Nijmegen School of Management

Department of Economics and Business Economics

Master's Thesis

Investigating the effects of GHG emissions on firms' stock market liquidity

Berkay Akçiçek (s1054347)

Nijmegen, 14 August 2022

Program: Master's Program in Economics

Specialisation: Corporate Finance & Control

Supervisor: Asst. Professor Imtiaz Sifat

Radboud University

Abstract

This study investigates the effects of GHG emissions and common firm-level practices to reduce emissions on firms' liquidity on a sample of 350 European companies. A novelty of this paper is its application of both emissions and firm-level initiatives, which leads to a deeper understanding on the salience of emissions metrics for stock liquidity. We apply a panel data fixed-effects model on a sample ranging from 2011 to 2020 and significant results while factoring in omitted variable bias. The principal finding is that firms with high levels of total emissions are associated with higher liquidity. Moreover, the most common measures of emissions performance—GHG intensity and change in emissions—are not related to the stock liquidity. Further analyses suggest that emissions reduction policy provides benefits in terms of more liquid stocks, while emissions trading participation does not. The findings of our study have implications for investors to assess the riskiness of an investment, the firms to obtain more liquidity from equity markets, and the policymakers to increase overall liquidity in stock markets.

Table of Contents

1. Introduction

Environmental, Social, and Governance (ESG) related issues have attracted considerable attention in recent decades. According to information disclosed by the United Nations, 2010 to 2019 was the warmest decade on record, and Greenhouse gases (GHG) are considered the central reason for the significant change in the climate. GHG emissions refer to any gas that traps heat in the atmosphere such as carbon dioxide, methane, and water vapor. Burning fossil fuels, cutting forests, and livestock farming are some of the human activities that drive the large increase in the concentration of greenhouse (GHG) emissions. As a consequence of growing production and industrialization, the concentration of GHG emissions significantly rose compared to pre-industrial levels. A high level of GHG emissions contributes to an increase in temperature by capturing the heat and threatens biodiversity and human life. This led intergovernmental organizations to take a step and encourage countries as well as corporations to act promptly to mitigate the unintended consequences of increasing levels of GHG emissions.

GHG emissions became one of the primary concerns, particularly after the Kyoto Protocol. Kyoto Protocol is an extension of the United Nations Framework Convention on Climate Change (UNFCCC) which commits the assigned countries to achieve specific emission reduction targets. Since GHG emissions are one of the outcomes of production activities, corporations are encouraged to report their emissions and they become more accountable. Furthermore, several mechanisms are developed throughout the Kyoto Protocol to help assigned countries to achieve specific emission targets. One of the important mechanisms implemented is the "Emission Trading Scheme (ETS)" which allows GHG emissions to be traded as a new commodity to ensure secure transfer of emission reduction between committed countries. ETS is an instrument to combat climate change by creating incentives to reduce GHG emissions and it sets a cap on the total amount that can be emitted by a company each year and requires monitoring. Companies that exceed this cap have to purchase an emission allowance for each tonne of CO2 emissions emitted. This leads some of the companies to purchase allowance and some of the companies to sell their surplus allowances, thus, emission allowances are the currency of the carbon market.

Even though GHG emissions are associated with most economic activities, corporations emitted the atmosphere without any costs for decades (Nerlinger and Riordan, 2022). After the

Kyoto Protocol, emitting became costly for companies, and the number of investors who demand information related to non-financial or ESG performance has rapidly increased. Recent findings suggest that the majority of mainstream investors believe that sustainability information is a financial material for their investment decisions (Amel-Zadeh and Serafeim, 2018). For instance, investors require a higher return for the additional risk involved in an investment, therefore, more risky stocks are generally associated with higher returns. And this return is positively affected by the illiquidity of the stock (Amihud, 2002). This implies more liquid stocks have a lower illiquidity risk and thus a lower premium. Hence the amount of emissions emitted by a company could have an effect on the liquidity of its stock. A stock's liquidity describes the extent to which the stock can be traded without substantially affecting the stock price. While more liquid stocks enable investors to execute high-volume transactions with smaller bid-ask spreads, less liquid stocks could be associated with delays in the selling process, thus, can limit the trading volume. Illiquid stocks are significantly affected by drops in market-wide liquidity, and holders of such stocks can move to more liquid stocks due to their overall portfolio liquidity concerns (Pastor and Stambaugh, 2001). Firms with more liquid stocks appear to have better performance (Fang, Noe, and Tice, 2009), and a higher firm value (Nguyen, Duong, and Singh, 2016).

Currently, the primary environmental concern is global climate change, hence, GHG emissions play a relatively important role in a firm's environmental performance. Intergovernmental efforts to combat climate change created a basis for more companies to become more committed to climate change-related concerns and their environmental performance. The vast majority of previous studies focus on total emissions, carbon performance, and disclosure and investigate whether firms' emissions performance provides benefits in terms of financial performance. Researchers' efforts to link the environmental and financial performance of companies have generated mixed evidence in the existing literature. In addition to that, firms also engage in various corporate sustainability initiatives as a response to climate change-related risks (Haque and Ntim, 2022). For instance, some firms implement a particular policy to reduce their emissions or participate in emissions trading activities which in turn provides a more socially responsible and credible outlook. Focusing on both emissions performance and climate change-related initiatives can provide a richer view of the extent to which companies pursue their emissions concerns. If the emissions performance of a firm is valued by markets, its efforts to reduce climate change-related risk can also be perceived positively. On the other hand, Companies could focus on legitimizing their environmental

performance rather than substantive environmental commitments due to the high costs of long-term investments to reduce emissions (Haque and Ntim, 2022). Therefore, when investigating emissions, studying both effects of initiatives and performance is most likely to provide stronger insights than investigating only emissions performance. This research focuses on both emissions performance and common firm-level climate-change related concerns.

Although many studies attempted to investigate GHG emissions, very little research asks the important question of whether emission performance or initiatives have an effect on firms' stock market liquidity. A considerable amount of studies provide evidence of a positive or negative relationship between a firm's emissions performance and financial performance. If climate change-related performance has a large effect on a firm's financial performance, this effect may also appear in the form of liquidity or illiquidity on the firm's stock. Liquidity has an important role for firms, investors, and overall stock markets. Therefore, understanding the effects on liquidity can provide useful insights from multiple perspectives. Firstly, liquidity plays an important role in the performance of stock-listed firms. Because, when there is a large volume of stock being traded, the company could obtain more financing by absorbing new investors (Singh, Gupta, and Sharma, 2015). Secondly, a stock's liquidity is one of the most important factors when considering stock returns (Lam and Tam, 2011). When an investor's portfolio consists of highly illiquid stocks, the portfolio holder might not be able to access their cash. This suggests more liquid stocks are associated with lower risk compared to illiquid stocks. Finally, liquidity has a crucial role in stock markets operating successfully. A more liquid market is most likely to be less risky compared to an illiquid market which is important to attract more investors. Despite its great importance, liquidity is a very rarely investigated topic throughout the sustainability literature.

Previous literature suggests that the number of investors who consider ESG information for investment purposes is more than the U.S. (Amel-Zadeh and Serafeim, 2018; Brandon et al. 2021). The study of Nerlinger and Riordan (2022) finds that carbon disclosure decreases bid-ask spread in the U.K. more than in the U.S. In line with this, conducting our analysis in the Europe continent could help draw more concrete results from the outcomes of this study. Therefore, this study considers S&P 350 Europe sample. This sample gives a broad view of the European economy and includes companies from various industries. The time frame covers the period starting 2011 to 2020 which immunes from the major financial crisis. Although this time

span includes the COVID-19 crisis, previous research shows that investors continue to value ESG performance during the global pandemic (Broadstock et al., 2020).

