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Economic policy uncertainty, carbon emissions and firm valuation: International evidence

Sudipta Bose [a], Syed Shams [b], Searat Ali [c], Abdullah Al Mamun [c], Millicent Chang [c,*]

[a] Discipline of Accounting and Finance, Newcastle Business School, University of Newcastle, Sydney, NSW, 2000, Australia
[b] School of Business, University of Southern Queensland Springfield campus, Toowoomba, Qld, 4350, Australia
[c] School of Business, University of Wollongong, Wollongong, NSW, 2522, Australia

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ABSTRACT

This paper explores how the uncertainty surrounding economic policies affects the decisions managers make, particularly with reference to carbon emissions. Notably, this is a pioneering effort as very few studies have examined the influence of economic policy uncertainty on decisions about either carbon emissions or renewable energy, and, in turn, the impact of these decisions on firm value. From a sample spanning 22 countries over the period 2007 to 2018, our results show that, while carbon emissions increase with policy uncertainty, this relationship is mediated by renewable energy consumption. Country factors such as climate change performance, emissions trading schemes, and business culture also affect this relationship. In countries where economic policy uncertainty tends to be high, firms generally have a lower market value, due in part to higher levels of carbon emissions. These findings highlight the importance of connecting policy uncertainty to decisions about carbon emissions and renewable energy. They also provide insights into the detrimental effects of policy uncertainty on firm value.

1. Introduction

In April 2013, the atmospheric concentration of greenhouse gas (GHG) emissions surpassed 400 parts per million, a level often referred to as the "point of no return" (The Guardian, 2016). Concerns about global warming and climate change due to carbon emissions prompted world leaders to act. In 2015, 195 countries signed the Paris Agreement, committing to keep global warming well below 2°Celsius (United Nations Framework Convention on Climate Change [UNFCCC], 2015). Additionally, in 2015, the Financial Stability Board (FSB) set up the Task Force on Climate-related Financial Disclosures (TCFD) to develop recommendations for fostering more transparent and sustainable economies (TCFD, 2017).

Against this backdrop, we examine how the uncertainty surrounding economic policies impacts firm-level decisions about carbon emissions. With climate change critically affecting businesses, firms must prioritise emissions reduction in their operating strategies (Lee, 2012). However, investing in low-carbon projects can shift resources away from a business's core activities, which, in turn, can lead to lower firm performance and lower firm valuations. This, of course, presents a dilemma for many managers. Yet, a firm's decision on whether to invest in activities that reduce carbon emissions, such as renewable energy, and the subsequent effects of those decisions on firm performance hinges partly on the external economic environment around that firm. In other words, the uncertainty

* Corresponding author.
E-mail addresses: sudipta.bose@newcastle.edu.au (S. Bose), syed.shams@usq.edu.au (S. Shams), searat@uow.edu.au (S. Ali), amamun@uow.edu.au (A. Al Mamun), mchang@uow.edu.au (M. Chang).

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surrounding an economic policy, defined as unexpected changes in national fiscal, regulatory, and monetary policies (Baker, Bloom, & Davis, 2016) can contribute to a firm's performance and overall value. Hence, developing a greater understanding of how managerial decisions to invest in these activities when policy uncertainty exists stands to be a highly worthwhile undertaking.

Research has addressed how macroeconomic factors affect carbon emissions at the country level. These factors include economic growth (Friedl & Getzner, 2003; Holtz-Eakin & Selden, 1995; Richmond & Kaufmann, 2006; Stern, 2004); foreign direct investment (FDI) (Abdouli & Hammami, 2017); urbanisation (Bekhet & Othman, 2017); and trade openness (Ling, Ahmed, Binti Muhamad, & Shahbaz, 2015). Further, at least three research teams have investigated the relationships between economic policy uncertainty (hereafter uncertainty, policy uncertainty or EPU) and carbon emissions also at the country level – Jiang, Zhou, and Liu (2019), Adedoyin and Zakari (2020) and Abbasi and Adedoyin (2021). However, no one has yet studied this relationship on a global scale.

At the firm level, Yu, Shi, Guo, and Yang (2021) find Chinese manufacturing firms tend to increase emissions when uncertainty is high by choosing cheaper and less environmentally friendly fossil fuels. Yet, we need a much clearer understanding of how uncertainty affects carbon emissions if we are to achieve net zero emissions by 2050. This insight will necessarily involve recognising how unexpected changes in national fiscal, regulatory, and monetary policies influence the decisions firms make. To the best of our knowledge, this multi-country study is the first to investigate the association between EPU and firm-level carbon emissions. Our goals are to determine: (1) whether environmental characteristics at the country, industry or firm level impact this relationship; (2) how renewable energy influences the relationship between EPU and carbon emissions; and (3) how the relationship between EPU and carbon emissions impacts firm value.

Our sample comprises 6545 firm-year observations from 22 countries across the period 2007 to 2018. We use Baker et al.'s (2016) EPU index to capture the uncertainty surrounding monetary and fiscal policies, along with changes to taxes or the regulatory regime (Baker et al., 2016). The results show a positive association between uncertainty and firm-level carbon emissions, indicating that firms in countries with more uncertainty surrounding their economic policies produce more carbon. More specifically, when the uncertainty increases from 25 percent to 75 percent, carbon emissions increase by 9.27%. These results remain robust after alternative tests, including Heckman's (1979) two-stage model, alternative proxies for EPU and carbon emissions, and different sample specifications.

Further, a cross-sectional analysis shows that the positive EPU–carbon emissions relationship is more pronounced among: countries with higher ratings on the Climate Change Performance Index (CCPI); countries participating in national emissions trading schemes; stakeholder-oriented countries; firms operating in carbon-intensive industries; and firms spending less on R&D activities. We also show the role of renewable energy in the relationship between EPU and carbon emissions through a mediation analysis. Here, higher levels of uncertainty are associated with higher emissions. In part, this is because, when faced with uncertainty, companies tend to be reluctant to use renewable energies in their business operations – a finding consistent with the theory of real options (to delay). Finally, the analysis shows that an increase in carbon emissions during periods of high uncertainty leads to a reduction in firm value, confirming the value relevance of this relationship.

This study makes several contributions to the literature. First, we show that country-level environmental characteristics, such as climate change performance, emissions trading schemes, and a stakeholder-oriented business culture, moderate the positive relationship between policy uncertainty and carbon emissions. Countries tend to differ significantly in terms of their environmental characteristics, and our sample of firms from 22 countries exemplifies this fact. Second, by focusing on renewable energy investments as a way to counter carbon emissions, our study extends prior work on the relevance of economic policy uncertainty to real corporate investments, such as mergers and acquisitions (M&A), capital expenditure, and R&D (Bonaime, Gulen, & Ion, 2018; Gulen & Ion, 2016; Sha, Kang, & Wang, 2020; Xu, 2020). Finally, we contribute to the literature by providing new evidence that carbon emissions are an important component of the value reduction caused by policy uncertainty. This evidence contributes to the current debate on the association between carbon emissions and firm valuations (Clarkson, Li, Pinnuck, & Richardson, 2015; Griffin, Lont, & Sun, 2017; Matsumura, Prakash, & Vera-Muñoz, 2014) by providing evidence that the uncertainty surrounding economic policies is an important factor to consider in this relationship.

The remainder of the paper is organised as follows. Section 2 presents a review of the relevant literature and hypotheses development. Section 3 describes the research design, while Section 4 and 6 report the main results. Sections 5 and 7 provide additional analyses and robustness checks of the results. Finally, Section 8 discusses the study's findings and concludes the paper.

