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Sustainability premium in energy bonds☆

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ABSTRACT

We investigate the extent to which belonging to a sustainable index leads to lower financing costs for companies in the energy industry. From an extensive sample that includes all energy bonds traded on the US corporate bond market between 2005 and 2014, we examine the differences between the yield spreads on bonds issued by green and non-green energy companies, based on the inclusion of issuers in the Dow Jones Sustainability Index. The yield spreads are computed from synthetic governmental bonds obtained discounting original cash flows from the zero-coupon yield curve. Controlling by bond fundamentals and market conditions, the sustainability premium averages 66 b.p. in yield spread terms. This premium depends on the credit quality of the issuer, ranging from 23 b.p. for investment grade bonds to 261 b.p. for junk bonds. This price premium that investors are willing to pay for the green energy company bonds entails a lower cost of debt for these companies.

1. Introduction

Over the past few years, environmental, social and governance (ESG) criteria have steadily climbed up the list of priorities for investors and debt issuers.[1] Sustainable, responsible and impact investing assets reach $12 trillion in the US by 2018 (US SIF Foundation 2018). Such an amount implies that these assets have increased nearly 18-fold since 1995 ($639 billion) and 38% since 2016 ($8.1 trillion). Impact investing adds, to the traditional goal of conventional investment to provide financial resources for a financial return, the goal of addressing social and environmental challenges. In general, socially responsible investing (SRI) consists of investment strategies in which ESG concerns of the companies prevails for investors in their investment decision making process. Investors' interest in ESG criteria is not new, in fact, it has been observed since the early 1990s. Several international institutions are also carrying out initiatives in favor of sustainable finance. For instance, the European Commission is actively promoting a comprehensive approach to green finance, understood as finance that supports economic growth while reducing pressures on the environment and considering social and governance aspects.

The expansion of investment in the assets of ESG companies has attracted the attention of academic research. But even though ESG investment focuses on corporate bond portfolios, the vast majority of empirical studies have focused on the impact of SRI and corporate social responsibility (CSR) on corporate financial performance, asset and loan prices, and stock returns. Although the evidence is mixed, most papers report a lower return on SRI stocks and a lower cost of equity capital (e.g., Heinkel et al. 2001; Amber and Lanoie, 2008; Galema et al. 2008; El Ghoul et al. 2011; Dhaliwal et al. 2011; Girerd-Potin et al. 2014; Chava 2014; Ng and Rezaee 2015). A similar pattern is observed in papers focusing on the energy industry (e.g., Bassen et al. 2006; Connors and Silva-Gao 2008; Gao and Connors 2011; Gonenc and Scholtens 2017; Brzeszczynski et al. 2019).

Only a small part of the empirical studies analyses the corporate bond market. Many of these studies examine the impact on the primary market, noting a lower cost of capital for CSR companies (e.g., Klock et al. 2005; Bauer and Hann 2010; Goss and Roberts 2011; Ge and Liu 2015; Ghouma et al. 2018; La Rosa et al. 2018). Few papers examine the impact of pro-environmental preferences on prices in the secondary bond market. Menz (2010) and Oikonomou et al. (2014) note that, in general, higher levels of CSR may lead to a narrowing of bond spreads

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[1] Environmental considerations relate to climate change mitigation and adaptation. Social considerations may relate to issues of inequality, inclusion, labor relations, investment in human capital and communities. The governance of public and private institutions affects the management structure, employee relations and executive compensation, to ensure the inclusion of social and environmental considerations in the decision-making process.

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in the European and US corporate bond markets, respectively. Focusing on the specific case of the green bond market, Hachenberg and Schiereck (2018) and Zerbib (2019) analyze 63 and 110 pairs of matched bonds, respectively, and observe an average yield premium close to zero (−1 and − 2 b.p. respectively) between green and conventional bonds. Therefore, there is limited research on the impact of investors who manage their portfolios according to ESG criteria on the performance of corporate bond markets. Besides, the literature on the cost of debt of energy companies is also scarce. We hence contribute to fill the gap in the literature by examining the effects of ESG practices on the specific case of energy company bonds.

In this context, most energy companies have traditionally been considered as contrary to sustainability due to the environmental impact of their activity. The nature of their business is subject to strict scrutiny by stakeholders and the media. In the recent years, the energy industry has gained awareness about the need to implement sustainable processes in line with the CSR framework, and to provide improvements in energy efficiency and renewable energy generation capacity. The renewable energy industry has experienced rapid investment growth thanks to public incentives, such as green credit policies, environmental regulations, and investment-conscious improvements. Recent papers analyze key barriers to investment in renewable energy, its impact on the capital structure, and factors that encourage investors to invest in this industry, such as investor attitudes and concerns (Masini and Menichetti 2012; Dockner et al. 2013; Noblet et al. 2015; Kastner and Matthies 2016; Niesten et al. 2018; Ng and Zheng 2018; Chang et al. 2019). There is a clear commitment to make a transition to greater sustainability by promoting environmentally friendly technologies and production methods. Current and past government initiatives support this transition. For instance, many energy policies of the US government and the European Union support more efficient use of energy at all stages of the energy chain, including generation, transmission, distribution and final consumption of energy.[2] In addition, investors are becoming active players in the energy and environmental transition.[3]

In this paper, we examine the sustainability premium embedded in the yield-to-maturity (YTM) at which bonds from energy companies with a CSR label are traded in the secondary bond market. Trading in these bonds should be particularly sensitive to sustainability-oriented investors. Comparing the yield spread (YS) of corporate bonds issued by energy industry companies included in a well-known social and environmental index, and that of similar energy bonds, provides a unique laboratory to broaden the understanding of a sustainability premium. The results obtained are particularly relevant for drawing clear conclusions about the sustainability premium in all industries. A sustainability premium would imply lower funding costs for companies that meet the criteria for CSR practices. Therefore, this paper aims to answer several questions. First, do investor value sustainability in the energy industry? Second, does the sustainability premium depend on the characteristics of the bond, or more specifically, is the sustainability of bonds with different credit ratings valued equally?

Our research examines bonds issued exclusively from a single industry, energy-related companies. According to Lee and Faff (2009), we use the Dow Jones Sustainability Index (DJSI) as a proxy for CSR, which means that energy companies included in the DJSI (green energy companies, GE) are expected to apply socially and/or environmentally responsible activities in their production processes, whereas companies not included in the DJSI (non-green energy companies, NGE) are assumed not to sufficiently implement such activities. We do not consider whether the specific issue is classified as a green bond or not, but rather whether the issuer itself is labelled as a GE or NGE company.[4]

Our initial dataset includes all transactions in the US corporate bond market from January 1, 2005 to December 31, 2014. Trade Reporting and Compliance Engine (TRACE) dataset provides trade-by-trade data on prices, volumes, and yields. After filtering and processing the intraday data, we transform the intraday transactions into a single daily observation per bond. The final sample consists of more than 1.3 million daily observations from the trading of 2852 bonds issued by 605 different issuers from the energy industry.

In the first part of our analysis we examine whether there are economically and statistically significant differences in the YS of bonds issued by sustainable energy companies compared to that of bonds issued by companies without such a qualifier in the same industry. The YS is computed as the difference between the YTM at which the corporate bond is traded and the YTM of a synthetic Treasury bond with the same cash flow structure (coupon and maturity). The price of this notional Treasury bond is calculated by discounting the original cash flows of the corporate bond from the then-current term structure of interest rates. We use the well-known daily estimates of the term structure of interest rates for the US Treasury market reported by the Federal Reserve Board website. We assume that the corporate energy bonds from companies included in the DJSI, i.e. GE bonds, benefit from trading at higher prices and therefore lower YTM on the secondary market than equivalent assets of non-indexed companies, i.e. NGE bonds. This result would imply lower financing costs on the primary market as sustainability investors would be paying a price premium for being environmentally and socially sustainable.

We identify the effect of ESG through a sustainability premium defined as the average difference between the daily YS of GE bonds and that of NGE bonds grouped in cohorts. Our results suggest that, overall, the bonds included in the DJSI incorporate a sustainability premium of about 77 basis points (b.p.). This premium is around 23 b.p. for investment-grade bonds. For instance, AA-rated GE bonds trade, on average, at a YTM 16 b.p. lower than the YTM of NGE bonds with similar characteristics. Average sustainability premiums are particularly relevant among speculative-grade bonds (more than 320 b.p.) and for older issues, i.e. bonds with both coupon rates above 6% (143 b.p.) and those with a remaining term to maturity of less than 5 years (102 b.p.). Investors therefore value the ESG label much more favorably in those energy companies with junk bond status.

In the second part, we conduct a linear regression analysis of the daily bond YS on a set of explanatory variables that represent the characteristics of the bond, its liquidity, the time period in which it is traded, and other relevant economic variables. Both the overall sustainability premium and the cross effects of the sustainability impact with each of the bond's credit categories are estimated. The results of the regression models fully support those of the preliminary cohort analysis. Considering the effect of the control variables, the average sustainability premium remains at 66 b.p. Distinguishing by credit rating, the premium of AA- and BBB-rated bonds is low (16 and 14 b.p. respectively). The highest sustainability premiums are observed for A-rated bonds, with 54 b.p., and for speculative-grade bonds, with 261 b.p. This result is consistent with that indicated by Oikonomou et al. (2014).

