 7 shows the main results for Equation (1). The coefficients associated with *Amount issued* are negative and statistically significant. Moreover, the presence of collateral reduces the bond credit spread. The outcomes show that the coefficient associated with *Green* is negative and significant for all specifications. The green bonds pay a lower premium than the conventional ones, in line with Tang and Zhang (2020) and Zerbib (2019). The *COVID* dummy is always positive, evidencing an increase in credit spread after the COVID-19 pandemic shock. The variable of interest *Green* ∗ *COVID* is positive and statistically significant. The green bonds generate an extra aggregate credit spread of 0.173% after the COVID-19 shocks. These results suggest that green bonds were generally associated with higher credit spread after the COVID-19 pandemic shock supporting our *Hypothesis 1b*.

Next, we investigated if the vaccine's impact on a green bond credit spread differed from the COVID-19 pandemic shock. The results are reported in Panel B of Table 7. The *Vaccine* dummy is always negative, evidencing a decrease of credit spread after Pfizer–BioNTech's announcement of their vaccine's effectiveness. Our variable of interest *Green* ∗ *Vaccine* is now negative and statistically significant, suggesting that the green bond credit spread was generally negatively affected by the announcement of the COVID-19 vaccine and paid a lower premium than the conventional ones (−0.044%). Thus, the results support *Hypothesis 2* (that the credit spreads of green bonds decreased more than conventional bonds after the announcement of the vaccine effectiveness on November 9, 2020). This result supports the argument of Park et al. (2020) regarding the increased sensitivity of green bonds to positive shocks. As green bonds have experienced rapid growth in recent years, investors view them with hope and react strongly to minor pieces of good news.

5 | ROBUSTNESS TESTS

In this section, we provide various robustness tests. To mitigate the potential confounding events, we considered monetary and fiscal interventions by the European Union to support the European economy during the COVID-19 pandemic. Specifically, we introduced two dummy variables (that take the value of one on the day of the fiscal and monetary policies announcements and zero otherwise) in our baseline model of Equations (1) and (2). As shown in Table 7, fiscal supports have a negative impact on credit spread; vice versa, monetary policy supports have a positive but negligible effect on credit spread (the effect is near zero). Our main results are robust to the inclusion of these additional controls.

TABLE 7 Difference-in-difference regressions for daily corporate credit spread

	(1) Baseline	(2) Fiscal and monetary support	(3) Core Europe	(4) Mediterranean country	(5) Financial industries	(6) Nonfinancial industries	(7) Investment grade	(8) High yield
Panel A								
Green	−.059**	−.059**	−.010	−.115***	−.109***	.075*	−.060**	.141***
	(−2.456)	(−2.456)	(−.224)	(−3.093)	(−3.872)	(1.716)	(−2.520)	(10.806)
COVID	.584***	.584***	.544***	.648***	.526***	.816***	.571***	.830***
	(82.584)	(82.584)	(45.656)	(56.590)	(66.918)	(60.993)	(78.659)	(35.755)
Green * COVID	.173***	.173***	.179***	.175***	.243***	−.031	.185***	−.113***
	(11.936)	(11.936)	(8.661)	(6.796)	(12.722)	(−1.592)	(12.593)	(−7.129)
Collateral	−.110**	−.110**	−.196**	−.122**	−.152***	.051	−.104**	.024
	(−2.468)	(−2.468)	(−1.964)	(−2.485)	(−2.781)	(1.032)	(−2.335)	(.394)
Amount Issued	−.106***	−.106***	−.111***	−.125***	−.106***	−.130***	−.109***	−.048*
	(−18.048)	(−18.048)	(−10.878)	(−12.825)	(−17.336)	(−6.662)	(−19.943)	(−1.862)
Fiscal Support		−.020***	−.022***	−.013***	−.032***	.031***	−.033***	.130***
		(−8.615)	(−5.465)	(−3.259)	(−13.166)	(5.633)	(−15.832)	(11.269)
Monetary Support		.005***	.006***	.006***	.006***	.002	.004***	.021***
		(3.792)	(2.707)	(2.964)	(3.997)	(.618)	(2.754)	(4.374)
Constant	6.182***	6.182***	5.645***	3.806***	6.350***	7.568***	7.174***	4.756***
	(12.274)	(12.274)	(6.994)	(12.230)	(14.630)	(16.463)	(24.192)	(6.691)
Observations	262,699	262,699	96,001	88,019	209,676	53,023	234,977	22,022
R^2	.861	.861	.872	.864	.830	.942	.697	.902
Time FE	YES	YES	YES	YES	YES	YES	YES	YES