2. Literature review and hypotheses development

2.1. Economic policy uncertainty (EPU) and corporate investment

The term 'policy uncertainty' refers to the risk arising from unpredictable shifts in macroeconomic policies, such as fiscal, regulatory, and monetary policies, with these shifts tending to be more severe than temporary economic downturns (Baker et al., 2016). The literature suggests that policy uncertainty has a considerable influence on the environment in which firms conduct their business and can prompt managers to adjust their investment decisions, including the acquisition of tangible and intangible assets and M&As. For example, consistent with Pindyck's (1990) real options theory, Gulen and Ion (2016) report that uncertainty shocks in economic policy increase the incentives for US firms to delay irreversible investments until some of the uncertainty is resolved. Similarly, Bonaime et al. (2018) find that US firms are less likely to engage in M&As during periods of high policy uncertainty, and that this relationship is stronger for deals involving more irreversible investments. A handful of studies also show that, depending on the context, high policy uncertainty can increase corporate investments (Hassett & Sullivan, 2015). Consistent with the 'real options to grow' concept, the study by Wu, Zhang, Zhang, and Zou (2020) finds that Australian firms increase investments during periods of higher policy uncertainty. Likewise, as reported in a study by Sha et al. (2020), the number of M&As in China increases with policy uncertainty, especially for non-state-owned enterprises. These authors argue that, although firms should delay irreversible investments in uncertain economic conditions, the cost of waiting can be high in competitive markets. In the context of intangible assets, Xu (2020) finds that policy uncertainty hinders innovation not only because traditional investments are irreversible but also because of the cost of capital. Similarly, Jia and Li (2020) show that uncertainty negatively affects sustainability investments at the firm level, as measured using environmental, social and governance (ESG) ratings.

Most studies report that the uncertainty surrounding economic policies limits a range of investments commonly made by firms (e.g., Bonaime et al., 2018; Gulen & Ion, 2016). These findings are generally based on widely available and reliable measures of EPU. However, there are some exceptions where uncertainty actually increases investment (Sha et al., 2020; Wu et al., 2020). Notably, though, academic focus tends to be fixed on economic investment decisions by firms, with relatively less attention paid to decisions about environmental investments. Our study fills this gap by examining the relationship between policy uncertainty and decisions related to carbon emissions, including investments into renewable energy.

2.2. EPU and carbon emissions

2.2.1. Existing studies

Prior studies have examined the relationship between uncertainty and carbon emissions from a macroeconomic standpoint using single- or multi-country samples. For example, Jiang et al. (2019) report that EPU influences carbon emissions across the industrial, residential, electrical power and transportation sectors in the US in both high and low periods of emissions growth. Wang, Xiao, and Lu (2020) find that EPU is positively associated with carbon emissions in the long term, while Adedoyin and Zakari (2020) noted that, while EPU seemed to decrease short-term carbon emissions in the UK, the long-term result was increased carbon emissions. Interestingly, Syed and Bouri (2022) show that, in the short term, EPU positively impacts carbon emissions and worsens environmental conditions in the US. However, in the long term, EPU leads to a significant reduction in carbon emissions and contributes to improving overall environmental quality. Conversely, Abbasi and Adedoyin (2021) show that policy uncertainty had no effect on carbon emissions in China for the period from 1970 to 2018. Likewise, Liu and Zhang (2022) analysed data from various regions in China from 2003 to 2017 and found that, generally, uncertainty has a negative impact on carbon emissions except in the central and western regions of China.

Using a multi-country sample, Pirgaip and Dinçergök (2020) report the positive impact of policy uncertainty on carbon emissions in Canada, Germany, and the US, with evidence of causality running from EPU to carbon emissions. In Italy, however, causality runs from carbon emissions to EPU. Adams, Adedoyin, Olaniran, and Bekun (2020) examine the association between uncertainty and carbon emissions for 10 resource-rich countries from 1996 to 2017, showing that not only is EPU associated with carbon emissions in the long term, but also that there is a bi-directional causality between EPU and carbon emissions. Anser, Apergis, and Syed (2021) examined the impact of policy uncertainty on carbon emissions in the top 10 carbon-emitting countries from 1990 to 2015. They show that EPU decreases carbon emissions in the short term but increases them in the long term. By contrast, Iqbal, Chand, and Haq (2023) indicate that EPU increases carbon emissions in both the long and short term for both developing and developed nations, namely the US, the UK, China, Pakistan, and India.

Studies at the firm level include Yu et al. (2021), who report that manufacturing firms in China tend to choose cheap and dirty fossil fuels during periods of high uncertainty, which leads to increased carbon emissions. However, although they emphasise that policy uncertainty does affect carbon emissions at the firm level, their study relies on unique microdata pertaining to non-publicly listed Chinese manufacturing firms from the China Taxation Survey (CTS), which are only accessible for the period from 2008 to 2011. This makes their findings less generalisable than would be ideal.

In more recent times, addressing climate change has become more of a priority to both firms and our survival as evidenced by initiatives such as the COP26. In a very recent study using a multi-country sample, Benlemlih and Yavaş (2023) show that uncertainty in economic policies leads to increased carbon emissions due to high tax rates and risk taking, with this effect strongly moderated by governance characteristics at, first, the firm level (i.e., through the gender diversity and independence of boards) and, second, at the country level (i.e., through government effectiveness, and controls over corruption and democracy).

2.2.2. Hypotheses development

The way in which managers make long-term investment decisions to reduce carbon emissions when faced with policy uncertainty can be explained using real options theory (Dixit & Pindyck, 2012). This theory assumes that managers have a high degree of flexibility and discretion over decisions about the scale and timing of sustainable investments. This flexibility makes it feasible to postpone investments, especially when economic prospects are wrapped in a significant level of uncertainty (Jia & Li, 2020). Moreover, in highly uncertain periods, the expected benefits from long-term investments become more obscure, which can cause managers to delay any investment that might be irreversible (Bernanke, 1983; Julio & Yook, 2012). Investments into renewable energies are typically complex, highly ambiguous (Zhang, Wang, Zhou, & Ding, 2019), and irreversible given their high sink costs (Fuss, Szolgayova, Obersteiner, & Gusti, 2008). Intuitively, a firm with irreversible renewable energy investments will have more to lose if these projects prove unprofitable. Thus, most firms will prefer to delay these investments until some of the uncertainty is resolved. Yet, at the same time, carbon emissions will continue to increase as companies are delaying their investments into renewable energy. Young and Makhija (2014) contend that regulatory institutions can influence firms to make decisions in favour of society and the environment because the environment has systemic effects on firms. However, Blyth et al. (2007) propose that policy makers should provide long-term regulatory certainty to reduce the cost of investing in low carbon technologies. Kumarasiri (2016) contends that climate policy uncertainty stops carbon-intensive firms from making long-term investments in projects dedicated to finding new ways to manage emissions, including adopting renewable energy. According to Jiang et al. (2019), in times of high uncertainty, regulators turn their attention away from environmental governance, thus increasing uncertainty as well as undermining the implementation of desired environmental protection policies. As an example, this was reflected in the budget cuts to the US Environmental Protection Agency (EPA) followed by Trump's decision to withdraw from the 2015 Paris Agreement on 1 June 2017. Thus, anticipating relaxed environmental requirements from regulators, firms might also put less effort into protecting the environment, resulting in an increase in carbon emissions.

By contrast, the 'real options to grow' avenue submits that managers can potentially increase a firm's long-term investments during periods of high uncertainty to avoid the significant costs of waiting in highly competitive or highly regulated environments (Sha et al., 2020). In the context of climate change, firms may be more likely to pursue renewable energy investments, despite high policy uncertainty, because they anticipate considerable increases in the future social costs of carbon. Regulators imposing carbon pricing mechanisms, like emissions trading schemes, or carbon taxes are signs that society is past ready to combat climate change. In addition, green subsidies, such as offsets and credits, might also be much less generous in future, providing yet another reason for firms to not defer renewable energy investments. Many subsidies are designed to be phased out over time; therefore, it is not unreasonable to expect that firms today will produce lower carbon emissions despite high policy uncertainty.