Our paper further contributes to the strand of the literature on the pricing of ESG companies. To the best of our knowledge, this is the first piece of research that analyzes the sustainability premium at which ESG-rated energy company bonds are traded in the US corporate

[2] In the case of US, some of these energy policies are the Energy Policy Act 2005, the Clean Energy Act 2007, the American Recovery or the Reinvestment Act 2009, or the American Renewable Energy and Efficiency Act 2017. In the case of the EU, the various policies adopted notably include Energy Efficiency Directives 2012 and 2018.

[3] Larry Fink, CEO of the world's largest fund manager (BlackRock), comments in his annual letter to CEOs (January 14, 2020): "we will be increasingly disposed to vote against management and board directors when companies are not making sufficient progress on sustainability-related disclosures and the business practices and plans underlying them.", https://www.blackrock.com/uk/individual/larry-fink-ceo-letter.

[4] It should be clear that the designation "green energy" should not be confused with the popular term "green bond". A green bond or climate bond is an issue that finances specific projects related to the climate or the preservation of the environment. These green bonds are singular issues of companies from very diverse industries, mainly utilities, banking, real estate and even governments. The mix of bonds from different industries complicates the analysis.

bond market. It also makes use of an extensive daily bond data set to test how investors are willing to pay such a premium to hold bonds issued by energy companies that meet the ESG criteria required for inclusion in a sustainability index. This premium in terms of YS significantly reduces the cost of debt capital at which these GE companies are financed. In addition, emphasis is placed on revealing some of the particularities of the link between the sustainability premium and the issuer's credit rating.

The remainder of the paper is organized as follows: Section 2 reviews the literature. On Section 3 we explain the main hypotheses. Section 4 presents the data sources. On Section 5 we describe the methodology to build the data sample and to conduct the analysis. Section 6 presents the empirical results. Finally, Section 7 concludes.

2. Literature review

Sustainability criterion have experimented an upward trend in investment decisions. Knoepfel (2001) and more recently Searcy and Elkhawas (2012) argue that investors are increasingly opting to invest in companies that implement the best practices in the field of sustainability, corroborating that not only companies are the economic agents most concerned about their social responsibility. This increasing interest of investors and companies in SRI, CSR and ESG criteria, has attracted the attention of the academic research.

The vast majority of empirical studies have focused on the impact of SRI and CSR on corporate financial performance, asset and loan prices, and stock returns. Renneboog et al. (2008) highlight that "*the crucial empirical question is whether or not investors are willing to pay for CSR*". They review the empirical standing literature on the pricing of CSR to ask the question about whether CSR is incorporated on stock prices. In their critical review paper, they conclude that the empirical literature on CSR and SRI does not provide concluding findings to affirm unequivocally that sustainability is priced by the capital markets.

Most results of studies exploring the impact of CSR on the cost of equity capital show that companies with better CSR (e.g., Amber and Lanoie, 2008, El Ghoul et al. 2011, Girerd-Potin et al. 2014), better environmental risk management (e.g., Sharfman and Fernando 2008), or both (e.g., Chava 2014; Ng and Rezaee 2015) benefit from a lower cost of equity capital. In addition, companies that present or disclose a higher performance on social responsibility have a lower cost of equity capital (e.g, Dhaliwal et al. 2011).

In the case of the effects of CSR on the cost of debt capital, the more recent papers provide new insights about the pricing of CSR on bond markets. However, the evidence found is also mixed and nowadays there are not unequivocal conclusions about the effects of CSR on the cost of debt. Many of these studies examine the impact on the primary market, noting a lower cost of debt financing for CSR companies with proactive environmental commitment. These results are drawn from primary market data for US bonds (e.g., Klock et al. 2005; Bauer and Hann 2010; Ge and Liu 2015), Canadian bonds (Ghouma et al. 2018), European bonds (La Rosa et al. 2018) and Chinese bonds (Ye and Zhang 2011) or bank loans (Goss and Roberts 2011).

Few papers examine the impact of pro-environmental preferences on prices in the secondary bond market. Menz (2010) focuses on the European corporate bond market and find differences, but with low statistical significance, between the risk premium of socially responsible firms and the risk premium of firms less responsible. Other authors as Oikonomou et al. (2014) provide evidence of lower (higher) corporate bond YS of firms with good (bad) CSR performance, suggesting that firms with good social performance are rewarded whereas companies that perpetrate infractions are penalized through lower and higher corporate bond YS, respectively. Focusing on the specific case of green bonds, Hachenberg and Schiereck (2018) find evidence of negative premiums statistically significant particularly for A-rated bonds. More recently, Zerbib (2019), using euro and USD denominated green bond data, which implicitly involve CSR since green bonds are associated with pro-environmental projects, finds that green bonds are traded at lower yields than conventional bonds suggesting that the cost of debt decreases for firms with better CSR.

Our paper presents relevant contributions to the literature, filling a series of gaps left by previous research. First, we contribute to existing literature on green investment by providing new evidence of the existence of a sustainability premium on the price at which corporate bonds issued by green energy companies are traded on the US secondary corporate debt market. These companies are under intense public scrutiny and are making remarkable efforts to improve their CSP.

Second, unlike previous studies, we focus on single-industry bonds. The joint study of bonds from heterogenous industries can introduce undesired "noise" into the analysis. Corporate bonds with the same credit rating but from different industries behave differently and have different risk premiums (see, e.g., Hickman 1958, Longstaff and Schwartz 1995). This fact could affect recent studies with small samples of green bonds. In our case, for instance, it should not be easy to quantify the concrete impact of sustainability on the price at which bonds as disparate as municipal or financial ones are priced. Second, it may even be the case that companies not included in a CSR index issue green bonds to finance a specific project. Third, comparisons between bonds from different countries is another source of "noise", given the impact of factors such as business cycle, currency, or zero-coupon risk-free yield curve.

Third, our paper differs from all those cited by the way we compute YS, the extent of the daily database with all transactions in the US corporate bond market, and in the CSR measurement criteria. We obtain the YS by comparing the YTM of the bond and the YTM of a synthetic government bond with the same cash flows as the original bond. Avoiding simplifications and rounding off, the actual maturities of each of the bond's cash flows are considered.

3. Hypotheses development

The focus of our study is the relationship between CSR and corporate bond YS. From a theoretical perspective, Fama and French (2007) propose the theory "disagreement, tastes and asset prices". There is a trade-off between the disagreement investors may show with respect to the probability distribution of future returns on SRI assets and investors' use of non-financial objectives when selecting investments. On the one side, traditional financial theory assumes that investors agree on the possible returns on assets and that they choose assets based on the expected return-risk combination. On the other side, behavioral finance theories assume tastes for assets as consumption goods and therefore these tastes may have price effects.

In the specific case of energy industry, Ng and Zheng (2018) studies whether both the disagreement and the environmental tastes substitute for financial performance in these companies. GE companies are assets with disagreements about future performance because they are an emerging and uncertain industry whose long-term success is being demonstrated. This implies greater risk and would imply higher expected return. However, GE companies represent consumers' taste for a clearly pro-environmental asset as opposed to the typical non-environmental energy company. These authors note that investor preferences affect the demand for GE companies, and therefore the price and return on their stocks. In addition, there is an excess demand for SRI stocks by green investors who prefer these stocks and are less sensitive to the returns obtained by SRI investment funds. In this way, these authors show that the trade-off proposed by Fama and French (2007) between the disagreement on future compensation for financial performance and environmental tastes ends up being on the side of the latter. Thus, the stocks of GE companies perform at least as well as their NGE counterparts.

This theory can also be applied to corporate fixed income assets issued by GE companies versus those issued by traditional energy companies which represent a clear "non-environmental" investment option. In other words, we analyze whether the impact of CSR on shareholder value is accompanied by an impact on bondholder value.

We hypothesize the following relationship as follows:

Hypothesis 1. (H1). Bonds from energy firms that include (do not include) CSR practices in their business have lower (higher) YS and hence higher (lower) price premiums.

Some studies have explored the effect of CSR on credit risk. The results are mixed. Some authors argue that CSR practices involve a waste of scarce resources that, through various mechanisms, increase volatility and the default risk (e.g., Friedman, 1970, Alexander and Buchholz, 1978, Goss and Roberts 2011). Other authors find that firms invest in more CSR activities reduce default risk and get more favorable credit ratings (e.g., Bauer and Hann 2010; Attig et al. 2013; Jiraporn et al. 2014; Sun and Cui 2014). Truong and Kim (2019) observe that companies with certain CSR practices reduce CDS premiums. However, Menz (2010) and Stellner et al. (2015) do not find that positive CSR significantly reduces credit risk. As for a possible differential impact of CSR practices depending on the credit rating, Oikonomou et al. (2014) observe a greater impact on YS of bonds rated A or CCC or lower, although they do not report specific figures. For green bonds, Hachenberg and Schiereck (2018) find green premiums close to zero (ranging from 0 to 4 b.p.) without a clear relationship with ratings and Zerbib (2019) observes that green premiums increase as ratings improve. Given this controversy, we propose to shed light on the literature by testing whether investors more readily value proactive participation in CSR practices the lower the credit quality of the issuer.