Moreover, this study contributes to the existing literature in the following aspects: (1) the study of Nerlinger and Riordan (2022) provides the first evidence regarding the relationship between carbon disclosure, carbon estimation error, and stock liquidity. In order to establish the first evidence regarding carbon emissions, they calculate carbon estimation error as the absolute value of the difference between expected and realized emissions. However, there is no research primarily investigating the direct relationship between total emissions or emissions performance and stock liquidity in the existing literature, hence, by covering a topic that has not been extensively investigated, this paper attempts to fill several gaps in a nexus connecting sustainability, financial economics, and corporate environmental performance. (2) When investigating GHG emissions it is important to consider different initiatives. In fact, some companies have stronger environmental initiatives and commitment compared to others. Therefore, focusing on a broad measurement of GHG emissions such as initiatives, rather than carbon-related performance measures provides a broader view of how GHG emissions can affect firms' stock market performance as well as stock liquidity. In order to obtain a deeper understanding of the relationship between GHG emissions and liquidity, this research incorporates a number of favorable initiatives that companies pursue related to climate change concerns. If better environmental performance can contribute to a firm's financial performance, these initiatives can also have an impact. This research incorporates emissions reduction policy and emissions trading participation. By doing this, our analysis aims to provide a broader view of the relationship between emissions and liquidity.

The remainder of this paper is constructed as follows. Section 2, includes the relevant literature review and hypotheses construction with respect to the research question. Section 3, describes the research design and important details regarding the analysis. Section 4, provides the regression results related to each hypothesis and robustness check to see test whether the outcomes of the primary models are robust under certain conditions.

2. Literature Review & Hypotheses

In this section, the relevant literature has been carefully illustrated as a basis for hypotheses to investigate our research question.

Previous literature shows that firms receive various benefits after improving their environmental performance. For instance, better environmental performance could bring higher efficiency, more credibility, and a better outlook. In order to understand why firms attempt to increase their environmental performance and become more committed, the following theoretical perspectives could be considered. (1) Signalling theory is based on the assumption that there is an information asymmetry between market participants and managers. Corporate decisions are the signals from managers to investors to be incorporated in their investment decisions. Considering the sustainability literature, firms with strong environmental initiatives or performance tend to be more transparent to signal that the future prospects of the firm are good. Therefore, firms can involve in environmental initiatives to signal a better outlook. Accordingly, firms that incentivize to minimize energy consumption and emissions exposure tend to promote their "green" type of business and improve the firm's reputation (Luo, Lan, and Tang, 2012). (2) Stakeholder theory presumes strong ties between a business and its employees, customers, clients, suppliers, and other stakeholders. As opposite to economic theory, stakeholder theory suggests that firms should create value for their stakeholders and not only for shareholders. The balance between all stakeholders' interests is the key consideration to achieving value creation. Since climate change is currently the biggest concern related to the environmental pillar, firms attempt to increase their environmental performance and emit less to create value for their stakeholders. (3) Efficient Market Hypotheses: According to EMH, efficient markets incorporate all available information into the asset prices. In a strong efficiency market, when firms disclose new information it will not create an effect on liquidity or returns, therefore, a better emissions

2.1. GHG Emissions, Financial Performance, and Liquidity

Investors become more socially responsible and started to require more transparency from corporations regarding their environmental performance over time. As a consequence, firms become more transparent in order to perform better on the environmental pillar. Firms

engaged in different climate-change related initiatives to improve their environmental performance. Whether the deviations in firms' environmental performance yield financial benefits has been a topic of considerable interest in the body of existing literature. Previously many scholars investigated the link between environmental disclosure, more specifically, carbon disclosure and firm performance. The study by Hardiyansah, Agustini, and Purnamawati (2021) shows that carbon disclosure is perceived as a form of corporate concern on environmental issues. It is positively perceived by the market, and thus, contributes to an increase in the firm value. Another important benefit noted as ESG disclosers have a lower cost of equity compared to their non-disclosed year and they are better able to raise larger equity capital after the initiations compared to non-initiating firms (Dhaliwal et al., 2011). Similarly, non-disclosing firms experience a negative reaction from the market (Matsumura, Prakash and Vera-Muñoz (2014); He, Tang, and Wang (2013)). In addition, when a firm is perceived as environmentally responsible it is also most likely to be considered fair in its relations with stakeholders, thus, further implies to a contribution to the financial performance (Tan et al., 2017). Consequentially, socially responsible investments (SRI) have rapidly become popular among investors. Since the primary concern is climate-change related issues, investors are already required to be compensated for the emission risks of a company (Bolton and Kacpeczyk, 2020). On the other hand, some previous evidence shows that firms that have strong environmental performance and commitment are rewarded by the market, while the poor performers are punished. Companies with poor environmental performance and less climate-change related commitments perform weaker in terms of financial performance compared to more sustainable firms. This indicates a positive effect on the image, credibility, and perceived quality of a brand (Koh, Burnasheva, and Suh, 2022). At the same time, companies with better environmental performance have the opportunity to promote their products as green or environmental-friendly.

Some scholars particularly focus on whether firms' carbon performance has an effect on their financial performance. Matsumura, Prakash and Vera-Muñoz (2014) provide evidence of the decrease in firm value by $212,000 on average for every additional thousand metric tons of carbon emissions. They further examine the decision of disclosure and results show that a further penalty is applied to non-discloser firms. Konar and Cohen (2001) investigated the relationship between emissions of toxic chemicals and the market value of firms by using a sample consisting of companies from the S&P 500 Index. They concluded that a 10% decrease in toxic chemical emissions reflects a $34 million increase in the market value of a company.

Kim, An, and Kim (2015) concluded a positive relationship between carbon risk and cost of equity with a Korean sample. Saka and Oshika (2014) find a negative relationship between corporate carbon emissions and market value of equity while the disclosure of carbon emissions is positively related. Accordingly, Lee, Min and Yook (2015) concluded that carbon emissions lead to a decrease in firm value and markets punish poor carbon performance more than good carbon performance is rewarded. Bolton and Kacperczyk (2020) find that high carbon intensity firms are associated with higher returns. This finding is re-examined by the study of Aswani, Raghunandan and Rajgopal (2022), according to their results the effect of carbon intensity on stock returns disappeared once they account for firm size and clustered standard errors. Luo (2022) attempts to find a link between stock returns and ESG practices in the U.K. context. The results of their study show that firms with poor ESG performance earn a higher return than the ones with better ESG performance. Brunborg and Haldorsen (2021) concluded an insignificant relationship between carbon intensity and the financial performance of a firm. Aswani, Raghunandan and Rajgopal (2022), investigated the relationship between emissions and stock returns. They find that the relationship between these variables disappears in both U.S. and the EU when considering firm size, industry, and clusters. In conclusion, they warn investors to be cautious about assuming that emissions are priced by the equity markets.