With the 'real options to delay' and 'real options to grow' arguments in mind, such uncertainty could either delay or expedite corporate investments into renewable energy. Respectively, these two results could have either a negative or a positive influence on carbon emissions at the firm level. Hence, we are not willing to make a prediction about the direction of this relationship. Rather, it is enough to say that a relationship exists between the two variables. Therefore, Hypothesis H1 is formulated as follows:

H1. There is an association between the uncertainty surrounding economic policies and carbon emissions in firms.

2.3. EPU, carbon emissions and firm valuation

In addition to the above relationship, we suspect that carbon emissions play a mediating role in the relationship between policy uncertainty and firm valuations. To establish this argument, we consider the theoretical link between policy uncertainty and the valuations made of firms. Generally, maximising a firm's value is one of management's prime financial objectives. This is usually achieved by allocating resources to investments with positive net present value (NPV), depending on future cash flows and discount rates. However, uncertainty surrounding economic policies can make it challenging for managers to estimate the future cash flows from such investments. Hence, managers may prefer to delay investment until the uncertainty is resolved (Gulen & Ion, 2016). These delays also apply to investments in renewable energy, especially since they are often complex and ambiguous (Zhang et al., 2019). Likewise, policy uncertainty can prompt fund providers to charge higher financing costs as compensation for bearing higher risk during uncertain times. For example, investors evaluating renewable energy projects will frequently apply a discount rate that is much higher than the market rate (Menegaki, 2008). Consequently, an economically feasible investment can easily be rejected (Drobetz, El Ghoul, Guedhami, & Janzen, 2018; Xu, 2020). These arguments suggest that uncertainty can hamper a manager's ability to grow a firm's value – a view supported by studies that document a negative relationship between policy uncertainty and firm value in a single-country settings. Yang, Yu, Zhang, and Zhou (2019), for example, report reduced market values for Chinese firms during times of high EPU. Similarly, Iqbal, Gan, and Nadeem (2020) use a sample of US firms to show the negative association between uncertainty and financial performance. We contribute to this research area by examining how the relationship between uncertainty and firm value is mediated by carbon emissions in a multi-country setting, noting that each country has a different business culture, benchmarks for environmental performance, and environmental policies.

Further, neoclassical economic theory posits that a manager's primary social responsibility is to maximise shareholder wealth (Friedman, 2007). In this context, socially responsible actions are analogous to imposing a tax on shareholders to serve non-shareholder interests. Therefore, investing in activities to protect the environment, such as using or developing renewable energy sources, translates to reallocating scarce resources from the company's core business, and this can potentially destroy firm values and shareholder wealth (Palmer, Oates, & Portney, 1995). By contrast, stakeholder theory states that environmental initiatives by firms to reduce carbon emissions can generate business opportunities and provide a competitive advantage, which, in turn, will increase a firm's value (Freeman, 2010; Makni, Francoeur, & Bellavance, 2008). Firms perceived as 'environmentally unsustainable' can significantly damage their reputation and lose market competitiveness. This can lead to subsequent increases in future cash flow uncertainty (Zhou, Zhang, Lin, Zeng, & Chen, 2020), resulting in increased financing costs (Jung, Herbohn, & Clarkson, 2018), which is detrimental to firm value. Empirical evidence supports both theories, while studies show either no relationship or a negative one between environmental performance and firm value (e.g., Ameer & Othman, 2012; Hassel, Nilsson, & Nyquist, 2005; Horváthová, 2012; Makni et al., 2008). Lee and Min (2015) find that investors consistently penalise firms for negative environmental performance (e.g., carbon emissions) and reward positive environmental actions (e.g., environmental R&D investments) with higher values. Similarly, in their meta-analysis of 32 empirical studies, Busch and Lewandowski (2018) show that, while improved carbon performance is generally positively related to firm valuation, carbon emissions are negatively related.

We argue that the interplay between policy uncertainty and carbon emissions is more likely to destroy firm value than either high uncertainty or high carbon emissions would independently. Consistent with our argument, Rjiba, Jahmane, and Abid (2020) show that the negative effect of EPU on firm value is attenuated by investments in corporate social responsibility (CSR). Similarly, Jia and Li (2020) document that firms with better sustainability investments have higher market value when EPU is higher. While these studies focus on investments in overall CSR, we focus on a crucial environmental concern, that is, climate change, and a specific operational performance measure, namely, firm-level carbon emissions. Therefore, we test the mediating role of carbon emissions in the association between EPU and firm value as follows:

H2. Carbon emissions mediate the association between EPU and firm value.

3. Research method

3.1. Data and sample

Our initial sample consisted of all firms responding to the Carbon Disclosure Project (CDP) questionnaire from 2007 to 2018. In the CDP database, carbon emissions data are only available from 2007 to 2018; hence, 2018 was the last year for which we collected data. Other financial data were gathered from the Refinitiv Worldscope database, while other non-financial data were collected from the ESG database. In addition, stock price data were gathered from the Datastream database; country-level EPU data were collected from the Economic Policy Uncertainty website; and country-level institutional variables were collected from the World Bank database. Country-level data pertaining to the Climate Change Performance Index and the Global Climate Risk Index were sourced from reports published by Germanwatch and the Climate Action Network.[1] After removing firm-year observations with incomplete data from the above-mentioned databases, we assembled an initial sample of 1319 unique firms with 6545 firm-year observations across 22 countries. Table 1, Panel A provides the details of the sample selection procedure.

Table 1, Panels B and C provide the industry and annual distributions of firms in our sample. The sector breakdown of the sample is as follows: firms from the transportation industry accounted for 9.20%, followed by utilities (7.70%), services (6.84%) and the mining/construction industries (6.46%), while firms operating in 'other' industries accounted for 0.35% of the sample. The most observations (13.32%) were seen in 2018, while 2007 had the lowest number (2.17%). The annual distribution shows that the number of firms reporting on carbon emissions has risen over the years.

3.2. Measures of carbon emissions

Following prior studies (e.g., Bose et al., 2021; Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014), we use each firm's total amount of reported carbon emissions as its carbon emissions. Firms across the world disclose their total global carbon emissions in metric tons of CO_2 equivalent (CO_2-e), segmenting them as direct and indirect sources of carbon emissions (World Business Council for Sustainable Development [WBCSD] & World Resources Institute [WRI], 2004). Direct sources encompass direct carbon emissions emitted by sources owned or controlled by the firm, while indirect sources include: first, indirect carbon emissions caused by a firm's use of purchased electricity, heating and cooling, or steam generated off-site but purchased by the firm; and, second, sources that are not owned or controlled directly by the firm but are nevertheless vital to its operations (WBCSD & WRI, 2004). We measured carbon emissions as the natural logarithm of a firm's total reported carbon emissions *(LNCO2)*. We also used the ratio of total carbon emissions to total sales revenue *(CO2TR)* as another measure of carbon emissions in the robustness analysis.

3.3. EPU measure

Scores on the EPU index were used as our variable of interest, as these have been used extensively in other studies (e.g., Duong, Nguyen, Nguyen, & Rhee, 2020; Gulen & Ion, 2016; Jory, Khieu, Ngo, & Phan, 2020). As firm-level carbon emissions and financial variables are available and readily accessible on an annual basis, monthly EPU data were transformed into annual data using the 12-month arithmetic average of the index for each of the countries in the study. To alleviate concerns that extreme values in certain years may influence the results, we measured EPU as the natural logarithm of the 12-month arithmetic average of the monthly index score ending in the fiscal year-end month.