Table 3 presents a formal test of the H1. If the daily quotient between the YS of GE bonds and the YS of NGE bonds (GE/NGE ratio) is consistently less than one, it should indicate that the average YS of GE bonds is less than that of NGE bonds. Our results support our hypothesis that bonds issued by energy companies that follow CSR practices have a lower YS, implying lower debt capital costs.

Hypothesis 2. (H2). Investors value CSR practices more (less) favorably in those companies that bear the highest (least) risk and have the worst (best) credit rating.

A poor credit rating signals a higher level of default risk, i.e., higher probability that the issuer fails to make full and timely payments of principal and coupons. Therefore, the lower the credit rating, the greater the uncertainty about future promised payments. In this sense, the theory of disagreement and taste by Fama and French (2007) provides theoretical support for H2. Investors in speculative grade bonds bear more risk, face more disagreement about future returns, and therefore ask for compensation in terms of lower prices and higher YS. However, investor tastes for sustainability could be amplified in the case of lower quality bonds and could counteract their higher YS. Consequently, the potential effects on the prices of those assets considered as consumer goods could be greater than those produced by the disagreement.

To test these hypotheses, it is essential to use a benchmark that allows us to determine which companies in the energy industry are publicly recognized as carrying out CSR practices. In this sense, the DJSI is among the most widespread and widely accepted indices. We use the fact of being included in the DJSI as a proxy for CSR, which means that energy companies included in the DJSI (green energy companies, GE) are expected to apply socially and/or environmentally responsible activities in their production processes, whereas companies not included in the DJSI (non-green energy companies, NGE) are assumed not to sufficiently implement such activities. Although there is no universally agreed-upon which is the best method of measuring corporate sustainability, this is a valid criterion due to the appropriateness of the multidimensional view of sustainability that the Index has, which becomes more accurate in contrast to other single-dimensional proxies of CSR (see, e.g., López et al. 2007; Lee and Faff 2009).

The DJSI employ a best-in-practice assessment process and guarantees that companies included in it lead the field in terms of corporate sustainability (Beloe et al. 2004; DJSI, 2011).[5] To its computation, the approach of the best in-class is adopted in order to select only those companies that apply the most sustainable practices among the companies in the same field (DJSI, 2011). Companies are required not only to develop sustainable practices but also to publicly expose them if they wish to have the possibility of being included in the index. The DJSI includes some of the 2000 largest capitalized companies in the world included in the Dow Jones Global Index (DJGI). Only the best 10% of these companies with the best sustainability practices on each field are included in the DJSI. It is revised annually meaning that its components are monitored along the entire year and down rated or even removed when they do not fulfill the sustainability criteria imposed by the index. For all these reasons, the inclusion of a firm in the DJSI becomes a reliable proxy for being a sustainability company.

4. Data description

The preparation of our data sample requires the information contained in four databases. Three of them contain qualitative and quantitative information from which the bonds to be included in the analysis are identified, and the fourth one reports all transactions made in the US corporate bond market.

The list of energy-related companies is extracted from the North American Industry Classification System (NAICS).[6] Codes and definitions are included in Table A1 in the Annex. Information on the companies included in the Dow Jones Sustainability Index each year is given by the DJSI database provided by RobecoSAM. The Mergent Fixed Investment Securities Database (FISD) is our third dataset, which provides qualitative and quantitative information on bond issuers and their issues. During the period from January 1, 2005 to December 31, 2014, we select issuers in FISD that match energy industry companies listed in NAICS. We find 1455 energy issuers that have 12,812 bond issues. Furthermore, we obtain detailed transaction information from the Trade Reporting and Compliance Engine (TRACE) dataset. It provides intraday information on all US corporate bond transactions during the 15-year sample period that comprises from January 1, 2005 to December 31, 2014. TRACE dataset includes, among others, information related with the trading volume, transaction prices and transaction YTM. From this database we extract all transactions involving identified bonds issued by companies in the energy industry. The CUSIP code obtained in FISD allows us to identify these issues in TRACE.

Intraday transactions have been filtered and corrected applying Dick-Nielsen (2009) algorithms and procedures with minor variations. We eliminate those trades with missing data such as price, trading volume and YTM, and trades with YTM set to zero or yields above 50%. We delete zero or variable coupon bonds, TIPS, STRIPS, perpetual bonds and bonds with embedded options, such as putable, callable, tendered, preferred, convertible or exchangeable bonds, municipal bonds, international bonds, Eurobonds, and those bonds that are part of a unit deal. Following Helwege et al. (2014) and Bessembinder et al. (2006), we eliminate those transactions where the bond price exceeds both the prior and the following prices by at least 20%, and when the bond price is less than those prices in the same magnitude. In addition, we exclude unrated bonds, transactions that take place before the delivery date of each bond, and transactions of bonds with a remaining maturity of less than one month.

Finally, we transform the intraday debugged, filtered, and corrected transactions into daily observations. To that purpose, and following the same underlying idea as in Friewald et al. (2012), who consider that

[5] The index employs different indicators to measure corporate social responsibility that deal with economic, environmental and social issues. For example, the degree of development of human capital, the number of strategic plans, the value of intangible assets, the level of corporate governance or the degree of relationship with investors.

[6] This information is the standard used by federal statistical agencies to classify business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the US business economy. See www.naics.com.

large trades embody more price information, we obtain daily volume-weighted average bond price and yield where the weights are computed according to the dollar volume traded by each transaction for each bond and day. In other words, if a bond trades several times in the same day, we get a daily price and a daily YTM for that bond.

The sample of daily transactions is then divided into two subsamples. Depending on whether the issuer of the bond is currently included in the DJSI, one subsample includes “green energy bond” transactions and the other includes “non-green energy” bond transactions. We eliminate AAA-rated bonds from our sample of NGE bonds, as the DJSI does not include any energy industry issuers with this credit rating.

Table 1 provides information on the main characteristics of the issues comprising the final sample, which consists of 1,345,188 daily observations from 2852 bonds issued by 605 issuers. The amount of debt financing in this industry during the sample period accounts for near $1,2 billion. Among the companies in the energy industry with bonds traded on the US corporate bond market, those listed on the DJSI barely reach 3% of the total. This percentage also holds true in terms of the number of GE bonds and the number of transactions with those bonds relative to the industry total. Specifically, we analyze 82 bonds issued by GE companies compared to 2770 bonds from NGE companies. Panel A includes statistics for the entire sample, meanwhile Panels B and C show statistics for GE bonds, and for all other energy bonds, or NGE bonds, respectively.

Since the number of GE bonds is much lower than the number of issues from energy companies not included in the DJSI, the statistics for these GE bonds are less dispersed than those for NGE bonds, although the median value of almost all variables is fairly comparable in both groups. They have a similar credit quality, with a numerical credit rating of 8 which is equivalent to Baa1 according to Moody's rating, a coupon rate of 6.05%, a remaining term to maturity of 8 years, and an age of 3 years. On the other hand, the average value of the offering amount and days traded is significantly higher in the case of GE bonds. These two variables point to higher liquidity of GE issues.

5. Methodology

Our hypothesis that investors are willing to pay a premium for the purchase of bonds from energy companies considered sustainable is examined on the basis of the YS at which GE bonds and their corresponding NGE bonds are traded. This is a measure of yield that takes into account the specific cash flows of the bond and the term structure of the interest rates prevailing at the time of trading. This methodology has certain advantages over the bond-matching approach used in previous papers (Bauer et al. 2005; Kreander et al. 2005; Renneboog et al. 2008; Hachenberg and Schiereck 2018; Zerbib 2019). We do not compare the YTM of the bond analyzed with those of two “similar” conventional bonds of the same issuer. Even when most of the factors that explain yield are identical among these three bonds, there are substantial differences that can affect the YTM. Among other factors, YTM depends on the coupon size and the slope of the term structure of interest rates. Without considering tax implications, a rising zero-coupon risk-free yield curve implies that for two identical bonds except for their coupon rates, the bond with the lower coupon will trade at a higher YTM.

We calculate the YS as the additional yield that the energy bond offers over a theoretical YTM that a hypothetical government bond with same cash flows would offer that same day. In other words, the YS is obtained as the difference between the YTM at which the corporate bond was actually traded and at which the theoretical government bond would have been traded, as given by an explicit term structure model.

$$YS = YTM - YTM_{th} \tag{1}$$

Table 1
Summary statistics of energy bonds.