While surveying the ESG literature it stands out that the issue of liquidity has received very limited attention in the body of existing research. Among the few studies found, Egginton and McBrayer (2018) investigate whether more transparent CSR disclosures have an effect on equity market liquidity and documented a positive relationship. They measure the effect of transparent disclosure for the three pillars and reported a positive effect between increasing transparency in CSR disclosure and equity market liquidity. According to their results, firms with more transparent CSR practices exhibit smaller bid-ask spreads, and their market liquidity increases. They attribute their findings to the reduction in information asymmetry. Nerlinger and Riordan (2021) primarily focus on the relationship between carbon disclosure and stock liquidity with a sample of U.S. firms. They focus on 6 months before and after the disclosure of CO2 emissions and show that the bid-ask spread decreases by around 13% for the CO2 disclosers. Furthermore, their study is the first evidence of the relationship between carbon estimation error and liquidity. They use average industry carbon emissions as a proxy for market estimation and calculate the estimation error as the absolute difference between carbon emissions and industry average emissions. Their results suggest that the effect of carbon disclosure has different effects on the firms with high and low estimation errors firms.

Considering the mixed evidence on whether high or low carbon intensity firms have better financial performance, the following hypothesis could be constructed:

H1: GHG emissions performance has an effect on the stock market liquidity of a firm.

H2: Total GHG emissions have an effect on the stock market liquidity of a firm.

2.2. Emissions Policy and Emissions Trading

Besides investigating the effects of emissions performance, scholars also effort to understand whether firms' emissions-related activities lead to a firm-level impact. Adopting an environmental policy or emissions reduction policy and engaging in emissions trading activities are the most essential initiatives that became increasingly popular among researchers, firms, and policymakers. Li, Ngniatedema, and Chen (2017) investigate the impact of green initiatives and green performance on financial performance from the resource-based perspective of the top 500 publicly traded industrial companies. They use concepts such as Green Pay Link and Sustainability Themed Committee and Audit as proxies for green initiatives. They measure green performance with measures such as carbon productivity and energy productivity. Their results show that the impact of green performance is not immediate and take more than a year for companies to observe when measuring with their explanatory variables. There are a number of studies investigating green initiatives from resource-based perspectives and conclude with mixed results. Different from those studies, this study focuses on environmental initiatives from an ESG perspective and not from a resource-based approach. Considering there are various ways to measure GHG initiatives or performance, this study focuses on multiple measurements in order to obtain a deeper understanding of whether firm-level initiatives or activities related to climate change concerns have an effect on the firm's stock market liquidity.

Reducing the level of greenhouse emissions (GHG) contributes to more sustainable and long-term development and it became one of the primary objectives that are expected from firms to achieve over time. Considering the previous studies regarding the effects of GHG emissions on firms' financial performance, there is some evidence produced to suspect that a carbon reduction policy could have a positive effect on firms. Kabir et al. (2021) attempt to

provide evidence on the effects of firms' environmentally favorable initiatives by using a sample consisting of companies from 42 different countries. They find that the risk of default decreases for the firms with visible efforts to reduce their emissions Al-Najjar and Anfimiadou (2012) investigated the link between firm-level environmental policies and financial performance. They concluded that those "eco-efficient" firms have higher market values than those neglects environmental strategies. Chandra and Tourani-Rad (2021) investigate the effect of environmental policies on stock returns by using Refinitiv ESG scores. They concluded a positive relationship, in particular, their study suggests that Australian investors significantly consider companies' efforts to reduce their emissions. Sikacz and Teneta-Skwiercz (2022) attempt to identify the relationship between the emission effectiveness tools in the Refinitiv database and environmental performance. They find that policy emissions score is one of the most correlated with environmental performance and it should be one of the interests of companies. Considering both GHG emissions performance and emissions related initiatives, in fact, firms with stronger climate-change related concerns are likely to be perceived as more environmental-friendly compared to firms with less environmental concerns. This research primarily focuses on the effects of GHG emissions, thus, it is important to examine different emission initiatives to see whether they are likely to be valued by the market participants and create an effect on liquidity. Based on the mixed evidence produced in the literature, the following hypotheses can be formalized:

H3: Emissions policy has an effect on the stock market liquidity of a firm.

Participating in emissions trading activities is one of the important activities that could be perceived as positive from the view of market participants. EU Emissions Trading Scheme (ETS) is the world's first major carbon market and it aims to reduce GHG emissions by setting an absolute limit on the total amount of emissions. This scheme enables regulated entities to buy emissions allowances that they can trade. EU ETS helps reduce overall 40 to 80 million tonnes of carbon emissions per year on average (Laing et al., 2014), and previously some scholars attempted to relate emissions trading activities to a firm's financial performance. Oestreich and Tsiakas (2015) investigated whether the EU ETS had an effect on firms' stock market returns. They find that during the first years of ETS, firms with free carbon emission allowances, on average, outperformed the other firms. Abrell, Faye, and Zachmann (2011) investigate the firm-level effects of EU ETS by using a sample consisting of European firms.

They find a negative relationship between ETS engagement and the profits of participating firms. Smale et al. (2006) investigated the effects of participation on EU ETS. According to their results, EU ETS has a positive (or at least non-negative) impact on EBITDA. This is because companies respond against increasing marginal costs resulting from EU ETS activities by reducing the quantity produced and increasing the prices by using a UK sample. Jaraite-Kažukauske and Di Maria (2016) attempt to link EU ETS participation to firms' financial performance. Their results show that ETS participation does not lead to a decrease in CO2 and does not have an effect on the profitability of a firm. Löschel, Lutz, and Managi (2016) noted that EU ETS had a positive effect on productivity during the first compliance period. Nordin (2018) examine the effect of ETS on financial indicators that impacts firm competitiveness and finds both positive and negative effects. According to their results, EU ETS positively affects labor productivity, turnover, and value-added while it is negatively related to profit before tax. Jung et al. (2021), find that ETS significantly increases the carbon productivity at the firm level and the carbon productivity brings more profitability to the firm. Wang et al. (2018) concluded that the cap-and-trade mechanism significantly impacts firms' operational and production decisions. As it could be observed, even though generally ETS participation increased productivity, there is mixed evidence regarding the profitability of ETS participation.

H4: Participating in emissions trading (ETS) has an effect on stock market liquidity of a firm.

3. Research Design

This section introduces the construction of variables and the methodological approach employed in this research and refers to important details regarding the analysis.

3.1. Data and Sample

The time span of this research covers the period from 2011 to 2020. As it is discussed in the previous sections, GHG emissions have mainly gained importance in recent decades, particularly after the Kyoto Protocol. Therefore, this time frame enables us to generate important insights and it is long enough to produce statistically reliable up-to-date results. At the same time, it is immune from the global financial crisis. During a financial crisis, companies

change their priorities to improve their survivability, therefore, the outcomes could be affected. The sample consists of companies from the S&P Europe 350 index which represents the European portion of S&P Global 1200 which is designed to represent a broad market benchmark. It contains 350 leading blue-chip companies from developed European markets which cover around 70% of Europe's market capitalization, therefore, it provides a wide view of market exposure. In more detail, this sample contains companies in different industries including IT, finance, manufacturing, energy, utilities, and more from 16 European countries which are the U.K., France, Switzerland, Germany, Netherlands, Sweden, Denmark, Spain, Italy, Finland, Belgium, Norway, Ireland, Austria, Portugal, Luxembourg). In order to examine the hypothesized relationships, time-series data for both dependent and independent variables were gathered from the Refinitiv ESG (formerly Thomson Reuters) database. Daily stock returns, ESG metrics, key metrics, and profitability indicators have been collected for the 10 years period for each firm and merged in a panel dataset.