3.4. Empirical models

To test the effect of EPU on carbon emissions (H1), we developed the following model:

$$LNCO2_{i,t} = \beta_0 + \beta_1 EPU_{j,t} + \beta_2 SIZE_{i,t} + \beta_3 MB_{i,t} + \beta_4 LEV_{i,t} + \beta_5 ROA_{i,t} + \beta_6 RDINT_{i,t} + \beta_7 SGROWTH_{i,t} + \beta_8 ENVPERF_{i,t} + \beta_9 FAGE_{i,t} + \beta_{10} LIQUIDITY_{i,t} + \beta_{11} CFO_{i,t} + \beta_{12} NEW_{i,t} + \beta_{13} CAPIN_{i,t} + \beta_{14} INTANG_{i,t} + \beta_{15} RISK_{i,t} + \beta_{16} CROSS_{i,t} + \beta_{17} LNGDP_{j,t} + \beta_{18} STAKE_{j,t} + \beta_{19} ENFORCE_{j,t} + \beta_{20} CRI_{j,t} + \sum INDUSTRY_{i,t} + \sum YEAR_{i,t} + \varepsilon_{i,t} \quad (1)$$

where i denotes the individual firm ($i = 1, 2, \ldots, 1319$); j represents the country ($j = 1, 2, \ldots, 22$); t is the time period ($t = 2007, 2008, \ldots, 2018$); β is the parameter to be estimated; and $\varepsilon_{i,t}$ is the idiosyncratic error term. *LNCO2* is the natural logarithm of total carbon emissions in CO_2-e metric tons, with a higher value indicating that the firm produces a higher level of carbon emissions. *EPU* is the measure of economic policy uncertainty, which was measured as the natural logarithm of the 12-month arithmetic average of the monthly EPU Index score ending in the fiscal year-end month. Appendix B provides definitions of all the variables.

Several control variables are included in Equation (1) that are likely to affect firm-level carbon emissions. The level of carbon

[1] For details about the country-level Climate Change Performance Index and the Global Climate Risk Index, see: https://www.climate-change-performance-index.org/downloads (accessed on 15 May 2023).

Table 1
Sample selection and distribution.

Panel A: Sample Selection	
Carbon emissions data coverage from 2007 to 2018	14,097
Less: Firm-year observations not matched with other databases	(1600)
Less: Observations with no available EPU data	(2764)
Less: Observations dropped due to one-year lead of Tobin Q's variable	(1808)
Less: Observations dropped due to insufficient control variables	(1380)
Final Sample	**6545**

Panel B: Industry-wise distribution of firms in sample

Name of Industry	Observations	% of Sample
Mining/Construction	423	6.46
Food	352	5.38
Textiles/Print/Publishing	295	4.51
Chemicals	382	5.84
Pharmaceuticals	235	3.59
Extractive	365	5.58
Manufacturing: Rubber/glass/etc.	157	2.40
Manufacturing: Metal	190	2.90
Manufacturing: Machinery	277	4.23
Manufacturing: Electrical Equipment	224	3.42
Manufacturing: Transport Equipment	410	6.26
Manufacturing: Instruments	225	3.44
Transportation	602	9.20
Utilities	504	7.70
Retail: Wholesale	131	2.00
Retail: Miscellaneous	405	6.19
Retail: Restaurant	51	0.78
Financial	81	1.24
Insurance/Real Estate	204	3.12
Services	448	6.84
Others	23	0.35
Total	**6545**	**100**

Panel C: Year-wise distribution of firms in sample

Year	Observations	% of Sample
2007	142	2.17
2008	224	3.42
2009	352	5.38
2010	397	6.07
2011	467	7.14
2012	533	8.14
2013	612	9.35
2014	694	10.60
2015	736	11.25
2016	823	12.57
2017	693	10.59
2018	872	13.32
Total	**6545**	**100**

emissions is closely related to a firm's scale of operations (Dahlmann, Branicki, & Brammer, 2019). Therefore, we include firm size *(SIZE)* as a control variable, expecting it to have a positive effect. Further, firms with better investment opportunities will tend to invest more in environmentally friendly technologies that enhance their carbon emissions management performance (de Villiers, Naiker, & van Staden, 2011). Therefore, we also controlled for investment opportunities *(MB)*, expecting this variable to have a negative effect. Debtholders are more interested in a firm's carbon emissions as this type of information reflects the firm's downside risk as well as the sustainability of its operations (Clarkson, Li, Richardson, & Vasvari, 2011; Qian & Schaltegger, 2017). We therefore controlled for leverage *(LEV),* which we expect to have a negative effect. Moreover, firms that are more profitable are more likely to perform better environmentally due to their ability to accommodate the relevant compliance costs (Clarkson et al., 2011; Qian & Schaltegger, 2017). Therefore, we controlled for profitability *(ROA)*, expecting it to have a negative effect. We also controlled for R&D intensity *(RDINT)* to capture a firm's innovation activities, in line with Clarkson et al.'s (2011) argument that firms with innovative management teams are more likely to pursue proactive investment strategies that help to protect the environment.

Sales growth *(SGROWTH)* was included to account for the talent of a firm's management and its ability to perform well environmentally (Clarkson et al., 2011). We expect this variable to have a negative effect on carbon emissions. We also controlled for relative environmental performance at the firm level *(ENVPERF)* to capture the impact a firm's environmental performance on firm-level carbon emissions. Firms that are older are more likely to have the necessary infrastructure in place to manage their carbon emissions at a lower cost (de Villiers et al., 2011). By the same token, older firms may have organisational inertia (Barnett & Salomon,

Table 2
Descriptive statistics.

	Observations	Mean	Std. Dev.	Median
CO2	6545	4.708	17.394	0.404
LNCO2	6545	0.791	1.018	0.339
EPU_TOTAL	6545	160.482	83.767	142.396
EPU	6545	4.989	0.414	4.966
LNREN	6545	0.762	0.942	0.000
TOBINQ	6545	1.707	0.942	1.398
SIZE	6545	9.047	1.352	9.002
MB	6545	2.918	3.269	2.048
LEV	6545	0.271	0.161	0.256
ROA	6545	0.051	0.060	0.046
RDINT	6545	0.026	0.047	0.003
SGROWTH	6545	0.039	0.168	0.032
ENVPERF	6545	41.01	32.963	46.77
FAGE	6545	2.267	0.909	2.485
LIQUIDITY	6545	1.449	1.282	1.103
CFO	6545	0.102	0.060	0.093
NEW	6545	0.505	0.172	0.474
CAPIN	6545	0.053	0.043	0.041
INTANG	6545	0.211	0.211	0.138
RISK	6545	0.020	0.009	0.018
CROSS	6545	2.014	1.382	2.000
LNGDP	6545	10.605	0.557	10.716
STAKE	6545	0.408	0.491	0.000
ENFORCE	6545	2.473	0.845	2.534
CRI	6545	3.713	0.564	3.807

Notes: Definitions of variables are provided in Appendix B. Std. Dev. = Standard deviation.

2006), which may increase their carbon emissions. Thus, we controlled for firm age *(FAGE)*. Next, we controlled for liquidity *(LIQUIDITY)* and cash flows *(CFO)* as firms with higher liquidity and sufficient cash flows can more easily invest in technologies for controlling carbon emissions, which would enhance their performance (Clarkson et al., 2011; Qian & Schaltegger, 2017).