Variable	Sample size	Mean	SD	Q_{10}	Q_{25}	Q_{50}	Q_{75}	Q_{90}
Panel A. Total sample								
#issues	2852							
#issuers	605							
Bond coupon (%)		6.05	1.97	3.50	4.88	6.05	7.25	8.50
Offering amount ($ thousand)		41.52	36.29	14.81	22.50	30.00	50.00	75.00
Average credit rating		8.85	3.18	5.41	6.73	8.24	10.00	13.90
Average time to maturity (years)		10.58	10.01	1.88	3.54	7.03	15.20	27.61
Average age (years)		4.29	4.36	0.69	1.39	2.87	6.09	9.02
Trading days per bond		457.72	407.29	69.00	146.00	343.00	640.00	1015.90
Panel B. Green energy (GE) bonds								
#issues	82							
#issuers	13							
Bond coupon (%)		5.98	1.66	3.54	5.07	6.05	6.97	7.62
Offering amount ($ thousand)		54.57	35.73	25.00	27.77	50.00	75.00	99.00
Average credit rating		7.43	1.63	6.00	6.00	7.88	8.84	9.37
Average time to maturity (years)		12.23	9.79	2.43	4.34	7.94	21.81	27.82
Average age (years)		4.92	4.64	0.66	1.63	3.22	7.30	12.51
Trading days per bond		512.81	374.25	124.60	267.50	375.50	766.50	1042.50
Panel C. Non-green energy (NGE) bonds								
#issues	2770							
#issuers	592							
Bond coupon (%)		6.05	1.98	3.50	4.88	6.05	7.25	8.50
Offering amount ($ thousand)		41.13	36.24	14.00	22.50	30.00	50.00	75.00
Average credit rating		8.90	3.20	5.38	6.78	8.30	10.00	13.99
Average time to maturity (years)		10.53	10.01	1.87	3.52	7.00	15.02	27.61
Average age (years)		4.28	4.35	0.70	1.38	2.85	6.07	8.97
Trading days per bond		456.09	408.18	68.00	145.00	340.00	638.00	1013.10

This table shows summary statistics of all energy bonds included in sample. *Panel A* displays statistics for the whole sample, while *Panel B* and *Panel C* include statistics for the green energy bonds (listed in the Dow Jones Sustainability Index) and for all other non-green energy bonds (non-listed in the DJSI), respectively. The numerical credit rating is encoded by assigning values 1 to AAA, …, and 25 to D according to the Long-term debt rating equivalences. Our sample covers the period from January 1, 2005 to December 31, 2014. Trading data is obtained from the TRACE dataset, bond characteristics from the FISD and industry specific information from the NAICS.

The theoretical YTM, YTM_{th}, is computed from the theoretical price, P_{th}, of the government bond. In turn, this price is obtained by discounting the original cash flows of the energy bond by the corresponding spot rates.[7] Therefore, the YS is not dependent on the calculation date or the specific shape of the bond's cash flow structure. This measure allows us to compare different bonds traded on different dates.

We use daily estimates of the zero-coupon interest rate term structure for the US Treasury market that we obtain from one of the most popular databases, publicly available on the Federal Reserve Board's website (FRB).[8] This database reports both the spot interest rate for annual maturities between 1 and 30 years, and the estimated parameters of Svensson's model (1994). This database is also used by Oikonomou et al. (2014) to compile their annual data, although they use a simplification. Instead of using the actual maturity of each of the cash flows generated by the bond, these authors round each maturity to the nearest whole number. Although this simplification allows them to use the spot rates reported by the FRB for annual maturities, it introduces a significant bias into bonds whose first coupon is close to being paid.

The FRB data set has two interesting features for our study. First, it allows the calculation of zero-coupon interest rates for any maturity without interpolation. This data set includes the six Svensson (1994) model's parameters resulting from each daily estimation (β_0, β_1, β_2, τ_1, β_3, τ_2), which allows to immediately compute the spot rate for any required maturity. Unlike Oikonomou et al. (2014), we use the six parameters, estimated for the day the bond is traded, to estimate the spot rate for each of the original maturities of the bond's cash flows.

The price of each synthetic Treasury bond, P_{th}, is obtained by discounting the n cash flows of the original corporate bond (coupon and principal payments), C_T,from the spot rates $D\left(T, \overline{b}\right)$ for each maturity T ($T = t_1, t_2, \ldots, t_n$):

$$P_{th} = \sum_{T=t_1}^{t_n} C_T \cdot D\left(T, \overline{b}\right) \tag{2}$$

where $D(T, \overline{b})$ is the discount function that depends on a vector of six parameters $\overline{b}$, reported by the FRB, for the date on which the corporate bond is traded. This discount function is calculated by transforming the instantaneous forward rate for each maturity, f_T, from the functional form proposed by Svensson (1994):

$$f_T = \beta_0 + \beta_1\, exp\left(-\frac{T}{\tau_1}\right) + \beta_2 \frac{T}{\tau_1}\, exp\left(-\frac{T}{\tau_1}\right) + \beta_3 \frac{T}{\tau_2}\, exp\left(-\frac{T}{\tau_2}\right) \tag{3}$$

where T is the term to maturity and (β_0, β_1, β_2, τ_1, β_3, τ_2) is the set of parameters.

The second interesting feature of the FRB database is that these spot rates reflect the average liquidity of the Treasury debt market (Díaz et al. 2019). The FRB estimates do not take into account Treasury bills and all the most recently issued Treasury bonds, i.e. "on-the-run" and "first-off-the-run", which are the most liquid bonds. These yield curves therefore reflect the "regular" liquidity level in the market. Therefore, our estimates of YTM are not dependent on the transaction date or the specific shape of the bond's cash flow structure.

The difference between the YS of NGE bonds (YS_{NGE}) and the YS of GE bonds (YS_{GE}) can be understood as a sustainability premium:

$$Sustainability\ Premium = YS_{NGE} - YS_{GE} \tag{4}$$

This premium reflects the lower yield investors' demand from these companies to purchase their bonds, or otherwise the higher price they are willing to pay to purchase them, than bonds from NGE issuers. Both groups of companies belong to the same industry and are therefore exposed to similar risks. In addition, we compare GE and NGE bonds with the most homogeneous characteristics possible in terms of default risk, remaining maturity and coupon rates.

The sustainability premium is analyzed on the basis of two methodologies. First, the bonds are grouped into cohorts and the daily YS per cohort is analyzed. A battery of tests for equality of means, medians and variances analyze the statistical differences between GE and NGE bonds. Second, based on the daily trading data for each bond, a linear regression model is conducted to explain the YS of each bond on a set of explanatory variables that capture the characteristics of the bond and a set of control variables.

6. Empirical analysis and results

6.1. Cohort analysis

In this preliminary analysis, we group the daily bond YS into homogeneous cohorts. For each cohort we have a sample of GE bonds and a sample of NGE bonds. Within each cohort, we get a daily time series of average YS. The average YS for each day is obtained as a simple average of the YS of all the bonds in the cohort that are trading that day. In this way, we transform the more than 1.3 million daily transactions at the individual bond level into the average daily YS values for each cohort during the 2498 trading days in our sample period. Following Helwege et al. (2014), YS have been winsorized at 1% level, meaning that all values above the 99% percentile are set to the 99% percentile and all values below the 1% percentile are set to the 1% percentile.

Cohorts are established according to the credit quality of the issuer. Additionally, limits are established between the cohorts according to the term to maturity and coupon rate of the bond, trying to preserve a similar number of observations in each group. Therefore, we separate transactions from bonds with a coupon rate of less than or more than 6%, with a remaining maturity of less than or more than 5 years, and according to four credit rating categories (AA, A, BBB, and BB or lower).

Table 2 shows a statistical summary of the daily mean YS and the sustainability premium. Some cohorts with fewer bonds outstanding do not allow YS to be computed for all days in the sample period. This is the case, for example, with speculative grade bonds. In order to obtain the sustainability premium per cohort, the two daily samples are paired, so the number of days considered is restricted by the observations of the GE bonds. There is a large difference in both the average and the median YS of the GE bond subsample and the NGE bond subsample. The average (median) YS of GE bonds is 194 basis points (166 b.p.), while that of NGE bonds reaches 271 b.p. (253 b.p.). This result provides preliminary evidence in favor of our main hypothesis. These values suggest that, in general, bonds included in the DJSI incorporate a sustainability premium of around 77 b.p. (86 b.p.).

The analysis of the data corresponding to the different cohorts into which we divide the sample provides us with additional information. Issues with a coupon rate above 6% are traded with a higher YS. In our sample period, a higher coupon rate indicates a higher default risk and is usually associated with an older bond, i.e. a bond issued at a time when interest rates were higher. Higher default risk and lower liquidity lead to higher YS. Investors demand compensation as perceived risk increases. Finally, a shorter residual maturity may indicate that the bond was originally issued with a short maturity, that the bond is an old and seasoned issue, and that the time at which the issuer must repay the principal is approaching. This implies high default risk and low liquidity, as a large part of the issue is likely to be held in inactive portfolios (see, e.g., classical papers of Johnson 1967, and Sarig and Warga 1989). In fact, the average sustainability premium for bonds with maturities of less than 5 years is 102 b.p. and for bonds with coupon rates above 6% it is 143 b.p.

[7] This method has been used by many other studies on corporate bonds. Among the former are Babbel et al. (1997), Díaz and Skinner (2001) and Díaz and Navarro (2002).

[8] This dataset is included in the section "Finance and Economics Discussion Series" and is linked to the Gürkaynak et al. (2007)'s working paper. These authors use a weighted version of the method by Svensson (1994) from prices of all the outstanding second and further off-the-run Treasury bonds. The database is daily updated.

Table 2
Summary statistics of daily average yield spreads.