TABLE 7 (Continued)

	(1) Baseline	(2) Fiscal and monetary support	(3) Core Europe	(4) Mediterranean country	(5) Financial industries	(6) Nonfinancial industries	(7) Investment grade	(8) High yield
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES	YES	YES	YES
Issuer FE	YES	YES	YES	YES	YES	YES	YES	YES
Rating FE	YES	YES	YES	YES	YES	YES	YES	YES
Panel B								
Green	.004	.004	.079	−.058	−.018	.041	.006	.159**
	(.160)	(.160)	(1.547)	(−1.510)	(−.481)	(1.270)	(.202)	(2.128)
Vaccine	−.104***	−.104***	−.097***	−.118***	−.082***	−.188***	−.099***	−.214***
	(−25.689)	(−25.689)	(−13.803)	(−18.127)	(−17.361)	(−28.406)	(−24.790)	(−20.554)
Green * Vaccine	−.044***	−.044***	−.057***	−.030**	−.070***	.020	−.046***	.023
	(−5.340)	(−5.340)	(−3.961)	(−2.263)	(−5.972)	(1.423)	(−5.508)	(1.074)
Collateral	−.122***	−.122***	−.149	−.044	−.150**	−.022	−.115**	−.078*
	(−2.611)	(−2.611)	(−1.579)	(−.690)	(−2.546)	(−.611)	(−2.234)	(−1.963)
Amount Issued	−.153***	−.153***	−.140***	−.192***	−.151***	−.189***	−.154***	−.137***
	(−22.505)	(−22.505)	(−11.408)	(−16.177)	(−21.601)	(−8.345)	(−23.919)	(−4.839)
Fiscal Support	−.000	−.000	−.000	−.002	.001	−.004	−.001	−.008***
	(−.287)	(−.287)	(−.132)	(−1.124)	(.321)	(−.920)	(−.508)	(−3.428)
Monetary Support	.007***	.007***	.008***	.003	.009***	−.002	.006***	−.004
	(3.162)	(3.162)	(2.769)	(.745)	(4.037)	(−.432)	(2.886)	(−1.335)

(Continues)

TABLE 7 (Continued)

	(1) Baseline	(2) Fiscal and monetary support	(3) Core Europe	(4) Mediterranean country	(5) Financial industries	(6) Nonfinancial industries	(7) Investment grade	(8) High yield
Constant	8.157***	8.157***	6.803***	5.013***	7.201***	10.474***	8.564***	10.401***
	(15.644)	(15.644)	(7.874)	(12.487)	(15.363)	(20.389)	(25.528)	(13.714)
Observations	302,787	302,787	110,469	101,088	239,357	63,430	270,366	26,671
R^2	.848	.848	.843	.858	.805	.954	.666	.936
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES	YES	YES	YES
Issuer FE	YES	YES	YES	YES	YES	YES	YES	YES
Rating FE	YES	YES	YES	YES	YES	YES	YES	YES

Note: This table reports the results of a Difference-in-Difference regression of daily corporate credit spread. $Green_i$ equals one for bond i that it is classified as "Green Bond" in the Thomson Reuter's Refinitiv fixed-income database and zero otherwise. $COVID_t$ equals one from February 24 to March 31, 2020, and zero before this period. $Vaccine_t$ equals one from November 9 to December 31, 2020, and zero before this period. In column 1, the specification includes the variables "Collateral," "Amount Issued," and time, country, sector, issuer, and rating fixed effects, in column 2 includes also the variables Fiscal and Monetary support, in column 3 we split the sample considering only countries defined as Core Europe (Germany, the Netherlands, Belgium, and Luxembourg), in column 4 we split the sample considering only countries defined as Mediterranean countries (Italy, Spain, and France), in column 5 we split the sample considering only Financial industry, in column 6 we split the sample considering only Nonfinancial industry, in column 7 we split the sample considering only bonds that are classified as Investment Grade, and in column 8 we split the sample considering only bonds that are classified as High Yield. In Panel A, we estimate the baseline model of Equation (1) for the period from January 1 to March 31, 2020. In contrast, in Panel B, we estimate the model of Equation (2) for the period from October 1 to December 31, 2020. Standard errors are heteroscedasticity robust. The numbers in parenthesis are t statistics. All variables are defined in Table 2.