3.2. Variables

3.2.1. Dependent Variable

Amihud's (2002) measure of illiquidity was employed as the dependent variable of this research. Since we cannot directly measure liquidity, an appropriate measurement has to be employed. Amihud's (2002) measure of illiquidity is a widely recognized measure of liquidity and it captures how much would price move with respect to trading volume. Many researchers have successfully employed this measure to explain the liquidity of a stock (Acharya and Pedersen, 2005; Daske et al., 2008; Nerlinger and Riordan 2022). Daily stock price data that covers the research obtained from the Refinitiv ESG database for each company in S&P Europe 350 index. In order to calculate illiquidity, daily trading volume is translated into billions and daily absolute returns are calculated as the difference between closing prices of today and one day before. Yearly average volume in billions divided by yearly average absolute returns to obtain the Amihud (2002) illiquidity measure for each firm:

$$\text{ILLIQ} = Average \sum_{i=1}^{t} \frac{|\mathrm{R}_t|}{DVOL_t/10^9}$$

Theoretically, illiquidity can be zero (Chordia, Huh, and Subrahmanyam, 2007), therefore, it is usually associated with outliers. In order to reduce the influence of extreme cases Hasbrouck (2005) suggests taking the square root measure of illiquidity. Therefore, we construct the illiquidity measure as its square root. Previously many researchers follow this approach to measure illiquidity (Chordia, Huh, and Subrahmanyam, 2007; Wang and Kong 2010; Ackert and Tian 2008).

3.2.2. Independent Variables

To test our first hypothesis, we regress GHG emissions performance with the Amihud measure of illiquidity. GHG emissions performance is calculated as the intensity of total CO2 and CO2 equivalent emissions. Carbon intensity is the most common measure of GHG performance and it considers the total amount of emissions by firm characteristics such as revenue or sales (Hoffman and Busch 2008; Nerlinger and Riordan 2022; Bolton and Kacperczyk 2021). CO2 equivalent emissions include other greenhouse gases such as methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCS), perfluorinated compound (PFCS), sulfur hexafluoride (SF6), nitrogen trifluoride (NF3) which also creates greenhouse effect by harming the ozone layer and contributing to the global warming. In the second hypothesis, we test whether the total amount of CO2 and CO2 equivalent emissions of a company are related to their equity market liquidity. As discussed in the literature review section the variation in total emissions leads to an impact on firms' financial performance. In addition to that, the study by Nerlinger and Riordan (2022) noted that disclosing emissions has different effects on companies equity market liquidity for the firms with high and low carbon estimation errors. Therefore, we also incorporate total emissions in our analysis to provide further evidence on the link between emissions and liquidity.

For hypotheses 3 and 4, we test whether emissions reduction policy or participation in emissions trading has an effect on liquidity. If these practices are valued by the market participants we would expect to observe a significant effect on illiquidity. To do this, emissions policy scores and emissions trading participation scores for each company regressed with the measure of liquidity. Both scores are employed from the Refinitiv database which assigns

individual scores for each company to assess specific policies or activities of a company. Refinitiv provides ESG performance indicators in two forms, it could be retrieved as a score between "0" to "10" or as a rating between “D-“ and “A+”. Since score variables contain more information compared to the ratings, GHG reduction initiative scores were obtained for each firm from ESG metrics. A higher GHG score indicates a stronger commitment of a company to climate-change-related concerns. Previously, many researchers incorporated emissions scores provided by the Refinitiv database (Tanthanongsakkun et al., 2022; Orazalin and Mahmood, 2021; Luo, 2022). The calculation method for each GHG score metric is provided transparently by Refinitiv. Emissions policy scores and emissions trading scores for each company were used as the independent variable to test our hypotheses 3 and 4 respectively. The emission policy score refers to the quality and effectiveness of the emissions policy of each firm and takes a value between "0" and "10". The emissions policy score is closer to "10", the more effective emissions policy of a company. The emissions trading score indicates the extent to which a company participates in emissions trading and if a company does not participate in any emissions trading, it gets the value of "0" for the respective period.

3.2.3. Control variables

In order to improve the internal validity of the regression models and generate statistically reliable outcomes, control variables that can have an effect on liquidity are incorporated into the analysis. Control variables are also obtained from the Refinitiv database for 10 years period, and merged in a panel dataset. These variables include Market Capitalization (MCAP), Return-on-assets (ROA), Price-to-Book (PB) ratio, Leverage (LEV), and total Property, Plants, and Equipment (PP&E)

Market capitalization refers to the value of a company determined by the stock market and calculated as the total market value of a company’s outstanding shares. Therefore, in order to control for firm size effects on liquidity, market capitalization is incorporated into regression models. Previously, Bogdan, Baresa, and Ivanovic (2012) conducted an analysis to determine the effect of market capitalization on both liquidity and illiquidity and find that companies with high market capitalization have more liquid stocks compared to the ones with low

capitalization. In addition, the vast majority of studies that investigates liquidity reported a positive relationship between more liquid stock and market capitalization.

The leverage ratio refers to the level of debt involved in a business. There are many reasons behind the fact that most companies' capital structure consists of a combination of both debt and equity. Generally, companies use debt to finance their operations which implies increasing leverage. Furthermore, high leverage companies are riskier for investment purposes since companies are obligated to pay out the debt before the equity. Due to the crucial role of leverage from an investor perspective, it will be included as a control variable in this analysis. Some previous studies produce evidence of a statistically significant relationship between leverage and stock liquidity (Norvaišiene and Stankeviciene, 2014). Previous studies produce evidence of a statistically significant relationship between leverage and stock liquidity (Norvaišiene and Stankeviciene, 2014).

PE ratio is an indicator of firm value and is calculated as the current share price divided by earnings-per-share (EPS). It is commonly used to evaluate whether a company’s stock is over- or undervalued. A high PE ratio represents a higher growth expectation from the investors’ side. In this research, the PE ratio is described as the current share price divided by EPS.

The price-to-book ratio is a common measure to evaluate stocks. It compares a firm’s stock market capitalization to its book value. It can be calculated by dividing the stock price per share by book value per share. A high(low) ratio indicates that the price of the stock exceeds above (below) the actual worth of the assets of a company.

The total value of Property, Plant, and Equipments long-term essential tangible assets of a company is incorporated as one of the control variables. Since these assets have an effect on the profitability of a firm, PP&E could capture a different aspect of liquidity. Table 1 refers to the construction of variables employed in this research.

Table 1: Definition of variables

Variable	Definition
ILLIQ	Amihud (2002) measure of illiquidity.
Intensity	Ratio of total CO2 and CO2 equivalent emissions in tones to sales.
GHG	Total CO2 and CO2 equivalent emissions in tones.
POL	A value between 0 and 1 that reflects the overall quality and effectiveness of companies' emissions reduction policy.
ETS	A value between 0 and 1 that indicates the extent in which a company engage in emissions trading activities.
MCAP	Natural logarithm of outstanding shares multiplied by share price of a company.
LEV_ratio	Leverage refers to the amount debt of a company, calculated as total debt divided by equity.
AT_ratio	Asset turnover ratio defines as revenue divided by total assets for the respective period.
PE_ratio	Price-to-earnings ratio calculated by stock price divided by earnings-per-share.
PB_ratio	Price-to-book ratio constructed as stock price per share divided by book value per share.
PP&E	Total property, plant and equipment of the company.

GHG, Market Capitalization, Price-to-book ratio, Leverage ratio, Price-to-earnings ratio, Price-to-book ratio, and PP&E are constructed as their natural logarithms. Since the Amihud ratio is generally associated with outliers, considering the suggestion of Hasbrouck (2005), it is constructed as the square root of the Amihud ratio.