Moreover, firms who have made investments into newer equipment have a higher propensity to use cleaner and less polluting technologies, improving the environmental performance of the firm (Clarkson et al., 2011; Qian & Schaltegger, 2017). Similarly, firms with a higher capital intensity should be more able to effectively maintain their carbon emissions performance (Clarkson et al., 2011; Qian & Schaltegger, 2017). Therefore, we controlled for both asset newness *(NEW)* and capital intensity *(CAPIN)*. We also controlled for intangibles *(INTANG)* as firms with more intangible assets will generally produce fewer carbon emissions (Griffin et al., 2017). Conversely, firms with a higher level of financial risk are more likely to show evidence of poorer environmental performance as their

Table 3
Country descriptive statistics.

	Observations	% of Sample	CO_2 (in million metric tons CO_2-e)	*EPU*	*STAKE*	*CCPI*	*ENFORCE*	*CRI*
Australia	298	4.55	2.557	120.575	0	39.104	3.196	36.846
Brazil	191	2.92	4.907	200.461	1	56.223	−0.205	54.839
Canada	454	6.94	3.256	188.452	0	39.128	3.180	54.948
Chile	7	0.11	2.653	126.445	1	–	2.293	50.549
China	10	0.15	4.346	223.607	0	48.955	−0.507	32.615
Colombia	16	0.24	2.443	116.343	1	–	−0.134	48.168
France	405	6.19	9.787	234.140	1	60.121	2.314	52.641
Germany	299	4.57	14.039	157.862	1	59.386	2.971	53.009
Greece	5	0.08	0.319	112.891	1	54.628	0.293	67.268
India	110	1.68	3.386	102.451	0	59.491	−0.437	22.768
Ireland	68	1.04	1.292	147.968	0	59.421	2.862	74.247
Italy	95	1.45	7.612	118.557	1	54.920	0.725	51.814
Japan	984	15.03	2.580	112.734	1	43.834	2.445	41.945
Mexico	19	0.29	1.350	46.541	1	62.396	−0.426	44.009
Netherlands	87	1.33	4.842	100.859	1	52.344	3.307	83.557
Russia	17	0.26	51.670	203.859	0	44.213	−1.223	65.668
Singapore	33	0.50	3.273	143.529	0	45.344	3.463	113.455
South Korea	243	3.71	5.139	144.293	1	45.916	1.480	74.709
Spain	142	2.17	8.510	124.198	1	54.677	1.620	58.528
Sweden	177	2.70	1.568	98.096	1	61.371	3.456	86.774
United Kingdom	952	14.55	1.886	269.662	0	63.180	3.029	59.573
United States	1933	29.53	5.011	131.845	0	46.445	2.541	26.097
Total/Average	**6545**	**100**	**4.708**	**160.482**		**50.547**	**2.473**	**45.998**

Note: Definitions of variables are provided in Appendix B.

Table 4
Correlation matrix.

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
EPU	**[1]**	1.000							
TOBINQ	**[2]**	−0.046***	1.000						
SIZE	**[3]**	−0.150***	0.300***	1.000					
MB	**[4]**	−0.037***	0.559***	0.250***	1.000				
LEV	**[5]**	0.043***	−0.096***	−0.007	0.067***	1.000			
ROA	**[6]**	−0.075***	0.575***	0.334***	0.363***	−0.217***	1.000		
RDINT	**[7]**	−0.109***	0.226***	0.199***	0.084***	−0.212***	0.104***	1.000	
SGROWTH	**[8]**	−0.012	0.082***	0.062***	0.068***	−0.065***	0.211***	0.012	1.000
ENVPERF	**[9]**	−0.010	−0.004	0.217***	−0.003	0.037***	0.009	0.090***	−0.052***
FAGE	**[10]**	−0.001	−0.004	0.080***	0.005	−0.011	0.017	0.032***	−0.054***
CFO	**[11]**	−0.083***	0.586***	0.275***	0.362***	−0.181***	0.681***	0.125***	0.149***
NEW	**[12]**	0.079***	−0.089***	−0.025**	−0.072***	0.207***	−0.035***	−0.255***	0.114***
CAPIN	**[13]**	−0.041***	−0.029**	0.029**	−0.043***	0.017	0.068***	−0.183***	0.130***
INTANG	**[14]**	0.136***	0.158***	0.120***	0.167***	0.061***	0.084***	0.131***	0.105***
LIQUIDITY	**[15]**	−0.190***	0.005	−0.029**	−0.013	0.039***	−0.086***	0.207***	−0.031**
RISK	**[16]**	0.069***	−0.196***	−0.400***	−0.214***	−0.028**	−0.300***	−0.025**	−0.072***
CROSS	**[17]**	−0.168***	0.012	0.380***	0.015	−0.008	0.003	0.181***	−0.054***
LNGDP	**[18]**	0.037***	0.008	0.080***	0.029**	−0.009	−0.033***	0.120***	−0.030**
ENFORCE	**[19]**	0.106***	−0.015	−0.046***	0.002	−0.092***	−0.026**	0.046***	−0.022*
CRI	**[20]**	0.299***	−0.161***	−0.183***	−0.104***	0.001	−0.114***	−0.150***	−0.065***

Notes: Superscript ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. Definitions of variables are provided in Appendix B.

less stable economic performance will likely mean they have not invested in cleaner and less polluting technologies (de Villiers et al., 2011). Hence, we also controlled for firm-level financial risk *(RISK),* expecting it to have a positive effect.

We also included several country-level factors as control variables that may influence firm-level carbon emissions. Firms that are cross listed *(CROSS)* are generally larger and so will tend reduce their carbon emissions. We controlled for gross domestic product (GDP) to capture country-level financial development (*LNGDP*) as firms operating in financially developed countries will typically invest more in initiatives that help to reduce carbon emissions. Additionally, firms in stakeholder-oriented *(STAKE)* countries and in better legal environments *(ENFORCE)* face more pressure from stakeholders to better manage their carbon performance – pressures that may greatly influence their carbon emissions. Finally, we controlled for country-level global climate change risk *(CRI)* as firms in countries with higher levels of climate change risk are motivated to better manage their carbon emissions.

3.5. Estimation methods

We tested our hypotheses through ordinary least squares (OLS) regression. To address heteroscedasticity and serial correlation in the residuals, we applied robust standard errors clustered by country. Additionally, we included industry and year fixed effects in each of the models to capture cross-sectional variation across industries and time. The mediation analysis was conducted using a simultaneous equation technique.

3.6. Descriptive statistics

Table 2 provides the summary of the descriptive statistics for the variables used in our study. The average value of the carbon emissions *(CO2)* is 4.708 million CO_2-e metric tons with a standard deviation of 17.394. The median value (0.404) of the carbon emissions is lower than the mean, suggesting a skewed distribution. This supports the logarithmic transformation of *CO2 (LNCO2)* for our analysis. The mean (median) value of EPU *(EPU_TOTAL)* is 160.482 (142.396) with a standard deviation of 83.767, which is comparable to the mean and median values reported in Drobetz et al. (2018). We also took the logarithmic transformation of *EPU_TOTAL (EPU)* as the mean of EPU, which is greater than the median. The mean value of *LNREN* is 0.762, showing that firms in our sample use, on average, an (unreported) 86.228 thousand gigajoules of renewable energy. The mean (median) value of *TOBINQ* is 1.707 (1.398) with a standard deviation of 0.942, similar to Rjiba et al. (2020). The mean firm size measured by the natural logarithm of market capitalisation *(SIZE)* is 9.047, implying a mean total market capitalisation of US$21.50 billion (unreported), which indicates that the firms in our sample are relatively large. The mean market-to-book ratio *(MB)* is 2.918, indicating that the firms in our sample have high growth opportunities. Additionally, the ratios to total assets are as follows: mean leverage *(LEV)* 27.10%, profitability (*ROA*) 5.10%, operating cash flows (*CFO*) 10.20%, and intangible assets *(INTANG)* 21.10%. Further, the mean R&D intensity *(RDINT)* is 2.60%, while capital intensity *(CAPIN)* is 5.30% of total sales revenue. The mean sales growth of firms in our sample is 3.90%, while environmental performance *(ENVPERF)* is 41.01. The mean firm age (unreported) is 12.30 years. Approximately 40.80% of firms are domiciled in countries with stakeholder-oriented business cultures *(STAKE)*, and the mean value of the legal environment score *(ENFORCE)* is 2.473.