	Green energy (GE) bonds				Non-green energy (NGE) bonds				Sustainability premium (NGE-GE bonds) (matched days)			
All energy bonds												
Mean	194.35				271.03				76.79			
Median	166.37				253.13				85.62			
#obs	2491				2498				2491			
Bonds by rating class	AA	A	BBB	BB or below	AA	A	BBB	BB or below	AA	A	BBB	BB or below
Mean	132.98	167.06	212.31	261.14	168.73	186.39	236.66	473.91	18.06	21.22	24.38	322.70
Median	92.73	134.87	185.69	261.32	141.25	171.95	219.73	468.83	41.53	21.18	31.04	316.55
#obs	1276	2384	2481	365	2490	2495	2496	2495	1276	2384	2480	365
Bonds by coupon rate (%)	[0–6]	>6			[0–6]	>6			[0–6]	>6		
Mean	191.80	197.58			192.83	339.11			0.92	142.99		
Median	155.02	173.21			183.16	333.30			16.54	151.68		
#obs	2483	2457			2497	2497			2483	2457		
Bonds by term to maturity (years)	[0–5]	>5			[0–5]	>5			[0–5]	>5		
Mean	204.83	188.55			306.56	250.61			101.52	62.32		
Median	151.81	166.32			287.49	236.42			124.13	65.98		
#obs	2452	2479			2495	2498			2452	2479		

This table shows a statistical summary of the average daily yield spreads for all energy bonds included in the sample. All bonds in each subsample are considered at the top of the table. In the upper middle of the table, the included bonds are divided by their credit rating. In the lower-middle part, we divide both subsamples by coupon rate. At the bottom of the table, the bonds included in each sub-sample are divided according to their remaining maturity. YS has been obtained as the difference between the current volume-weighted daily yield-to-maturity (YTM) of a bond and its theoretical YTM estimated as given by an explicit term structure model. YS have been previously winsorized at 1% highest and lowest levels. Our sample covers the period from January 1, 2005 to December 31, 2014 and includes 1,345,188 daily observations. Trading data is obtained from the TRACE dataset, bond characteristics from the FISD and industry specific information from the NAICS.

The comparison of cohorts according to the credit rating of the issuer provides us with valuable information. As expected, the lower the credit rating, the higher the YS for both GE and NGE companies. What is remarkable is that the sustainability premium is also a function of the credit rating. For the three categories of investment-grade bonds considered (AA, A and BBB), the average sustainability premium hardly varies by 3 b.p. per category (18, 21 and 24 b.p.). The substantial difference can be seen with the category of speculative-grade or junk bonds (BB or lower), for which the average premium rises to 322 b.p. This indicates that the differentiation between GE and NGE bonds is more pronounced in the lowest credit quality bonds. Alternatively, the fact that an energy company that issues junk bonds is listed in the DJSI is valued much more favorably by investors than when that company issues investment grade bonds.

To assess the statistical significance of the differences observed in the YS between GE and NGE bonds, we conduct several tests that could shed light on the possible existence of a sustainability premium. From the time series of daily YS, we calculate the daily quotient between the YS of GE bonds and the YS of NGE bonds. In other words, we get the GE/NGE ratio for each day of the 2498 days that make up our 15-year sample. If the value of the GE/NGE ratio is consistently less than one, it should indicate that the average YS of GE bonds is systematically lower than that of NGE bonds. This would provide statistical evidence that sustainable energy bonds offer a lower YS than conventional energy bonds. Otherwise, investors in sustainable energy bonds would be paying a price premium.

Table 3 presents the statistics and results of the equality tests for the GE/NGE ratio. The percentage of times the ratio is greater than the unit ranges from 0 to 37.5%. For the three categories of investment-grade bonds, the YS of GE bonds is lower than that of NGE bonds, i.e. the sustainability premium is positive, approximately three quarters of the time. In the case of speculative-grade bonds, this occurs on 100% of the days in the sample period. This percentage is also above 95% for bonds with longer maturities and higher coupon rates. The large difference underlying these percentages is corroborated by formal equality tests. The standard *t*-test is used to test the null hypothesis that the mean of the GE/NGE ratio is equal to the unit. We apply two nonparametric tests for equality in medians, the sign test and the Wilcoxon signed-rank test. We also calculate the Levene test to check whether the two series of YS, from GE and NGE bonds, in each cohort have the same variances, i.e., the homogeneity of the variance of the two subsamples.

The results indicate that there are clear statistically significant differences in the group averages, except in the sample of bonds with a coupon rate of less than 6%. All other equality tests reject the null hypothesis of median and variance equality for all cohorts. We obtain therefore evidence that the YS whose GE bonds are traded on the US corporate bond market are significantly lower than those of other companies in the energy industry. Logically, this fact has a direct impact on funding costs when issuing new bonds in the primary or issue market. Energy companies included in the DJSI, i.e. those that meet the criteria for CSR practices in their business, benefit from lower debt costs. This result is corroborated when it is controlled by the credit rating class, by the coupon rate of the bond, and by the remaining term to maturity. In addition, the sustainability premiums between GE and NGE companies are particularly high and statistically significant for those companies that issue junk bonds. Again, we obtain evidence that DJSI listing is most favorably valued among older energy bonds and those issued by energy companies of lower credit quality.

These results are consistent with previous literature on CSR. Companies with high CSR are more reliable for financial investors. However, our sustainability premium is significantly higher than the impact on YTM observed in recent studies, such as Ge and Liu (2015) for the US primary market, Menz (2010) for the European secondary market, Oikonomou et al. (2014) for the US secondary market, and Hachenberg and Schiereck (2018) and Zerbib (2019) for green bonds. In all these cases the average corporate spreads reported are only a few basis points. Hachenberg and Schiereck (2018) and Oikonomou et al. (2014) note that the greatest impact is on bonds rated A and CCC or lower.

Table 3
Test results for statistical differences between yield spreads from green energy bonds and non-green energy bonds.

GE/NGE ratio	Mean	Median	% >1.0	t-test	Sign test	Signed-rank test	Variance test
All bonds							
	0.732	0.686	6.7	−71.008***	43.198***	39.988***	7.655***
				(0.000)	(0.000)	(0.000)	(0.006)
Bonds by rating class							
AA bonds	0.885	0.695	22.5	−5.173***	19.624***	15.686***	128.318***
				(0.000)	(0.000)	(0.000)	(0.000)
A bonds	0.901	0.887	27.5	−16.433***	21.935***	20.649***	39.997***
				(0.000)	(0.000)	(0.000)	(0.000)
BBB bonds	0.914	0.874	22.5	−17.926***	27.410***	25.985***	4.524**
				(0.000)	(0.000)	(0.000)	(0.034)
Bonds BB or below	0.456	0.458	0.0	−197.524***	19.053***	16.556***	86.695***
				(0.000)	(0.000)	(0.000)	(0.000)
Bonds by coupon rate							
0%–6%	1.010	0.924	37.5	1.189	12.402***	7.242***	169.805***
				(0.235)	(0.000)	(0.000)	(0.000)
> 6%	0.594	0.551	1.8	−129.290***	47.773***	42.335***	225.648***
				(0.000)	(0.000)	(0.000)	(0.000)
Bonds by term to maturity							
0–5 years	0.690	0.580	15.5	−39.310***	34.149***	32.618***	8.689***
				(0.000)	(0.000)	(0.000)	(0.003)
> 5 years	0.747	0.726	4.8	−102.255***	45.030***	42.137***	5.897**
				(0.000)	(0.000)	(0.000)	(0.015)

This table shows some statistics and the results of statistical tests of equality of the daily quotient between the YS of GE bonds and the YS of NGE bonds (GE/NGE ratio). Tests are conducted for each cohort according to coupon rate, rating category and remaining bond maturity. The hypothesis that the mean of the GE/NGE ratio is equal to unity is tested using a standard t-test. A sign test is used to test that the median of the GE/NGE does not change. A Wilcoxon signed-rank test is used to test that the median of the GE/NGE ratio is equal to the unit. The Levene statistic is used to test the equality of variances between GE and NGE YS series. Our sample covers the period from January 1, 2005 to December 31, 2014. Trading data is obtained from the TRACE dataset, bond characteristics from the FISD and industry specific information from the NAICS. *** and ** indicate significance at the 1% and 5% levels, respectively, in a two-tailed test.

6.2. Regression analysis

Our preliminary results point to YS of bonds from GE companies as significantly lower than those of bonds from NGE firms. In order to give further insights, we test our hypotheses one (bonds of energy companies that include CSR practices in their business have lower YS) and two (investors value CSR practices more favorably in companies that bear the greatest risk and have the worst credit rating) through regression analysis. We conduct an analysis in which we use cross-sectional time series, pooled OLS regression analysis (controlling for bond characteristics, bond liquidity, year effects, and energy prices), and the Newey–West consistent covariance matrix for testing purposes, to test our main hypotheses.

To that purpose, we regress the daily bond YS on a set of variables that represent the CSR of the bond's issuer, bond features, bond liquidity, other well-known controlling variables used in prior literature, and the prices of main energy sources (oil, gas and electricity), which could affect energy firm asset pricing.[9] The dependent variable is the YS, expressed in b.p., at which the bond i trades the day t, YS_{it}. The sustainability premium is obtained from a dummy variable, $DJSI_{it}$, that reflects whether the company issuing the i bond is labelled as a GE company at time t. This dummy variable is equal to 1 when the company is included in the DJSI and 0 otherwise. Since this dummy variable shows the lower YS at which GE bonds are traded relative to other bonds, the negative value of its estimated coefficient is interpreted as the sustainability premium.