3.3. Methodology

Each regression model proposed below controlled for heteroskedasticity and robust standard errors. The first two models are estimated to test our first hypothesis while the third and fourth models test hypotheses 2 and 3 respectively.

- A panel data regression to observe whether there is a link between carbon performance and the stock market liquidity of a firm.

- A panel data regression to observe whether there is a relation between total carbon emissions and stock market liquidity.
- A panel data regression examine the relationship between emissions reduction policy on stock market liquidity.
- A panel data regression to examine the relationship between trading emissions on stock market liquidity.

In order to estimate statistically reliable outcomes on the relationship between GHG emissions and stock liquidity from 2011 to 2020, this research applies panel data analysis. In order to determine whether the random effects or fixed effects (FE) model better fits with proposed regression models, we applied the Hausman test. The outcomes of the Hausman test are significant at the 1% level for each model specification which implies the null hypothesis to be rejected. According to the results, the fixed-effects model has been employed. One of the major benefits of applying the FE model is that it controls for all time-invariant differences among firms even the ones that are impossible to observe, hence, both measurable and unmeasurable time-invariant differences among firms are controlled. In the second regression, PP&E was excluded from the model due to its high correlation with total emissions which makes sense. Table 2 represents the regression models estimated to test our hypotheses.

Table 2: Regression models

Model	Equation
(1)	$ILLIQ_{it} = \alpha_i + \beta_1 Intensity + \beta_2 MCAP_{it} + \beta_3 AT\_ratio_{it} + \beta_4 DE\_ratio_{it,} + \beta_5 PE\_ratio_{it} + \beta_6 PB\_ratio + \beta_7 PP\&E + \varepsilon_{it}$
(2)	$ILLIQ_{it} = \alpha_i + \beta_1 + GHG + \beta_2 MCAP_{it} + \beta_3 AT\_ratio_{it} + \beta_4 DE\_ratio_{it,} + \beta_5 PE\_ratio_{it} + \beta_6 PB\_ratio + \varepsilon_{it}$
(3)	$ILLIQ_{it} = \alpha_i + \beta_1 POL_{it} + \beta_2 MCAP_{it} + \beta_3 AT\_ratio_{it} + \beta_4 DE\_ratio_{it,} + \beta_5 PE\_ratio_{it} + \beta_6 PB\_ratio + \beta_7 PP\&E + \varepsilon_{it}$
(4)	$ILLIQ_{it} = \alpha_i + \beta_1 ETS_{it} + \beta_2 MCAP_{it} + \beta_3 AT\_ratio_{it} + \beta_4 DE\_ratio_{it,} + \beta_5 PE\_ratio_{it} + \beta_6 PB\_ratio + \beta_7 PP\&E + \varepsilon_{it}$

* Table 2 refers to regression models employed to test our hypotheses. PP&E excluded from the model 2 due to high correlation.

4. Results

In this section, results for descriptive statistics, correlation matrix, regression results, and robustness checks provided accordingly.

4.1. Descriptive statistics

Table 3 refers to the mean, standard deviation, minimum, and maximum values of our sample S&P Europe 350. Extreme observations that may have a substantial impact on the overall distribution of variables have been excluded. Amihud's (2002) measure of illiquidity is associated with large outliers, hence, we follow the suggestion of Hasbrouck (2005) by constructing the Amihud measure (ILLIQ) as square root of it. A "0" score in policy emissions (POL) and emissions trading (ETS) indicates that the firm has no policy or emissions trading activity for the respective period. It can be observed from the table GHG emissions, Market Capitalization, Leverage ratio, Price-to-earnings ratio, Price-to-book ratio, and Property, Plant, and Equipment are constructed as natural logarithms.

Table 3: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
ILLIQ	0.5329	0.5989	0.0056	4.904
Intensity	1.1914	2.5805	0.0012	15.8183
GHG	12.6562	2.4618	6.9097	19.0874
POL	6.0330	2.6491	0	9.743
ETS	1.5407	3.3552	0	9.844
MCAP	4.1629	0.4304	2.9366	5.4440
AT_ratio	0.7856	0.5434	0.02	4.11
LEV_ratio	-0.2277	0.6037	-4.2646	1.0386
PE_ratio	1.2469	0.2550	0.2004	2.0369

PB_ratio	0.3339	0.3642	-0.6778	1.4382
PP&E	3.2843	0.9544	0.2033	5.3031

* Table 3 represents the descriptive statistics of S&P Europe 350 for the 10 years period.

4.2. Correlation Matrix

The matrix of correlation is represented in table 4 with respective significance levels. It is noticeable that GHG intensity is positively and significantly correlated with GHG emissions as they are both indicators of emissions. The largest correlation in the sample is between PP&E and total GHG emissions (0.815). Because a high PP&E value indicates the more tangible assets owned by a firm, these companies are most likely to be associated with higher total emissions. Therefore, the PP&E variable is excluded from our second model which measures the effect of total GHG emissions. On the other hand, ETS is positively correlated with our Intensity and GHG variable which suggests emissions traders are generally the firms that are associated with a high level of emissions.

Table 4: Matrix of Correlation

	1	2	3	4	5	6	7	8	9	10	11
1. ILLIQ	1.0000										
2. Intensity	0.056***	1.0000									
3. GHG	-0.052***	0.635***	1.0000								
4. POL	-0.188***	-0.102***	-0.093***	1.0000							
5. ETS	-0.013	0.487***	0.572***	0.064***	1.0000						
6. MCAP	-0.261***	0.026	0.351***	0.106***	0.095***	1.0000					
7. AT_ratio	0.03	-0.152***	-0.012	0.011	-0.013	-0.149***	1.0000				
8. LEV_ratio	-0.073***	0.059***	0.128***	0.076***	0.063***	0.100***	-0.148***	1.0000			
9. PE_ratio	0.072*	-0.045**	-0.082***	-0.007	-0.121***	0.031	0.110***	-0.095***	1.0000		
10. PB_ratio	0.001	-0.144***	-0.213***	-0.047***	-0.160***	0.007	0.253***	-0.169***	0.473***	1.0000	
11. PP&E	-0.177***	0.366***	0.815***	0.241***	0.396***	0.528***	-0.102***	0.289***	-0.130***	-0.288***	1.0000

Statistical significance of 1%, 5%, and 10% denominated as ***, **, * respectively.

4.3. Fixed-Effects Estimation

Results for the regression models are represented in table 5. In the first column, GHG intensity regressed with the Amihud measure of illiquidity to test whether there is a difference between firms with good and poor emissions performance. GHG intensity which is the most common measure of emissions performance has a negative (-0.0063) but insignificant coefficient against ILLIQ. Among the control variables, MCAP is statistically significant at 1% with a negative coefficient (-0.2649) which suggests that a higher market capitalization reduces illiquidity or in other words improves the liquidity of a stock. Overall R^2 is 0.12 for the first model which indicates that 12% of the variation in illiquidity is explained by our first model. In the second regression model, we test whether the total GHG emissions of a company are related to the illiquidity of its stock. It could be observed from table 5, total emissions have a negative (-0.0491) and significant coefficient at a 10% level. This implies firms that are associated with high emissions tend to be more liquid compared to less emitting firms. Therefore, our hypothesis 2 could be accepted. Control variables MCAP, and PB_ratio are also significantly related to illiquidity at 1%, and 10% levels respectively.