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Abbreviation: FE, fixed effect.

Second, we conducted a separate analysis on more homogeneous subsets of bonds. We re-estimated the main models by splitting the sample into two homogeneous subsets of bonds: Core Europe (Germany, the Netherlands, Belgium, and Luxembourg) and Mediterranean countries (Italy, Spain, and France). Our results remain virtually the same. We do not find any difference in the impact on the two-subsample considered (Columns 3 and 4 of Table 7, Panel A for the COVID-19 pandemic, and Panel B for the vaccine announcement).

Third, we conducted an alternative robustness test by splitting the sample by industry (Financial vs Nonfinancial). Interestingly, our main findings only remain unaltered for the corporate bonds issued by the financial and banking sectors (column 5 of Table 7, Panel A for the COVID-19 pandemic, and Panel B for the vaccine announcement). While, for the other industries, we did not find any statistically significant evidence (column 6 of Table 7, Panel A for the COVID-19 pandemic, and Panel B for the vaccine announcement).

Fourth, we did an alternative segmentation in terms of investment-grade versus high-yield bonds. Interestingly, our main findings only remain unaltered for the corporate bonds with an investment-grade rating, in line with Zerbib (2019). For the high-yield rating, we find a negative statistically significant impact of the COVID-19 outbreak on the credit spreads of green bonds concerning conventional ones (columns 7 and 8 of Table 7, Panel A for the COVID-19 pandemic, and Panel B for the vaccine announcement). To explanation these results, we turn to Panel B of Table 5, which clarifies that no green bond issued in our sample had a rating below B. Moreover, a large part of conventional bonds is low-rated. These issues may be influencing the results. Replicating the analysis for the class of high-yield bonds that have a rating between Ba1 and B3 could be more feasible. Unfortunately, given the paucity of data, such an analysis may not be consistent at a statistical level.

Furthermore, the decision to issue a green bond might be correlated with other factors, such as bond size or the presence of collateral, which could render the coefficient of the DID term (β_3) in our model inconsistent. To disentangle the possible differences between the treatment and the control group, we added a robustness test using a PSM technique (Rosenbaum & Rubin, 1985). To solve the issue, we first estimated a probit model as follows:

$$Green_i = \beta_0 + \beta_1 Amount\ Issued_i + \beta_2 Collateral_i + \epsilon_i. \tag{3}$$

$Green_i$ is a dummy variable that equals one for bond i classified as "Green Bond" in Thomson Reuter's Refinitiv fixed-income database and zero otherwise. $Amount\ \ Issued_i$ is the natural logarithm of the bond amount issued during the pretreatment period; $Collateral_i$ is a dummy variable equal to one if the collateral was pledged at bond origination, and zero otherwise. ϵ_i is the error term. Then, we computed the propensity scores using the estimates obtained from the above equation. We also imposed the condition that the propensity score must lie within a .01 range of the bond's propensity score. Using a 1:1 matching strategy, the matched sample is similar in bond size and collateral. The matching produces a sample of bonds with similar bond sizes and collateral. The values for bond size are 20.375 (treatment group) and 20.360 (control group), with p values of .98. The value for collateral is .214 (treatment group) and .211 (control group), with p values of .96.

In the second step, we included only the matched sample from the first step. To control for fiscal and monetary policies employed in the European Union, we also included the variables capturing the European Fiscal and Monetary support in the model. The results reinforce the previous estimates (see column 1 of Table 8 for the COVID-19 pandemic and column 2 for the Vaccine announcement).

TABLE 8 Robustness checks

	(1) *p* Score	(2) *p* Score
Green	−.058**	.005
	(−2.384)	(.180)
COVID	.584***	
	(82.285)	
Green ∗ COVID	.170***	
	(11.655)	
Vaccine		−.108***
		(−27.097)
Green ∗ Vaccine		−.041***
		(−5.249)
Collateral	−.111**	−.120**
	(−2.494)	(−2.556)
Amount Issued	−.107***	−.153***
	(−18.025)	(−22.374)
Fiscal Support	−.018***	−.000
	(−8.068)	(−.129)
Monetary Policy Support	.005***	.007***
	(4.348)	(3.186)
Constant	6.191***	8.139***
	(12.278)	(15.600)
Observations	261,918	300,450
R^2	.861	.848
Time FE	YES	YES
Country FE	YES	YES
Sector FE	YES	YES
Issuer FE	YES	YES
Rating FE	YES	YES