The credit rating of the issuer at time t is represented by the set of dummy variables, AA_{it}, A_{it}, BBB_{it}, and $Speculative\ Grade_{it}$, the latter being the one corresponding to junk bonds (BB or lower). As variables of bond features, we include $Coupon\ Rate_i$ (in percentage), $Term\ to\ Maturity_{it}$ (in years), and $Size_i$ or offering amount (in logs) of bond i. The amount outstanding (Fisher 1959) and the term to maturity (Amihud and Mendelson 1991) of an issue are classic measures of a bond's liquidity. In addition, other simple measures have traditionally been used in the literature as proxies for bond liquidity. This is the case of the trading frequency ($Number\ of\ Trades_{it}$) and $Trading\ Volume_{it}$ (in logs), all of which refer to transactions carried out with the bond i during the day t. We discard more complex liquidity measures since studies show that these measures do not always provide the expected results when analyzing fixed-income assets (Díaz and Escribano 2017). We also control for market conditions and macroeconomic fundamentals by considering dummy variables for each year in the sample. Finally, we consider prices of main energy sources by including changes on prices of oil ($Oil\ price_{it}$), gas ($Gas\ price_{it}$), and electricity ($Electricity\ price_{it}$).

The general forms of the models that are estimated are:

$$YS_{it} = f(DJSI_{it} Rating_{it} DJSI_{it} \times Rating_{it} Bond\ Features_{it} Liquidity_{it}\ Year_{it} Energy\ Prices_{it}) \tag{5}$$

where $DJSI_{it} \times Rating_{it}$ are the interaction terms between the $DJSI$ dummy variable and each of the different credit rating dummies. The models are estimated from the daily trading data of each bond. In total, we deal with more than 1.3 million observations.

The analysis of Pearson's correlation coefficients for the variables of interest shows relatively low values, being always lower than 0.4 in absolute value. Therefore, no multicollinearity problems are expected in the regression analyses that have been performed. It should be noted that the correlation coefficients between the $DJSI$ and the credit ratings are less than 0.1, which will allow us to properly interpret the regression coefficients of the interaction terms (Kam and Franzese 2007).[10]

The regression results of the main empirical analyses are reported in Table 4. Model (1) analyses the impact of an energy industry issuer's inclusion in a CSR index on the trading of its bonds in the US corporate bond market. Controlling for the characteristics of the bond, its liquidity

[9] We obtain daily time series of spot prices of oil (West Texas Intermediate) and gas (Henry Hub Natural gas), and monthly average prices of electricity (Consumer Price Index of all urban consumers in US), from the Federal Reserve Economic Data website (https://fred.stlouisfed.org/).

[10] For the sake of brevity, the correlation matrix is not reported, but is available from the authors.

Table 4
Regressions of bond yield spreads against energy bond issuers' CSR controlled by bond features, bond liquidity and market conditions.

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-146.18^{***}	1.02	-127.03^{***}	-63.34^{***}	-135.45^{***}	239.58^{***}
	(−10.52)	(0.07)	(−8.95)	(−4.40)	(−9.85)	(15.19)
DJSI	-65.92^{***}	-23.29^{***}	-67.55^{***}	-65.24^{***}	-122.31^{***}	-258.22^{***}
	(−18.24)	(−7.00)	(−18.30)	(−16.24)	(−20.96)	(−21.26)
Speculative Grade		200.09^{***}				
		(46.82)				
DJSI×Speculative Grade		-237.53^{***}				
		(−18.78)				
AA			-51.53^{***}			-232.29^{***}
			(−11.35)			(−37.32)
DJSI× AA			51.47^{***}			231.86^{***}
			(3.01)			(10.87)
A				-70.03^{***}		-223.52^{***}
				(−30.06)		(−47.45)
DJSI ×A				11.65^{*}		218.67^{***}
				(1.60)		(16.32)
BBB					-49.92^{***}	-188.99^{***}
					(−22.07)	(−44.30)
DJSI × BBB					107.83^{***}	246.91^{***}
					(15.26)	(19.43)
Coupon Rate	54.88^{***}	35.39^{***}	54.38^{***}	49.71^{***}	54.15^{***}	33.46^{***}
	(53.05)	(31.34)	(52.02)	(46.53)	(52.96)	(28.61)
Term to Maturity	-5.35^{***}	-3.78^{***}	-5.30^{***}	-5.07^{***}	-5.24^{***}	-3.70^{***}
	(−48.59)	(−33.87)	(−47.79)	(−46.25)	(−47.55)	(−32.75)
Size	1.72^{***}	-2.44^{***}	0.60	−0.24	3.11^{***}	-4.14^{***}
	(1.89)	(−2.80)	(0.65)	(−0.26)	(3.38)	(−4.66)
Number of Trades	3.69^{***}	3.03^{***}	3.70^{***}	3.61^{***}	3.57^{***}	3.04^{***}
	(15.15)	(13.58)	(15.16)	(14.84)	(15.05)	(13.54)
Trading Volume	0.73^{**}	-3.24^{***}	0.69^{**}	−0.43	0.50	-3.66^{***}
	(2.31)	(−10.75)	(2.20)	(−1.38)	(1.59)	(−12.07)
Oil price	-1.07^{***}	-1.09^{***}	-1.07^{***}	-1.10^{***}	-1.05^{***}	-1.11^{***}
	(−7.04)	(−7.43)	(−7.14)	(−7.25)	(−6.90)	(−7.61)
Gas price	-5.01^{***}	-5.21^{***}	-5.08^{***}	-5.13^{***}	-4.88^{***}	-5.30^{***}
	(−5.13)	(−5.45)	(−5.20)	(−5.28)	(−5.01)	(−5.56)
Electricity price	-5.01^{***}	-4.22^{***}	-4.48^{***}	-4.09^{***}	-4.80^{***}	-3.98^{***}
	(−5.13)	(−9.79)	(−9.98)	(−9.18)	(−10.73)	(−9.26)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
# Observations	1,345,188	1,345,188	1,345,188	1,345,188	1,345,188	1,345,188
Adjusted R-squared	0.1881	0.2460	0.1891	0.1982	0.1949	0.2489

This table shows the results from the regression analysis. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. The *t*-statistics are calculated by robust standard errors for each coefficient and appear in parenthesis. *DJSI*, *AA*, *A* and *BBB* refer to Dow Jones Sustainability Index and AA, A and BBB credit ratings, respectively.

and market conditions, a statistically significant ($p < 0.01$) average sustainability premium of 66 b.p. (negative value of the estimated coefficient associated with the *DJSI* dummy) is observed. This value is fully consistent with that observed in the daily cohort analysis of the previous section (77 b.p.).

Since investors may assess an energy company differently depending on whether the company is considered a CSR and on its credit quality, we consider jointly these two facts. Models (2) to (6) in Table 4 examine sustainability premium behavior for different credit rating categories. Each model incorporates a variable dummy that corresponds to a rating and the interaction effect of that rating multiplied by the *DJSI*. Model (2) is the one corresponding to the speculative grade bonds. The value of the coefficient associated with the *DJSI* is negative (−23.29) and highly statistically significant ($p < 0.01$). It shows the sustainability premium of the rest of the bonds, i.e. investment-grade bonds (23 b.p.).

In the case of speculative grade bonds, the coefficient is highly statistically significant ($p < 0.01$) and has a positive effect on *YS* (coefficient = 200.09). This result suggests that a junk bond trades at higher YS, on average about 200 b.p., given the compensation investors demand for bearing higher default and illiquidity risks. More interesting for our analysis is that, the sustainability premium for these bonds reaches 261 b.p. This value is obtained by adding the coefficients associated with *DJSI* and the interaction effect of $DJSI \times SpeculativeGrade$ (23.29 + 237.53). A similar value is obtained in Model (6), in which all investment grade ratings are considered together and therefore the *DJSI* coefficient (258 b.p.) shows the case of junk bonds. Although both values, 261 and 258 b.p., are appreciably lower than the 322 b.p. obtained in the cohort analysis, they provide evidence that investors particularly reward CSR practices in the segment of energy companies with the lowest credit quality, the speculative grade companies. This 261 b.p. premium in YTM terms shows how CSR issuers of junk bonds are financed at a substantially lower cost than other companies in the same energy industry. This lower cost of debt implies a clear competitive advantage. For example, if a NGE company with a speculative grade rating were to bear an average debt cost of 7.5%, a GE company with the same characteristics would bear a debt cost of only 4.89%.

Columns (3), (4) and (5) in Table 4 show the results of the estimates that analyze the specific cases of AA, A and BBB bonds, respectively. Regression coefficients of *AA*, *A* and *BBB* on Models (3), (4) and (5), respectively, are highly statistically significant ($p < 0.01$) and have a negative effect on YS. Sustainability premiums of 16 b.p. (67.55–51.47) are obtained for GE AA-rated bonds, 54 b.p. (65.24–11.65) for A bonds, and 14 b.p. (122.31–107.83) for BBB bonds. Although the average premium for AA and BBB bonds is in line with that obtained in the cohort analysis (18 b.p. for AA, and 24 b.p. for BBB in Table 3) and for all the investment grade bonds observed in the Model (1), the value of 54 b.p. for A-rated bonds stands out (21 b.p. for A in Table 3). The joint analysis of the three investment grade categories conducted in the Model (6) does not shed light on this issue. From this Model (6), sustainability premiums of 26, 40, and 11 b.p. are derived for AA, A, and BBB bonds, respectively. In any case, this result is consistent with that indicated by Hachenberg

Table 5
Bootstrapped models of the regressions of bond YS against energy bond issuers' CSR.