Models 3 and 4 test the two most popular practices related to emissions among firms and in the existing literature. In the third regression model, we test whether a more effective emissions reduction policy has an effect on the illiquidity of a firm. POL variable exhibits a negative (-0.0363) and significant coefficient at a 5% level. These results suggest that our result for hypothesis 3 is robust when subsampling. According to the coefficient, firms with better emissions policy are associated with larger stock liquidity when measuring with the Amihud measure. MCAP and PB_ratio are also significantly related to illiquidity. In line with our previous regression models, MCAP (-0.1950) and PB_ratio (-0.1849) have a negative and significant coefficient. The negative coefficient of the PB_ratio suggests that firms with high PB_ratio tend to be more liquid compared to low PB_ratio firms. On the other hand, emissions trading participation (ETS) results are proposed in the fourth column. It is the only variable that shows a positive coefficient against illiquidity, however, it is insignificant. ETS is the only main independent variable that shows a positive coefficient against illiquidity, however, it is insignificant. Therefore, there is no evidence found to accept our hypothesis 4. In addition, MCAP and PB_ratio remain significant in line with our previous regression models.

Table 5: Regression Results for Fixed-Effects Estimation

	ILLIQ (1)	ILLIQ (2)	ILLIQ (3)	ILLIQ (4)
Intensity	-0.0063			
	(-0.76)			
GHG		-0.0491*		
		(-1.67)		
POL			-0.0363**	
			(-2.19)	
ETS				0.0063
				(1.62)
MCAP	-0.2649***	-0.1952***	-0.2374*	-0.2303
	(-2.60)	(-1.59)	(-1.65)	(-1.64)
AT_ratio	0.0162	0.0325	0.1436	0.1460
	(0.22)	(0.49)	(1.37)	(1.34)
LEV_ratio	-0.0410	-0.0371	-0.0217	-0.0284
	(-0.80)	(-0.78)	(-0.48)	(-0.55)
PE_ratio	0.0452	0.0137	0.0523	0.0462
	(1.03)	(0.38)	(1.10)	(0.95)
PB_ratio	0.0970	-0.1849*	-0.2090*	-0.2183*
	(-1.31)	(-1.67)	(-1.77)	(-1.86)
PP&E	0.0897		-0.0199	-0.0563
	(1.05)		(-0.23)	(-0.61)
Constant	1.3730***	2.1156***	1.8442***	1.6892***
	(3.00)	(5.37)	(3.27)	(3.01)
N	1,721	1,973	1,920	1,920
R^2	0.12	0.13	0.10	0.09
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Robust Std. Errors	Yes	Yes	Yes	Yes

Table 5 indicates the results for Fixed-Effects estimations for each model that are proposed in the previous section. GHG intensity, total GHG, policy emissions, and emissions trading are estimated accordingly in each column. As this is discussed previously, due to the high correlation PP&E excluded from the second model. Control variables Market Capitalization,

Asset Turnover ratio, Leverage ratio, Price-to-Book ratio, and Property, Plant, and Equipment are incorporated as control variables In addition, year fixed-effects and robust standard errors are controlled. Statistical significance of 1%, 5%, and 10% reflected by ***, **, * respectively.

4.4. Robustness Checks

The robustness checks are applied to ensure that the outcomes of our baseline regression models are robust under certain conditions and to provide further insights. These tests are proposed under this section.

4.4.2. Change in Emissions Intensity and Performance

In order to provide deeper insights and check whether our results are robust, change in intensity and change in total emissions are included as the independent variables. The change in emissions is an alternative measurement of GHG performance which was employed by many researchers previously (Bolton and Kacperzcyk, 2020; Aswani, Raghunandan and Rajgopal, 2022). Year fixed-effects are also incorporated together with robust standard errors in both estimations. The results show that change in intensity and total emissions exhibits negative and insignificant coefficients against the illiquidity measure. Although the negative coefficients of change variables are in line with our baseline regressions, they exhibit an insignificant relationship with illiquidity. MCAP and PP&E were significantly related to illiquidity at 1% and 10% levels respectively in both estimations. This suggests high PP&E firms are associated with less liquidity when measuring with Amihud's (2002) measure which is in line with the study of Nerlinger and Riordan (2022).

Table 6: Regression Results for Change in Intensity and Total Emissions

	ILLIQ (1)	ILLIQ (2)
ΔIntensity	-0.0374 (-1.01)	
ΔGHG		-0.0164

		(-0.42)
MCAP	-0.2775***	0.2741***
	(-3.72)	(-3.80)
AT_ratio	0.0220	0.0234
	(0.30)	(0.33)
LEV_ratio	-0.0629	-0.0577
	(-1.40)	(-1.31)
PE_ratio	0.0463	0.0305
	(1.00)	(0.70)
PB_ratio	-0.0352	-0.0544
	(-0.58)	(-0.78)
PP&E	0.2210*	0.2116*
	(1.88)	(1.80)
Constant	0.7648	2.4224*
	(1.54)	(1.68)
N	1,474	1,515
R^2	0.11	0.11
Firm FE	Yes	Yes
Year FE	Yes	Yes
Robust Std. Errors	Yes	Yes

Table 5 represents the results of Fixed-Effects estimations for change (Δ) in GHG intensity and total emissions for each firm. In the first column, the change in intensity is estimated while the change in total emissions is included in the second column. Control variables Market Capitalization, Asset Turnover ratio, Leverage ratio, Price-to-Book ratio, and Property, Plant, and Equipment are incorporated as control variables In addition, year fixed-effects and robust standard errors are controlled. Statistical significance of 1%, 5%, and 10% reflected by ***, **, * respectively.

4.4.3. Subsampling

Since S&P Europe 350 consists of several industries, the robustness test for hypotheses 3 and 4 are applied by cutting the sample size. Industrial companies have been selected to conduct our robustness test for the following reasons. First, the largest amount of components in S&P Europe 350 are industrial firms. Second, most industrial companies have a policy to reduce emissions. Third, the number of industrial companies that trade emissions is relatively high compared to other industries in our sample. Results for our second robustness test are

represented in table 6. Policy emissions scores have a negative coefficient (-0.0993) suggests that companies with higher policy scores have higher liquidity than companies with lower policy scores. On the other hand, ETS has a positive coefficient of 0.0122 which can be interpreted as firms with a high ETS score tend to be more illiquid compared to companies with a lower ETS score, however, the ETS participation remains insignificant. Control variable PB_ratio is negative and significantly related to stock liquidity throughout both models. This suggests firms that have a higher market value compared to their book value (overvalued firms) have more liquidity in their stocks which is in line with previous evidence (Syamala, Chauhan, Wadhwa 2014).

Table 6: Regression Results for Subsampling

	ILLIQ (3)	ILLIQ (4)
POL	-0.0993** (-2.09)	
ETS		0.0122 (0.76)
MCAP	0.3116 (0.76)	0.5110 (0.71)
AT	0.1411 (0.64)	0.0139 (0.87)
LEV_ratio	0.0143 (0.17)	-0.0123 (-0.11)
PE_ratio	-0.0484 (-0.31)	0.0341 (-0.78)
PB_ratio	-0.5845* (-1.62)	-0.0673* (-1.82)
PPE	0.0381 (0.20)	-0.1569 (-0.80)
Constant	0.3267 (0.22)	2.3719 (-0.33)

N	509	509
R^2	0.16	0.12
Firm FE	Yes	Yes
Year FE	Yes	Yes
Robust Std. Errors	Yes	Yes

The results of the robustness test of models 3 and 4 have shown in table 6. The first column represents the estimation for emissions reduction policy, and the second column emissions trading participation. Control variables Market Capitalization, Asset Turnover ratio, Leverage ratio, Price-to-Book ratio, and Property, Plant, and Equipment are incorporated as control variables. Statistical significance of 1%, 5%, and 10% reflected by *, **, *** respectively.