Table 3 presents the country-level descriptive statistics. Our sample is dominated by firms from the US (29.53%), followed by firms

[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]
1.000											
0.049***	1.000										
−0.037***	−0.030**	1.000									
0.039***	−0.087***	−0.149***	1.000								
−0.033***	−0.056***	0.303***	0.257***	1.000							
−0.055***	−0.015	0.029**	−0.237***	−0.313***	1.000						
0.002	0.002	0.035***	−0.088***	−0.013	−0.076***	1.000					
−0.074***	−0.135***	−0.105***	0.061***	0.113***	−0.176***	0.302***	1.000				
0.142***	0.066***	0.037***	−0.165***	−0.007	−0.026**	0.086***	−0.060***	1.000			
−0.011	0.105***	−0.014	−0.139***	−0.083***	0.126***	0.219***	−0.150***	0.179***	1.000		
−0.063***	0.081***	−0.033***	−0.088***	−0.032**	0.096***	0.056***	−0.089***	0.116***	0.720***	1.000	
−0.027**	−0.076***	−0.128***	0.038***	0.009	0.001	−0.290***	0.115***	−0.122***	−0.021*	0.074***	1.000

from Japan (15.03%) and from the UK (14.55%). These percentages are consistent with Dhaliwal, Li, Tsang, and Yang (2014). On average, firms in Russia produce higher levels of carbon emissions (mean of 51.670), followed by Germany (mean of 14.039) and France (mean of 9.787), while Greek firms (mean of 0.319) have relatively less carbon emissions. In terms of EPU, the UK EPU (mean of 269.662) is the highest, followed by France (mean of 234.140) and China (mean of 223.607), while the lowest EPU is in Mexico (mean of 46.541). It is interesting to note that the UK also has the highest level of climate change performance (mean of 63.180). In terms of global climate change risk (*CRI*), Singapore is the least vulnerable (mean of 113.455), followed by Sweden (mean of 86.774), while India (mean of 22.768) has the highest risk of the countries in the sample.

3.7. *Correlation analysis*

Table 4 presents Pearson's bivariate correlation analysis. Correlations between the variables are generally low, except for *LNGDP* and *ENFORCE*. Gujarati and Porter (2009) suggest that multicollinearity problems are not caused by bivariate correlations less than 0.80.[2] The mean variance inflation factor (VIF) value is 1.83, ranging from 1.05 to 3.84. A VIF value greater than 10 raises concerns of multicollinearity (Gujarati & Porter, 2009). Our results are therefore unlikely to suffer from multicollinearity problems.

4. Empirical results

4.1. *Does economic policy uncertainty (EPU) affect firm-level carbon emissions? (H1)*

Table 5 presents the regression results of the hypothesis tests for H1: a non-directional association between EPU and firm carbon emissions. Model (1) reports these results using EPU and all other firm-level and country-level control variables, while Model (2) shows the results for all firm- and country-level control variables, excluding *EPU*. The EPU coefficient is positive and statistically significant ($\beta = 0.163$, p-value<0.01) in Model (1), suggesting that firms in countries with high levels of policy uncertainty have high carbon emissions. This result shows that, due to uncertainty around economic policies, firms in these countries are reluctant to invest in activities that reduce carbon emissions; consequently, carbon emissions are high. A positive association between EPU and firm-level carbon emissions was also reported in Yu et al. (2021). In terms of economic significance, a 1% increase in EPU is associated with a 16.30% increase in the level of carbon emissions. This translates to a 9.27% increase in the level of carbon emissions, moving from a firm in the first quartile of uncertainty to one in the third quartile.[3]

Table 5 reports that the *R*-squared (R^2) value of Model (1) is 0.523, which implies that the independent variables collectively capture 52.30% of the variation in carbon emissions. To assess *EPU's* incremental contribution, we used Gujarati's (2003) *F*-statistic and re-ran Model (1) after excluding *EPU*. The results show that the explanatory power of this regression drops to 52%, as reported in

[2] We include *LNGDP* and *ENFORCE* separately to check whether their exclusion or inclusion in the model affects our findings. The findings suggest that their exclusion or inclusion does not influence our results.

[3] The first quartile of EPU is 4.736 and the third quartile of EPU is 5.186 (not reported in Table 2). The economic magnitude of 9.27% is computed as follows: ((5.186–4.736) × 0.163)/0.791).

Model (2). Using the R^2 statistics reported in Models (1) and (2), we then compute the *F*-statistic as 32.30, which is significant at the 1% level, suggesting that *EPU* significantly enhances the explanatory power of the model. Therefore, consistent with our prediction in H1, *EPU* is incrementally informative in explaining carbon emissions at the firm level.

In terms of the control variables, we find that *SIZE*, *FAGE*, *NEW, RISK* and *CROSS* have significant and positive influences on the level of carbon emissions. As shown in Model (1), firm size *(SIZE)* is positively associated with carbon emissions. This suggests that larger firms produce higher carbon emissions due to their larger scale of operations. Firm age *(FAGE)* is also positively associated with carbon emissions, suggesting that older firms may have organisational inertia, resulting in higher carbon emissions. Asset newness *(NEW)* is also positively associated with carbon emissions, contradicting our expectations. However, when we included firm fixed effects in Model (3), the result was a negative coefficient. Time-invariant omitted variable bias is a possible reason for the positive coefficient of *NEW*.

RISK is also positively associated with carbon emissions, suggesting that firms with a higher level of financial risk, and therefore less stable economic performance, do not invest in cleaner technologies. Thus, they have higher carbon emissions. Furthermore, firms that are cross listed *(CROSS)* are positively associated with carbon emissions. This is unsurprising as cross listed firms tend to be larger.

By contrast, we find investment opportunities *(MB)*, profitability *(ROA)*, R&D intensity *(RDINT)*, liquidity (*LIQUIDITY)* and capital intensity *(CAPIN)* have a significant negative influence on carbon emissions. As shown in Model (1), investment opportunities *(MB)* are strongly negatively associated, indicating that firms with higher investment opportunities invest more in environmentally friendly technologies that reduce their carbon emissions. Similarly, profitability *(ROA),* R&D intensity *(RDINT),* liquidity *(LIQUIDITY)* and capital intensity *(CAPIN)* are all negatively associated with carbon emissions levels, suggesting that firms that are profitable, those that are more R&D intensive, and those with higher levels of liquidity and capital intensity are more likely to pursue proactive investment strategies in cleaner technologies that help to reduce their carbon emissions.

Although we include several firm- and country-level control variables in Equation (1) that could potentially affect both *EPU* and a firm's total reported carbon emissions (*LNCO2)*, our findings may suffer from omitted time-invariant variable bias. To mitigate this bias, we controlled for both firm and country fixed effects. The regression results for Models (3) and (4) appear in Table 5. The coefficients of *EPU* are positive and statistically significant ($\beta = 0.031$, p-value<0.05; $\beta = 0.111$ p-value<0.05) after controlling for firm fixed effects and country fixed effects, respectively. We therefore conclude that our findings are robust after controlling for firm-level and country-level omitted time-invariant variable bias.