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	−71.01***	46.00***	−50.68**	28.43	−41.42**	317.44***
	[−97.20, −43.30]	[20.70, 73.36]	[−77.05, −21.93]	[1.83, 56.64]	[−66.96, −13,667]	[289.76, 346.97]
DJSI	−72.92***	−25.61***	−75.21***	−76.50***	−127.92***	−247.64***
	[−75.56, −70.37]	[−27.95, −23.27]	[−77.94, −72.52]	[−79.82, −73.28]	[−131.99, −123.86]	[−257.23, −238.05]
SG		217.48***				
		[208.84, 226.19]				
DJSI×SG		−226.76***				
		[−236.67, −216.84]				
AA			−68.21***			−257.82***
			[−78.51, −57.08]			[−270.78, −244.15]
DJSI×AA			69.02***			235.16***
			[57.70, 79.42]			[221.06, 248.99]
A				−85.40***		−243.96***
				[−90.55, −80.22]		[−253.28, −234.42]
DJSI×A				28.90**		211.33***
				[23.70, 34.08]		[200.82, 221.72]
BBB					−53.55***	−203.70***
					[−58.48, −48.47]	[−212.37, −194.78]
DJSI×BBB					109.02***	231.08***
					[103.91, 113.98]	[220.94, 241.25]
Controls	Yes	Yes	Yes	Yes	Yes	Yes
# Obs.	84,102	84,102	84,102	84,102	84,102	84,102
Adj. R-sq.	0.1860	0.2451	0.1874	0.2041	0.1980	0.2546
	[0.1859, 0.1861]	[0.2450, 0.2452]	[0.1873, 0.1875]	[0.2040, 0.2042]	[0.1979, 0.1982]	[0.2545, 0.2547]

This table shows the results from the regression analysis of bootstrapped models after 10,000 iterations. ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. 95% confidence intervals of the estimated coefficients are displayed in brackets. *DJSI*, *SG*, *AA*, *A* and *BBB* refer to Dow Jones Sustainability Index, Speculative grade, and AA, A and BBB credit ratings, respectively.

and Schiereck (2018) and Oikonomou et al. (2014) who point out that, apart from CCC bonds or lower, the greatest sustainability impact on YS is seen in A-rated bonds.

Among the explanatory variables, *Coupon Rate*, *Term to Maturity* and *Number of Trades* are highly statistically significant ($p < 0.01$) and their associated coefficients present similar values for all models. The *Coupon Rate* shows a positive relationship with *YS*, as companies with lower credit quality must offer a higher promised return to investors to compensate for the higher default risk and lower liquidity of their bonds. The negative impact of *Term to Maturity* on *YS* may be conditioned by

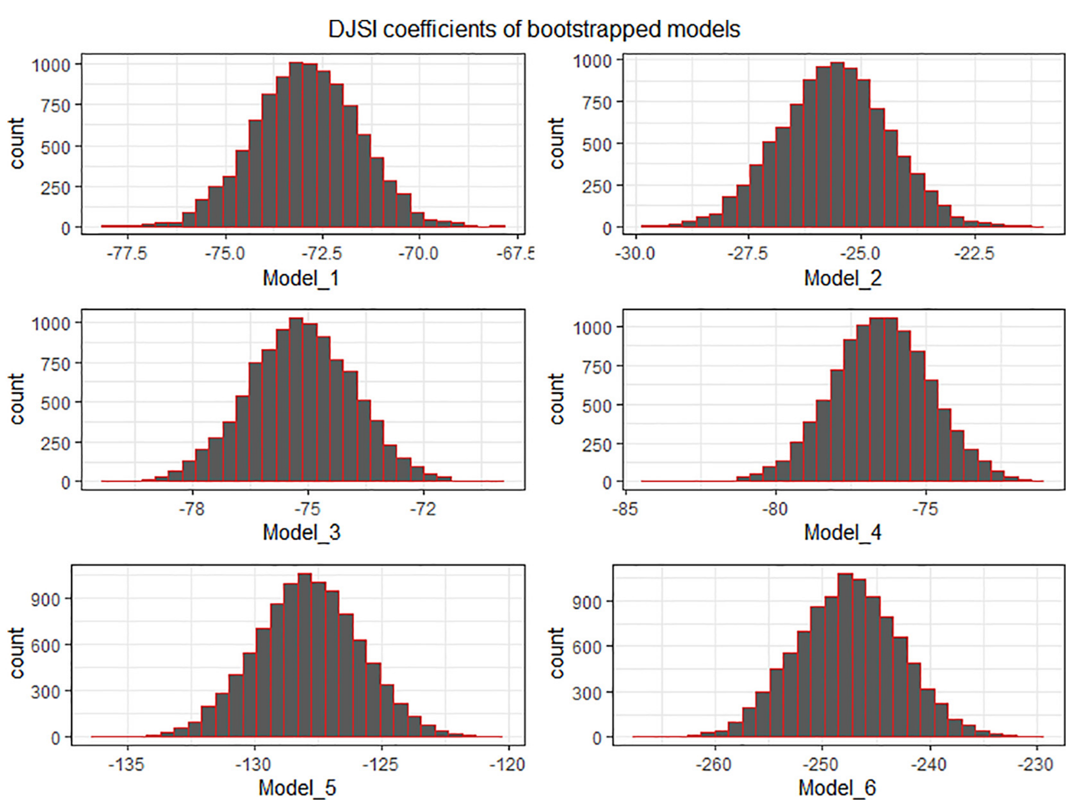

Fig. 1. Histogram of DJSI coefficients from the bootstrapping procedure with equal sample size for GE and NGE observations. Note: This figure shows the histograms of the DJSI coefficients of the blocked bootstrapped Models (1) through (6). The number of iterations is 10,000 and the number of observations in each iteration is 84,102.

the fact that bonds with lower credit quality tend to be issued with shorter maturities. Although the *Number of Trades* per day is often interpreted as a liquidity proxy, its positive coefficient denotes a direct relationship with the *YS*. In addition, the statistical significance and value of the coefficients associated with the *Size* and *Trading Volume* variables vary between models. Finally, the regression coefficients of *Oil price*, *Gas price*, and *Electricity price* are negative and highly statistically significant ($p < 0.01$) in all models suggesting that large fluctuations in energy prices affect negatively to *YS*. Given the composition of our daily data sample by bond and the explanatory variables used, the fact that the adjusted R^2 varies according to the model between 19% and 25% is a remarkable result.

In sort, our regression results show that sustainable energy bonds offer a lower YS than conventional energy bonds in the US corporate bond market, and that this sustainability premium is higher for worsen rated bonds.

6.3. Robustness

The composition of the sample of observations of GE and NGE bonds is determined by all transactions carried out in the market during the sample period. Although this composition is beyond our control, it is noteworthy that the sample sizes of both subsamples are markedly different. The observations of the GE bonds subsample represent slightly less than 3% of the total sample of 1,345,188 observations. In order to avoid potential sampling biases and excessive noise in the NGE subsample, we propose a robustness analysis that applies a bootstrap sampling procedure to perform regression analysis from random subsamples. The bootstrapped models are estimated with a variance-covariance matrix of the estimators that produce bias-corrected confidence intervals around the coefficients.

The bootstrap sampling procedure consists of estimating each model for 10,000 samples drawn randomly from the original sample. The randomness in the composition of each sample affects exclusively the NGE observations, since the 42,051 GE observations are included in all the extractions. That is, we resample the initial dataset with 84,102 observations, which always include the 42,051 GE observations and an identical number of 42,051 observations randomly extracted from the subsample of 1,303,137 NGE observations. This procedure guarantees an equal sample size for GE and NGE observations.

The results regarding the variables of interest (*DJSI* and its interactions with the rating dummies) of applying the bootstrap algorithm to the six models analyzed in Table 4 are summarized in Table 5. The bootstrap coefficients are highly statistically significant and the bootstrapped OLS analysis also provides similar good performance in terms of relatively high adjusted R^2. It is remarkable that the average of the coefficients obtained in the 10,000 simulations for each model

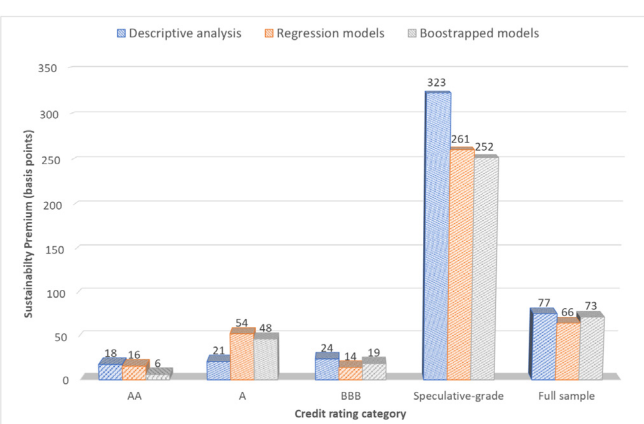

Fig. 2. Sustainability premium for GE bonds from different methodologies.