Note: In this table we replicate the tests from Table 7, column 1, but use a propensity score matched sample on bonds size ($Amount\ Issued_i$) during the pretreatment period and $Collateral_i$ as described in Section 5, Equation (3). $Green_i$ equals one for bond i that it is classified as "Green Bond" in the Thomson Reuter's Refinitiv fixed-income database and zero otherwise. $COVID_t$ equals one from February 24 to March 31, 2020, and zero before this period. $Vaccine_t$ equals one from November 9 to December 31, 2020, and zero before this period. Standard errors are heteroscedasticity robust. The numbers in parenthesis are t statistics. All variables are defined in Table 2.

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Abbreviation: FE, fixed effect.

For the next step, we verified whether our results change when, controlling for the ESG rating of the issuing companies.[8] Indeed, ESG scores are priced by the markets and affect the cost of capital and debt. First, we hand-collected the ISIN for each issuer using the Datastream excel-addin (since Thomson Reuter's Refinitiv fixed-income database only gives the issuer's name, but not the identification code, i.e., ISIN). Second, the ESG score is available only for the listed firms. For this reason, we lost observations in these steps. In the baseline specification, we have 7935 bonds issued by 810 firms. Matching the ESG score for all the firms listed, we are left with 2845 bonds issued by 393 firms (99 green bonds issued by 56 firms and 2746 conventional bonds issued by 388 firms). Then, we re-estimated both Equations (1) and (2).

In the first specification, we solely controlled for the ESG score of the bonds' issuer. In the second specification, we calculated a dummy variable representing the firms in the 75th percentile of the ESG score (higher value of ESG score). Subsequently, we explored if firms with high ESG scores (*ESG*_75th) that issued a green bond experienced a lower credit spread than if they issued conventional one (we interact *ESG*_75th with *Green*). We also considered if such firms were especially impacted by the COVID-19 outbreak and the vaccine announcement news (*ESG*_75th∗*Green*∗*COVID* and *ESG*_75th∗*Green*∗*Vaccine*). We find evidence that companies with high ESG scores have greater resilience to adverse shocks (COVID-19), but we do not find any evidence for a positive shock (vaccine announcement). In contrast, when we included the *ESG*_75th dummy, we found that firms in the 75th percentile (high ESG ratings) have a lower credit spread, in line with the empirical literature (Albuquerque et al., 2020; Zerbib, 2019).

Lastly, when we controlled for the COVID-19 outbreak and the vaccine announcement, we did not find evidence that firms with high ESG scores that issued a green bond experienced a higher/lower credit spread during negative/positive shocks. Our results may reflect that the firms that issued green bonds and had a higher ESG score (75th) did not experience an increase in the credit spread relative to conventional ones during the COVID-19 outbreak and the vaccine announcement. Finally, our main results are robust to the inclusion of the ESG variables (see Table 9).

6 | CONCLUDING REMARKS

Green bonds are innovative financial instruments that provide access to capital for environment-friendly projects, such as green housing and architecture, sustainable agriculture and forestry, energy savings and renewal, climate adaptation, and emissions reduction projects. Since the first issuance in 2007, the green bonds market has evolved dramatically, becoming one of the most dynamic and fast-growing segments of global financial markets. In this paper, we constructed a comprehensive data set covering all corporate green bond issuances in Europe area from January 1 to December 31, 2020. Importantly, we provide the first empirical analysis of the green bond market's reaction to the COVID-19 pandemic. Our empirical analysis suggests that the COVID-19 pandemic had a significant impact on the European green bond market. Overall, green bonds showed a higher risk exposure and lower resilience to distress compared with conventional bonds, while profiting more from any upside. Specifically, the results show an increase in the credit spreads of green bonds compared with conventional ones in the aftermath of pandemic's outbreak, supporting *Hypothesis 1b*.