5. Additional analyses

In our analyses so far, we have found that, as EPU increases, so do the level of carbon emissions. In this section, however, we present three extensions to these baseline results. First, we examine whether the environmental characteristics of the country, industry, or firm moderate the relationship between EPU and carbon emissions. Next, we test how EPU influences carbon emissions through renewable energy. Finally, we analyse how the relationship between EPU and carbon emissions affects firm value.

5.1. Moderating role of country-level characteristics

In this section, we examine the role played by different country-level institutional factors in the association between EPU and carbon emissions. It makes sense that firms in countries with better climate change performance might be under more pressure to invest in activities that reduce emissions (Bose et al., 2021). Therefore, we examined the moderating influence of climate change performance at the country level (*CCPI*), using the Climate Change Performance Index developed by Germanwatch and the Climate Action Network (2019) as a proxy for *CCPI*. The countries were divided into two groups – *HIGH* and *LOW* – based on the annual median of climate change performance *(CCPI)*. We then created an indicator variable that took a value of 1 if that country's *CCPI* score was equal to or higher than the median *(HIGH_CCPI)*, and 0 otherwise *(LOW_CCPI)*. Table 6, Panel A presents the regression results of the sub-sample analysis. As expected, the results show that the impact of EPU on carbon emissions is more pronounced for the *HIGH_CCPI* group ($\beta = 0.168$, p-value<0.01). This finding means that, when faced with high policy uncertainty, firms in these countries are more reluctant to invest in emissions reduction activities despite the need to reduce their carbon emissions.

Prior studies also report that firms in countries with a national emissions trading scheme are often required to reduce their carbon emissions below some industry-specific emission limits imposed by the regulators (Kolk, Levy, & Pinkse, 2008). This consequently increases the costs associated with carbon emissions. Hence, we also examined how national emissions trading schemes (*ETS*) moderate the relationship between EPU and carbon emissions. Again, we established an indicator with a value of 1 if the firm operates in a country that has a national emissions trading scheme, and 0 otherwise (see Appendix C for details on national emissions trading schemes). The regression results, which are reported in Table 6 Panel B, suggest that the positive association between EPU and carbon emissions is more pronounced when a national emissions trading schemes is in place. In other words, any uncertainty in economic policies makes firms reluctant to invest in emissions reduction activities. Consequently, carbon emissions are higher, despite whatever pressure is felt from an emissions trading scheme.

Simnett, Vanstraelen, and Chua (2009) document that a country's business culture has an impact on firm-level sustainability initiatives. Hence, we also examined the moderating role of the underlying business culture of a country in the association between EPU and carbon emissions. Following Ball, Kothari, and Robin (2000), we determined a firm to have a shareholder-oriented business culture when the firms was domiciled in a common law country, and a stakeholder-oriented business culture when the firm was domiciled in a code law country. That said, we coded some countries as 0 even though these countries are not shareholder-oriented (e.g., China). However, excluding these countries did not change the tenor of the results. From the regression results reported in Table 6,

Table 5
Regression results of association between economic policy uncertainty (EPU) and carbon emissions.

	Dependent variable (DV) = Carbon Emissions (*LNCO2*)			
	Model (1)	Model (2)	Model (3)	Model (4)
EPU	0.163***	–	0.031**	0.111**
	(3.689)		(2.245)	(2.033)
SIZE	0.363***	0.362***	0.014	0.348***
	(8.531)	(8.234)	(1.355)	(8.180)
MB	−0.029***	−0.030***	−0.002	−0.029***
	(-3.537)	(-3.573)	(-1.585)	(-3.433)
LEV	−0.047	−0.048	−0.005	−0.032
	(-0.256)	(-0.261)	(-0.110)	(-0.175)
ROA	−1.235***	−1.246***	−0.250**	−1.392***
	(-3.657)	(-3.614)	(-2.364)	(-4.263)
RDINT	−2.632***	−2.625***	−0.282	−2.477***
	(-4.911)	(-4.828)	(-0.988)	(-4.683)
SGROWTH	−0.061	−0.068	0.046**	−0.025
	(-0.597)	(-0.634)	(2.007)	(-0.239)
ENVPERF	−0.000	0.000	0.001***	−0.000
	(-0.058)	(0.015)	(3.708)	(-0.166)
FAGE	0.026**	0.028**	−0.001	0.026**
	(2.222)	(2.374)	(-0.100)	(2.037)
LIQUIDITY	−2.185***	−2.231***	0.003	−2.054***
	(-7.008)	(-7.152)	(0.026)	(-6.316)
CFO	−0.315	−0.326	0.092*	−0.346
	(-1.666)	(-1.627)	(1.653)	(-1.465)
NEW	2.550**	2.528**	−0.320**	2.666***
	(2.760)	(2.734)	(-2.355)	(3.018)
CAPIN	−0.722***	−0.690***	0.120***	−0.780***
	(-5.907)	(-5.666)	(3.309)	(-7.174)
INTANG	0.006	−0.002	0.007	0.007
	(0.247)	(-0.091)	(1.257)	(0.256)
RISK	11.540**	12.477**	0.255	10.869**
	(2.400)	(2.568)	(0.435)	(2.333)
CROSS	0.059*	0.055*	–	0.060**
	(2.054)	(1.806)		(2.250)
LNGDP	0.007	0.009	−0.080**	−0.141
	(0.119)	(0.157)	(-2.441)	(-1.401)
STAKE	−0.097	−0.139**	–	−0.115
	(-1.635)	(-2.094)		(-1.661)
ENFORCE	0.002	0.003	0.014	0.073
	(0.043)	(0.056)	(0.423)	(1.104)
CRI	−0.033	0.009	−0.001	−0.032
	(-1.553)	(0.489)	(-0.122)	(-1.477)
Intercept	−2.914***	−2.345***	0.900**	−1.060
	(-5.673)	(-4.543)	(2.210)	(-0.880)
Year Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	No	Yes
Firm Fixed Effects	No	No	Yes	No
Country Fixed Effects	No	No	No	Yes
Observations	6545	6545	6545	6545
R-squared	0.523	0.520	0.974	0.533
Gujarati (2003) ΔR^2-*F*-statistic (Model 1 vs. Model 2)	32.30***			

Notes: Superscript ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. Numbers in parentheses are *t*-statistics. Definitions of variables are provided in Appendix B.

Panel C, we find the impact of EPU on carbon emissions to be positive and significant in both types of countries, although this relationship is more pronounced for firms operating in a country with a stakeholder-oriented business culture. The probable reason is that stakeholder-oriented countries have fewer investor protection mechanisms in place compared to their counterparts. So, firms in these countries might be reluctant to address any investor risk resulting from carbon emissions by investing in emissions reduction technologies. Thus, carbon emissions will worsen when high levels of uncertainty are present.

5.2. Moderating role of industry- and firm-level characteristics

Prior studies report that firms operating in carbon-intensive industries not only face significant levels of uncertainty and risk, but also that these firms often incur other costs associated with environmental performance, such as clean-up costs, compliance and litigation costs, and damage to the firm's reputation (Bose et al., 2021; Griffin et al., 2017; Matsumura et al., 2014). Consequently, these firms must invest significant amounts in emissions reduction activities. However, policy uncertainty can give firms an incentive

Table 6
Moderating role of country-, industry- and firm-level characteristics.