5. Discussion of Results

Our first hypothesis was focusing on the GHG emissions intensity calculated by the ratio of total CO2 and CO2 equivalent emissions to revenue. The regression results show that there is no significant relationship between emissions intensity and the measure of illiquidity. On the other hand, total emissions which is our second hypothesis significantly related to illiquidity at the 10% level. The coefficient for the total emissions is negative which means illiquidity decreases when firms have higher total emissions, in other words, firms with high total emissions have more liquid stocks when measuring with the Amihud (2002) measure. These results can also be interpreted as high emissions stocks most likely to generate lower returns compared to companies with lower total emissions. Previously Bolton and Kacperczyk (2021) also concluded that carbon premium in stock returns related to the level of total emissions and not emissions intensity, by using a sample of high emissions U.S. firms. They attribute their results to the nature of climate change policies which are primarily related to total emissions rather than intensity. According to their results, firms with high total emissions generate higher returns compared to firms with lower emissions which is contradictory to the outcomes of our empirical analysis. These differences could be resulting from two main reasons. Firstly, investors' awareness related to environmental performance is stronger in Europe compared to the U.S. Secondly, the sample that we use consists of both high and low emissions firms while the study of Bolton and Kacperczyk (2021) uses a sample of high emissions firms. For the robustness check, we follow the approach from the study of both Bolton and Kacperczyk (2021) and Aswani, Raghunandan and Rajgopal (2022) by employing two alternative measurements of emissions performance which are change in intensity and total emissions. Both studies provide contradictory results as these studies are covered in the literature review section. Our results are in line with the study of Aswani, Raghundan and

Raigopal (2022) which suggests an insignificant relationship between the change in the level of both intensity and emissions and the stock liquidity of a firm. ETS is the only main independent variable that shows a positive coefficient against illiquidity, however, it is insignificant. Therefore, there is no evidence found to accept our hypothesis 4. In addition, MCAP and PB_ratio remain significant in line with our previous regression models.

In our third and fourth hypotheses, we focused on two common firm-level emissions practices, namely, emissions policy and emissions trading. It could be observed from table 4, emissions policy is significantly related to the illiquidity of a stock. Therefore, our hypothesis 3 could be accepted. The coefficient for policy emissions is negative which suggests that firms with a stronger emissions reduction policy have more liquid stocks compared to firms with a poor policy or without a policy. This result is in line with the existing literature that suggests investors value firms' efforts to reduce their emissions (Chandra and Tourani-Rad, 2021). The study of Chandra and Tourani-Rad (2021) suggests that firm-level emissions reduction efforts primarily drive investors' reaction to environmental policies, therefore, stocks of these companies are associated with higher returns in the Australian market. Our results extend their results to the Europe continent and suggest that European investors also positively value emissions policy and consider this information in their investment decisions. For the robustness check, we focus on industrial firms which have the largest components throughout S&P Europe 350. The results for policy emissions remain significantly negative when cutting the sample size which confirms the results of our regression model. On the other hand, ETS participation is insignificant in both the main regression model and robustness checks. Since there is no significant relationship between emissions trading participation and illiquidity of a stock, hypothesis 4 could be rejected.

Overall, our results suggest that emissions intensity or change in emissions, the two most common measures of emissions performance, are not incorporated into the decision-making process of investors while emissions policies are taken into account. Since the stronger efforts related to climate-change concerns can affect firms' stock liquidity and the actual emissions performance is not, these results could be seen as in line with signaling theory.

6. Conclusion and Limitations

This study focuses on the effects of GHG emissions from two different aspects, namely, emissions performance and common firm-level initiatives on the stock liquidity of a firm by employing multiple measurements. The empirical analysis showed that only total emissions and emissions policy significantly related to liquidity and other common measures of emissions, and ETS participation is not. The outcomes of our analysis provide the first insights regarding the direct relationship between emissions and liquidity. Our outcomes can be useful for investors, firms, and policymakers and could be interpreted as follows:

First, firms with high carbon emissions have more liquid stocks compared to firms with low carbon emissions. Liquid investments can easily be converted to cash as opposite to illiquid stocks, therefore, our results may implications for investors. For instance, investors who want to generate higher returns by investing in more risky stocks can invest in low emissions stocks. Since these stocks are more illiquid they are most likely to behave more volatile than high emissions stocks. In addition to that, some previous evidence shows that carbon performance and change in emissions are also related to high stock returns in the U.S. However, according to our results, European investors may want to focus only on total emissions rather than alternative measurements of emissions performance. As discussed before, this can be attributed to the primary aim of intergovernmental steps to reduce total emissions and not improve emissions performance.

Second, emissions policy has a positive impact on the stock liquidity. Our empirical analysis shows that firms with a better emissions policy have more liquid stocks. Consequentially, we can observe that European investors value firm-level environmental practices. Therefore, companies may want to consider adopting an emissions reduction policy or improving their existing emissions policy in order to increase their equity market liquidity. In addition to that, policymakers may want to encourage companies on adopting or improving their emissions policy to improve overall liquidity in stock markets.

Third, although some previous evidence shows that ETS participation improves the profitability of a firm, according to our empirical results, emissions trading participation does not provide any advantages in terms of stock liquidity. This brings us to the limitations of our research; The insignificant results for ETS participation could be due to the small number of

companies that participate in emissions trading activities in our sample. Another limitation of our empirical results, this study mainly focuses on a sample of European companies, therefore, our results may not be generalized to other continents. Finally, our analysis relies a data that is retrieved from single database which is Refinitiv, therefore, the results may not be fully accurate.

In order to obtain a deeper understanding and draw more concrete results, our recommendation for future research is as follows: First, replicate our analysis for GHG performance and total emissions in a different context or continent. However, using an international sample may not be relevant since regulations and investors' awareness of GHG emissions vary among different continents. Second, currently the number of companies that trade emissions are not very large, therefore, in order to examine the effect of emissions trading, researchers may focus on a sample that consists of emissions traders together with the amount of emissions allowances. Third, this research relies on the data retrieved from one database, therefore, future research should obtain the data across multiple databases and make a comparison to improve the accuracy of the results.

References

Abrell, J., Ndoye Faye, A., & Zachmann, G. (2011). Assessing the impact of the EU ETS using firm level data (No. 2011/08). Bruegel working paper.

Ackert, L. F., & Tian, Y. S. (2008). Arbitrage, liquidity, and the valuation of exchange traded funds. Financial markets, institutions & instruments, 17(5), 331-362.

Al-Najjar, B., & Anfimiadou, A. (2012). Environmental policies and firm value. Business Strategy and the Environment, 21(1), 49-59.

Aswani, J., Raghunandan, A., & Rajgopal, S. (2022). Are carbon emissions associated with stock returns?. Columbia Business School Research Paper Forthcoming.

Bogdan, S., Bareša, S., & Ivanović, S. (2012). Measuring liquidity on stock market: Impact on liquidity ratio. Tourism and hospitality management, 18(2), 183-193.

Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk?. Journal of Financial Economics, 142(2), 517-549.

Bolton, P., & Kacperczyk, M. T. (2020). Carbon premium around the world.