TABLE 9 Robustness checks

	(1) ESG score	(2) ESG score	(3) ESG score	(4) ESG score	(5) ESG score	(6) ESG score
Green	−.086***	−.086***	−.065**	−.054*	−.054*	−.036
	(−2.951)	(−2.951)	(−2.004)	(−1.712)	(−1.712)	(−1.108)
COVID	.698***	.698***	.698***			
	(66.928)	(66.928)	(66.925)			
Green * COVID	.136***	.136***	.132***			
	(7.653)	(7.653)	(7.327)			
ESG	−.056***	−.056***	−.056***	−.017	−.017	−.017
	(−7.391)	(−7.391)	(−7.388)	(−1.191)	(−1.191)	(−1.332)
ESG_75th		−.603***	−.606***		−.564**	−.560**
		(−3.064)	(−3.084)		(−2.490)	(−2.478)
ESG_75th * Green			−.097			−.078
			(−1.420)			(−.927)
ESG_75th * Green * COVID			.024			
			(.468)			
Vaccine				−.134***	−.134***	
				(−25.264)	(−25.264)	
Green * Vaccine				−.023**	−.023**	
				(−2.439)	(−2.439)	
ESG_75th * Green * Vaccine						−.010
						(−.555)
Collateral	−.077	−.077	−.076	−.047	−.047	−.047
	(−1.356)	(−1.356)	(−1.336)	(−.727)	(−.727)	(−.714)
Amount Issued	−.095***	−.095***	−.095***	−.154***	−.154***	−.153***
	(−10.839)	(−10.839)	(−10.826)	(−16.062)	(−16.062)	(−16.042)
Constant	9.653***	9.653***	9.657***	9.532***	9.532***	9.607***
	(14.270)	(14.270)	(14.270)	(8.465)	(8.465)	(8.932)
Observations	119,043	119,043	119,043	138,771	138,771	138,771
R^2	.826	.826	.826	.823	.823	.823
Time FE	YES	YES	YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
Sector FE	YES	YES	YES	YES	YES	YES

TABLE 9 (Continued)

	(1) ESG score	(2) ESG score	(3) ESG score	(4) ESG score	(5) ESG score	(6) ESG score
Issuer FE	YES	YES	YES	YES	YES	YES
Rating FE	YES	YES	YES	YES	YES	YES

Note: This table reports the results of a Difference-in-Difference regression of daily corporate credit spread. $Green_i$ equals one for bond i that it is classified as "Green Bond" in the Thomson Reuter's Refinitiv fixed-income database and zero otherwise. $COVID_t$ equals one from February 24 to March 31, 2020, and zero before this period. $Vaccine_t$ equals one from November 9 to December 31, 2020, and zero before this period. *ESG* is the value of ESG of the bonds' issuer. *ESG_75th* is a dummy variable equal to one if the firm is on the 75th percentile of the ESG score (higher value of ESG score), and zero otherwise. In columns 1–3 we estimate the model for the period from January 1 to March 31, 2020. In contrast, in columns 4–6, we estimate the model for the period from October 1 to December 31, 2020. Standard errors are heteroscedasticity robust. The numbers in parenthesis are *t* statistics. All variables are defined in Table 2.

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Abbreviations: ESG, Environmental, Social, and Governance; FE, fixed effect.

The empirical evidence may reflect investor concerns about the objective risk of executing green projects brought on by the pandemic induced recession. The fight against the pandemic quickly became the absolute global priority, while the climate crisis moved into the background. In this unprecedented context, companies and governments had to postpone plans for green investment and focused their spending on managing the economic fallouts from the COVID-19 pandemic.

The renewable energy sector—which greatly depends on imports from other regions, mainly China, to meeting its equipment and material demands—has been heavily impacted by the COVID-19 pandemic. The reduction in global energy demand following the pandemic-induced lockdowns has blunted investments in renewable energy (Hoang et al., 2021). The lockdown measures, implemented to reduce the spread of the virus, led to supply chain disruptions, the large scale shutting down of production, low traffic, and pauses on nonessential manufacturing activities—all of which—have caused significant delays in the deployment of renewable energy projects (Hoang et al., 2021). According to Bloomberg New Energy Finance, installations for solar and wind projects fell by 8% and 12%, respectively, in 2020. Some major planned projects were temporarily put-on-hold thanks to the pandemic, including 3000 MW of combined solar and wind in India (Oxford Business Group, 2021) and 25 GW of wind power in the United States (Weko et al., 2020). Up to 150 GW of renewable energy projects will be delayed or canceled in Asia through 2024 if the recession continues (Frangoul, 2020). In Europe, several countries have stopped auctions for renewable energy or have reduced future volumes (Wigand et al., 2020).