(Table 5) barely deviates a few basic points from the coefficients estimated in the regression analysis of the entire sample (Table 4). The 95% confidence intervals of the estimated coefficients from the 10,000 estimates of each model shows a small amplitude, which gives robustness to our results.

To illustrate the results of the bootstrapping procedure, Fig. 1 displays the histogram of the sequence of the 10,000 bootstrap estimates for the DJSI coefficient in Models (1) through (6). As observed, the distribution of the bootstrap estimates of regression coefficients is very well approximated by a normal distribution.

7. Conclusions

This paper is focused on the analysis of YS differentials between corporate bonds issued by energy industry companies, with similar features about rating and bond fundamentals, and traded on the same day, but with differences on their issuers' CSR. We employ an extensive dataset that covers the period from January 1, 2005 to December 31, 2014 and that includes more than 1.3 million daily observations computed from intraday data involving 2852 bonds issued by 605 different energy industry issuers. To accurately identify the effect of CSR on the YTM at which these energy bonds are traded in the market we work with YS. The YS of each bond is estimated daily from its YTM and the YTM of an identical synthetic government bond, which is obtained by discounting the bond's original cash flows from current risk-free interest rates. By controlling for the characteristics of the bond, the liquidity with which it is traded, the creditworthiness of its issuer, and the market conditions, the sustainability premium is obtained as the difference between the YS of the bond issued by green energy companies and the YS of the bonds issued by energy companies that do not have such a qualifier (non-green firms).

We identify significant sustainability premiums between GE and NGE companies. Our analysis quantifies the impact of energy companies' proactive involvement in CSR practices on the prices at which their corporate bond issues are traded. In aggregate terms, the sustainability premium averages 66 b.p. measured in terms of daily bond YS. This overpricing that investors are willing to pay for these bonds shows the increased investor demand for these GE bonds and leads to lower financing costs for these companies. This is a clear competitive advantage of GE companies over NGE companies. The sustainability premium depends on the credit rating of the issuer. While it is about 23 b.p. for investment grade bonds, with some differences between ratings, it is about 261 b.p. for speculative grade bonds (see Fig. 2). The sustainability label involved in being listed in the DJSI is more favorably priced for investors in lower credit quality bonds. GE companies that issue junk bonds may benefit from significant reductions in the cost of debt.

Our findings support the result of Ng and Zheng (2018) focusing on the stock market where the role of green investor preferences within the framework of the theory of disagreement, tastes, and asset prices of Fama and French (2007) prevails. That is, the uncertainty generated by the disagreement about the probability distributions of future payments on assets is more than offset by the fact that investors may consider assets as consumer goods. Investors are willing to pay a sustainability premium for bonds of GE companies. The price effect of CSR investor tastes could be amplified for riskier bonds. However, a limitation of our study needs to be acknowledged. Our data sample may be biased, as there may be companies in the energy industry that develop CSR practices that are not listed in the DJSI.

Our study has important implications for both managers and investors. Company managers should be more aware of the impact that practices in accordance with or against to CSR could have on the cost of debt. The managerial efficient and good performance in terms of CSR could act as a positive signal towards stakeholders worried with the managers' commitment with the company and could serve as a channel to access to cheaper sources of funding. This is especially noticeable in the case of CSR junk bond issuers. They are mostly young and perceived as highly risky, so they benefit even more from lower financing costs. This result should encourage CSR firms to seek debt capital even if they have a lower debt rating. On the other hand, investors worried about investing in sustainable, social, and environmentally friendly companies could take into account the relationship between bond YS and CSR, as well as other bond fundamentals, in their decision-making process.

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Annex

Table A1
NAICS codes for energy related companies.

NAICS CODE	ACTIVITY
211	OIL & GAS EXTRACTION
21,111	OIL & GAS EXTRACTION
21,311	SUPPORT ACTIVITIES POR OIL AND GAS EXTRACTION
22,111	ELECTRIC POWER GENERATION
22,112	ELECTRIC POWER TRANSMISION, CONTROL AND DISTRIBUTION
22,121	NATURAL GAS DISTRIBUTION
22,131	WATER SUPPLY AND IRRIGATION SYSTEMS
22,132	SEWAGE TREATMENT FACILITIES
32,411	PETROLEUM REFINERIES
32,512	INDUSTRIAL GAS MANUFACTURING
33,431	AUDIO AND VIDEO EQUIPMENT MANUFACTURING
42,472	PETROLEUM AND PETROLEUM PRODUCTS MERCHANT WHOLESALERS (EXCEPT BULK STATIONS AND TERMINALS)
48,611	PIPELINE TRANSPORTATION OF CRUDE OIL
48,621	PIPELINE TRANSPORTATION OF GAS NATURAL
48,691	PIPELINE TRANSPORTATION OF REFINED PETROLEUM PRODUCTS
48,699	ALL OTHER PIPELINE TRANSPORTATION
52,393	INVESTMENT ADVICE
53,249	OTHER COMMERCIAL AND INDUSTRIAL MACHINERY AND EQUIPMENT RENTAL AND LEASING
54,136	GEOPHYSICAL SURVEYING AND MAPPING SERVICES
211,111	CRUDE PETROLEUM AND NATURAL GAS EXTRACTION
211,112	NATURAL GAS LIQUID EXTRACTION
212,111	BITUMINOUS COAL AND LIGNITE SURFACE MINING
213,111	DRILLING OIL AND GAS WELLS
213,112	SUPPORT ACTIVITIES POR OIL AND GAS OPERATIONS
221,111	HYDROELECTRIC POWER GENERATION
221,112	FOSSIL FUEL ELECTRIC POWER GENERATION
221,113	NUCLEAR ELECTRIC POWER GENERATION
221,119	OTHER ELECTRIC POWER GENERATION
221,121	ELECTRIC BULK POWER TRANSMISSION AND CONTROL
221,122	ELECTRIC POWER DISTRIBUTION
221,210	NATURAL GAS DISTRIBUTION
221,310	WATER SUPPLY AND IRRIGATION SYSTEMS
221,320	SEWAGE TREATMENT FACILITIES
237,110	WATER AND SEWER LINE AND RELATED STRUCTURES CONSTRUCTION
237,120	OIL AND GAS PIPELINE AND RELATED STRUCTURES CONSTRUCTION
237,130	POWER AND COMMUNICATION LINE AND RELATED STRUCTURES CONSTRUCTION
238,210	ELECTRICAL CONTRACTORS AND OTHER WIRING INSTALLATION CONTRACTORS
238,220	PLUMBING, HEATING AND AIR-CONDITIONING CONTRACTORS
238,910	SITE PREPARATION CONTRACTORS
324,110	PETROLEUM REFINERIES
324,191	PETROLEUM LUBRICATING OIL AND GREASE MANUFACTURING
324,199	ALL OTHER PETROLEUM AND COAL PRODUCTS MANUFACTURING
325,199	ALL OTHER BASIC ORGANIC CHEMICAL MANUFACTURING
333,132	OIL AND GAS FIELD MACHINERY AND EQUIPMENT MANUFACTURING
334,111	ELECTRONIC COMPUTER MANUFACTURING
334,220	RADIO AND TELEVISION BROADCASTING AND WIRELESS COMMNICATIONS EQUIPMENT
334,511	SEARCH, DETECTION, NAVIGATION, GUIDANCE, AERONAUTICAL AND NAUTICAL SUSTEM AND INSTRUMENT MANUFACTURING
335,311	POWER DISTRIBUTION AND SPECIALTY TRANSFORMER MANUFACTURING
335,312	MOTOR AND GENERATOR MANUFACTURING
424,710	PETROLEUM BULK STATIONS AND TERMINALS
424,720	PETROLEUM AND PETROLEUM PRODUCTS MERCHANT WHOLESALERS (EXCEPT BULK STATIONS AND TERMINALS)
454,311	HEATING OIL DEALERS
454,312	LIQUEFIED PETROLEUM GAS (BOTTLED GAS) DEALERS
483,111	DEEP SEA FREIGHT TRASNPORTATION
486,110	PIPELINE TRANSPORTATION OF CRUDE OIL
486,210	PIPELINE TRANSPORTATION OF NATURAL GAS
486,910	PIPELINE TRASNPORTATION OF REFINED PETROLEUM PRODUCTS
486,990	ALL OTHER PIPELINE TRANSPORTATION
511,210	SOFTWARE PUBLISHERS
522,298	ALL OTHER NONDEPOSITORY CREDIT INTERMEDIATION
523,991	TRUST, FIDUCIARY AND CUSTODY ACTIVITIES
541,360	GEOPHYSICAL SURVEYING AND MAPPING SERVICES
541,512	COMPUTER SYSTEMS DESIGN SERVICES
551,112	OFFICES AND OTHER HOLDING COMPANIES
562,998	ALL OTHER MISCELLANEOUS WASTE MANAGEMENT SERVICES
811,310	COMMERCIAL AND INDUSTRIAL MACHINERY AND EQUIPMENT (EXCEPT AUTOMOTIVE AND ELECTRONIC) REPAIR AND MAINTENANCE
926,130	REGULATION AND ADMINISTRATION OF COMMUNICATIONS, ELECTRIC, GAS AND OTHER UTILITIES

This table lists the codes that the North American Industry Classification System (NAICS) assign to the different activities related with the energy sector. Source: www.naics.com.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2021.105113.

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