Brandon, R. G., Glossner, S., Krueger, P., Matos, P., & Steffen, T. (2021). Do responsible investors invest responsibly. European Corporate Governance Institute–Finance Working Paper.

Broadstock, D. C., Chan, K., Cheng, L. T., & Wang, X. (2021). The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China. Finance research letters, 38, 101716.

Brunborg, T. B., & Haldorsen, P. K. (2021). The Impact of Carbon Emissions on US Stock Returns: An empirical study of how carbon intensity impacts financial performance.

Chandra, M., & Tourani-Rad, A. (2021). Do Investors Value Environmental Corporate Policies? Evidence from the Australian Market. Journal of Risk and Financial Management, 14(3), 124.

Chordia, T., Huh, S. W., & Subrahmanyam, A. (2009). Theory-based illiquidity and asset pricing. The Review of Financial Studies, 22(9), 3629-3668.

Dhaliwal, D. S., Li, O. Z., Tsang, A., & Yang, Y. G. (2011). Voluntary nonfinancial disclosure and the cost of equity capital: The initiation of corporate social responsibility reporting. The accounting review, 86(1), 59-100.

Egginton, J. F., & McBrayer, G. A. (2019). Does it pay to be forthcoming? Evidence from CSR disclosure and equity market liquidity. Corporate Social Responsibility and Environmental Management, 26(2), 396-407.

Fang, V. W., Noe, T. H., & Tice, S. (2009). Stock market liquidity and firm value. Journal of financial Economics, 94(1), 150-169.

He, Y., Tang, Q., & Wang, K. (2013). Carbon disclosure, carbon performance, and cost of capital. China Journal of Accounting Studies, 1(3-4), 190-220.

Hoffmann, V. H., & Busch, T. (2008). Corporate carbon performance indicators: Carbon intensity, dependency, exposure, and risk. Journal of Industrial Ecology, 12(4), 505-520.

Jaraite-Kažukauske, Jurate, and Corrado Di Maria. "Did the EU ETS make a difference? An empirical assessment using Lithuanian firm-level data." The Energy Journal 37.1 (2016).

Jung, H., Song, S., Ahn, Y. H., Hwang, H., & Song, C. K. (2021). Effects of emission trading schemes on corporate carbon productivity and implications for firm-level responses. Scientific Reports, 11(1), 1-10.

Kim, Y. B., An, H. T., & Kim, J. D. (2015). The effect of carbon risk on the cost of equity capital. Journal of Cleaner Production, 93, 279-287.

Koh, H. K., Burnasheva, R., & Suh, Y. G. (2022). Perceived ESG (Environmental, Social, Governance) and Consumers' Responses: The Mediating Role of Brand Credibility, Brand Image, and Perceived Quality. Sustainability, 14(8), 4515.

Konar, S., & Cohen, M. A. (2001). Does the market value environmental performance?. Review of economics and statistics, 83(2), 281-289.

Hardiyansah, M., AGUSTINI, A. T., & PURNAMAWATI, I. (2021). The effect of carbon emission disclosure on firm value: environmental performance and industrial type. The Journal of Asian Finance, Economics and Business, 8(1), 123-133.

Haque, F., & Ntim, C. G. (2022). Do corporate sustainability initiatives improve corporate carbon performance? Evidence from European firms. Business Strategy and the Environment.

Kabir, M. N., Rahman, S., Rahman, M. A., & Anwar, M. (2021). Carbon emissions and default risk: International evidence from firm-level data. Economic Modelling, 103, 105617.

Lam, K. S., & Tam, L. H. (2011). Liquidity and asset pricing: Evidence from the Hong Kong stock market. Journal of Banking & Finance, 35(9), 2217-2230.

Laing, T., Sato, M., Grubb, M., & Comberti, C. (2014). The effects and side-effects of the EU emissions trading scheme. Wiley Interdisciplinary Reviews: Climate Change, 5(4), 509-519.

Lee, K. H., Min, B., & Yook, K. H. (2015). The impacts of carbon (CO2) emissions and environmental research and development (R&D) investment on firm performance. International Journal of Production Economics, 167, 1-11.

Li, S., Ngniatedema, T., & Chen, F. (2017). Understanding the impact of green initiatives and green performance on financial performance in the US. Business Strategy and the Environment, 26(6), 776-790.

Löschel, A., Lutz, B. J., & Managi, S. (2016). The Impacts of the EU ETS on Efficiency–An Empirical Analyses for German Manufacturing Firms. ZEW-Centre for European Economic Research Discussion Paper, (16-089).

Luo, L., Lan, Y. C., & Tang, Q. (2012). Corporate incentives to disclose carbon information: Evidence from the CDP Global 500 report. Journal of International Financial Management & Accounting, 23(2), 93-120.

Matsumura, E. M., Prakash, R., & Vera-Munoz, S. C. (2014). Firm-value effects of carbon emissions and carbon disclosures. The accounting review, 89(2), 695-724.

Nguyen, T., Duong, H. N., & Singh, H. (2016). Stock market liquidity and firm value: an empirical examination of the Australian market. International Review of Finance, 16(4), 639-646.

Nordin, L. (2018). Firm Competitiveness and the EU ETS: An empirical study using Swedish firm-level data.

Norvaišienė, R., & Stankevičienė, J. (2014). Impact of companies' internal factors on stock liquidity in Baltic markets. Procedia-Social and Behavioral Sciences, 156, 543-547.

Oestreich, A. M., & Tsiakas, I. (2015). Carbon emissions and stock returns: Evidence from the EU Emissions Trading Scheme. Journal of Banking & Finance, 58, 294-308.

Pástor, Ľ., & Stambaugh, R. F. (2003). Liquidity risk and expected stock returns. Journal of Political economy, 111(3), 642-685.

Riordan, R., & Nerlinger, M. (2022). Carbon Liquidity. Available at SSRN 3938563.

Saka, C., & Oshika, T. (2014). Disclosure effects, carbon emissions and corporate value. Sustainability Accounting, Management and Policy Journal, 5(1), 22-45.

Singh, T., Gupta, M., & Sharma, M. (2015). Stock market liquidity and firm performance. Accounting, 1(1), 29-36.

Sikacz, H., & Teneta-Skwiercz, D. (2022). The role of selected tools of institutionalising the environmental area in the process of generating the environmental performance. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, 66(1), 115-133.

Smale, R., Hartley, M., Hepburn, C., Ward, J., & Grubb, M. (2006). The impact of CO2 emissions trading on firm profits and market prices. Climate Policy, 6(1), 31-48.

Syamala, S. R., Chauhan, Y., & Wadhwa, K. (2014). Institutional investors and stock liquidity: Evidence from Indian stock market. Global Business Review, 15(3), 461-476.

Tan, S. H., Habibullah, M. S., Tan, S. K., & Choon, S. W. (2017). The impact of the dimensions of environmental performance on firm performance in travel and tourism industry. Journal of environmental management, 203, 603-611.

Tanthanongsakkun, Suparatana, Sirimon Treepongkaruna, and Pornsit Jiraporn. "Carbon emissions, corporate governance, and staggered boards." Available at SSRN (2022)

Wang, S., Wan, L., Li, T., Luo, B., & Wang, C. (2018). Exploring the effect of cap-and-trade mechanism on firm's production planning and emission reduction strategy. Journal of cleaner production, 172, 591-601.

Wang, M., & Kong, D. (2011). Illiquidity and asset pricing in the Chinese stock market. China Finance Review International.