This above scenario, coupled with the heightened risk of greenwashing due to increasing market pressure on companies to go green (Severo et al., 2021) and the effect of high oil price volatility (Lee et al., 2021), may have led investors to perceive sustainable investment assets as riskier than conventional ones, triggering sell-off in the green bond market. However, we can assume that the positive news about the vaccine relieved some of investors' concerns and allowed them to focus on the broader impact of the coronavirus outbreak. Consequently, they may have perceived a commitment toward environmentally friendly behaviors as a value-enhancing strategy. This led them to regain confidence in the future profitability of green bonds and in the ability of their issuers to pay off their debt. As a result, investors started buying green bonds, which led to lower credit spreads, in support of *Hypothesis 2*.

We attribute the renewed investor confidence to the fact that the COVID-19 pandemic, which threatens firms' survival, may have led to increased investor belief that consumer demand for green products and services would grow in the long run. They may have also anticipated that green investments will have a positive impact on the economic recovery in the post-COVID world. Furthermore, the COVID-19 pandemic has raised investors' awareness of climate-change and other environmental issues, highlighting the risks associated with the inevitable and imminent process of green reconversion incorporated in traditional bonds. This may have led investors to demand higher yields for conventional bonds than green ones to compensate for the risk of green reconversion. In this context, the appearance of green bonds as a vehicle to finance green projects represents a unique opportunity to promote a green economic recovery, integrating environmental considerations into decision-making processes. In this way, green bonds will support the achievement of EU objectives in the reduction of national emissions by 2030.

This paper has several implications. First, from the issuers' point of view, our results show that green bonds' credit spreads dropped after the positive shock incurred by the announcement of the vaccine efficacy. This event alleviated the external finance premium arising from the financial market turmoil. These results highlight the opportunity for issuers to benefit from a diversification of their bondholder base by providing green products, thereby securing the financing needed for a green recovery while enjoying long-term pricing advantages. Second, from the investors' point of view, the results highlight the importance of shifting toward greener investment opportunities as part of the fixed-income allocation, thereby financing a green recovery beyond COVID-19. Our findings also confirm the potential of green bonds to become an effective diversifier for investors in traditional assets in times of extreme market turmoil. Furthermore, our findings lend strong statistical and economic validity to the Recovery Plan for Europe agreed to by the European Commission, the European Parliament, and EU leaders. At its heart is the largest stimulus package ever financed in Europe worth, €2.018 trillion to support the recovery after COVID-19 and steer the transition toward a greener, more digital, and more resilient Europe (30% of the EU funds, the highest share ever of the European budget, are aimed at fighting climate change).

Going forward, there are multiple directions for future research. First, since we used data on Europe's green bond market, future studies could expand our experimental setting by analyzing the impact of the COVID-19 pandemic on the global green bond market and investigate whether our results hold in different contexts. Second, by issuing green bonds, companies credibly signal their commitment to the environment (Flammer, 2021). Future work could investigate the role played by green bond issuers in rebuilding a greener and more resilient economy after this crisis and verify whether the funded green projects have actually produced tangible and measurable improvements in environmental performance post-issuance. Finally, due to a lack of data, we could not examine the difference between green "use of proceeds" bonds (i.e., bonds earmarked for green projects but backed by the issuer's entire balance sheet) and green "revenue" bonds (green project bonds and green securitized bonds, i.e., bonds backed by the revenue or asset expected from the project's implementation). For this second type of green bond, the changing risk of execution or greenwashing would make a difference in terms of the credit spread differential in comparison to traditional bonds. Thus, this area warrants further research.

ENDNOTES

[1] https://www.climatebonds.net/resources/reports/green-bonds-market-summary-q3-2020

[2] https://www.moodys.com/research/Moodys-Coronavirus-shrinks-green-bond-issuance-while-spurring-social-bonds-PBC_1227042

[3] See "The dark side of green bonds," Financial Times, June 13, 2015: https://www.ft.com/content/16bd9a48-0f76-11e5-b968-00144feabdc0

[4] For further information on this topic see Baker and Wurgler (2006).

[5] Since the per Amount Issued is in logarithmic terms, we use the exponential of 20.3675 (19.3174), which is equivalent to 700,636,664.00 (245,154,700.00) million euro for green bonds (conventional bonds).

[6] Since the Ln Credit Spread is in logarithmic terms, we use the exponential of 4.45 (4.69), which is equivalent to 96 (109) b.p. credit spread (conventional bonds).

[7] https://www.pfizer.com/news/press-release/press-release-detail/pfizer-and-biontech-announce-vaccine-candidate-against

[8] We thank the anonymous reviewer for their insightful comments and suggestions to improve this part of the paper.

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