Panel A: Country-level climate change performance		
	DV = Carbon Emissions (*LNCO2*)	
	HIGH_CCPI	LOW_CCPI
	Model (1)	Model (2)
EPU	0.168***	0.155*
	(4.107)	(1.756)
Intercept	−2.841***	−3.284***
	(-4.641)	(-4.215)
Control Variables	Yes	Yes
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
Observations	4260	2260
R-squared	0.543	0.508
Test of equality of coefficients	0.030	

Panel B: Country-level emissions trading schemes		
	DV = Carbon Emissions (*LNCO2*)	
	ETS	NON-ETS
	Model (1)	Model (2)
EPU	0.174**	0.118
	(2.664)	(1.731)
Intercept	−1.997	−3.191***
	(-1.299)	(-4.644)
Control Variables	Yes	Yes
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
Observations	5260	1285
R-squared	0.556	0.516
Test of equality of coefficients	3.420*	

Panel C: Country-level stakeholder orientation		
	DV = Carbon Emissions (*LNCO2*)	
	STAKEHOLDER	SHAREHOLDER
	Model (1)	Model (2)
EPU	0.194**	0.144**
	(2.995)	(2.926)
Intercept	−4.385**	−3.403***
	(-2.492)	(-5.253)
Control Variables	Yes	Yes
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
Observations	2670	3875
R-squared	0.531	0.577
Test of equality of coefficients	0.580	

Panel D: Industry-level carbon sensitivity		
	DV = Carbon Emissions (*LNCO2*)	
	CSI	NON_CSI
	Model (1)	Model (2)
EPU	0.274**	0.058
	(2.550)	(1.235)
Intercept	−3.127**	−1.963**
	(-2.741)	(-2.777)
Control Variables	Yes	Yes
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes

(*continued on next page*)

Table 6 (*continued*)

Panel D: Industry-level carbon sensitivity		
	DV = Carbon Emissions (*LNCO2*)	
	CSI	NON_CSI
	Model (1)	Model (2)
Observations	2776	3769
R-squared	0.534	0.487
Test of equality of coefficients	13.910***	

Panel E: Research and development (R&D)		
	DV = Carbon Emissions (*LNCO2*)	
	HIGH_RND	LOW_RND
	Model (1)	Model (2)
EPU	0.146***	0.291**
	(3.357)	(2.504)
Intercept	−3.209***	−2.615**
	(-5.351)	(-2.403)
Control Variables	Yes	Yes
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
Observations	5318	1227
R-squared	0.524	0.574
Test of equality of coefficients	3.660*	

Notes: Superscript ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. Numbers in parentheses are *t*-statistics. Definitions of variables are provided in Appendix B.

to avoid or defer such investments. For this reason, we examined the role carbon-sensitive industries play in the relationship between EPU and carbon emissions. Following CDP (2008) classifications, industries classified as carbon-intensive included mining and construction; textiles, printing and publishing; chemicals and pharmaceuticals; extractive; manufacturing; transportation; and utilities as carbon-sensitive industries *(CSI)*, with the remaining industries classified as carbon-non-intensive industries. Table 6, Panel D presents the sub-sample analysis with the regression results confirming that the positive association between EPU and carbon emissions is more pronounced for firms operating in carbon-intensive industries.

Recent studies report that firm-level investment in R&D positively affects environmental performance (e.g., Fei, Rasiah, & Shen, 2014; Lee & Min, 2015). Hence, we made R&D expenditure at the firm our next moderating factor to analyse. We created an indicator with a value of 1 if the firm's R&D expenditure was greater than or equal to the median *(HIGH_RND)*, and 0 otherwise *(LOW_RND)*. Table 6, Panel E presents the sub-sample analysis. The regression results suggest that the positive impact of EPU on carbon emissions is more pronounced for firms spending less on R&D activities. This means that policy uncertainty makes firms are reluctant to invest in innovation that might reduce their carbon emissions. Additionally, the test of equality of coefficients shows a significant (insignificant) difference in the coefficient estimates between the two subsamples for country-level emissions trading schemes (country-level CCPI and business culture), industry-level carbon sensitivity, and firm-level R&D at the 10% level or below.

5.3. *Mediating role of renewable energy*

Beyond these moderating variables alluded to in the literature, we also suspected that investments into renewable energy might modify the relationship between EPU and carbon emissions. To test this conjecture, we followed prior studies that use mediation analysis (e.g., Daradkeh, Shams, Bose, & Gunasekarage, 2023; DeFond, Lim, & Zang, 2016; Pevzner, Xie, & Xin, 2015; Tsang, Xie, & Xin, 2019) and developed the following set of equations to conduct the mediation test:

$$LNCO2_{i,t} = \beta_0 + \beta_1 EPU_{j,t} + \sum Controls_{i,t} + \sum INDUSTRY_{i,t} + \sum YEAR_{i,t} + \varepsilon_{i,t} \quad (2.1)$$

$$LNREN_{i,t} = \gamma_0 + \gamma_1 EPU_{j,t} + \sum Controls_{i,t} + \sum INDUSTRY_{i,t} + \sum YEAR_{i,t} + \varepsilon_{i,t} \quad (2.2)$$

$$LNCO2_{i,t} = \omega 0 + \omega_1 EPU_{j,t} + \omega_2 LNREN_{i,t} + \sum Controls_{i,t} + \sum INDUSTRY_{i,t} + \sum YEAR_{i,t} + \varepsilon_i \quad (2.3)$$

where *LNCO2* is the natural logarithm of carbon emissions in CO_2-e metric tons; *EPU* is the economic policy uncertainty, which is the treatment variable; and *LNREN* is the natural logarithm of the firm's total renewable energy consumption in gigajoules.[4] Other variables are defined in Appendix B.

We note that a variable can be a mediator when three criteria are met. First, the treatment variable is significantly related to the dependent variable. Second, the treatment variable is significantly related to the mediator. Third, that when the impacts of both the treatment and mediator variables are considered together, the impact of the treatment on the dependent variable is weakened, which suggests a significant mediation effect. If the treatment variable is no longer significant when the mediator is controlled for, the finding supports full mediation. If the treatment variable is still significant when the mediator is controlled for, the finding supports partial mediation.

Additionally, in this study, we assume that a firm's investment into renewable energy is reflected by its renewable energy consumption as firms that invest more into renewable energy are likely to consume more renewable energy (e.g., Jia & Li, 2020; Lys, Naughton, & Wang, 2015). Renewable energy includes annual aggregated energy from wind, solar, biomass, small-scale hydro projects, and waste sources, which is consistent with the definition given by the United Nations (2021). As the disclosure of renewable energy consumption is voluntary and not reported by all firms, we followed Atif, Hossain, Alam, and Goergen (2021) to set *LNREN* to 0 if this information was not available.

We begin with Equation (2.1), which examines the overall effect of *EPU* on *LNCO2*, denoted by $\beta 1$. The effect of *EPU* on renewable

Table 7
Mediation regression results of association between economic policy uncertainty (EPU), carbon emissions and renewable energy.

	DV = *LNCO2*	DV = *LNREN*	DV = *LNCO2*
	Model (1)	Model (2)	Model (3)
EPU	0.163***	−0.304***	0.160***
	(5.680)	(-3.100)	(5.596)
LNREN	–	–	−0.008**
			(-2.205)
SIZE	0.363***	0.122***	0.364***
	(40.560)	(3.990)	(40.630)
MB	−0.029***	0.000	−0.029***
	(-9.330)	(0.050)	(-9.335)
LEV	−0.047	−0.246	−0.049
	(-0.720)	(-1.110)	(-0.750)
ROA	−1.235***	−0.031	−1.236***
	(-5.340)	(-0.040)	(-5.343)
RDINT	−2.632***	2.551**	−2.612***
	(-8.930)	(2.530)	(-8.858)
SGROWTH	−0.061	−0.094	−0.062
	(-1.000)	(-0.450)	(-1.016)
ENVPERF	0.000	0.007***	0.000
	(-0.140)	(7.410)	(0.065)
FAGE	0.026**	0.028	0.026***
	(2.570)	(0.800)	(2.592)
LIQUIDITY	−2.185***	0.018	−2.185***
	(-8.920)	(0.020)	(-8.923)
CFO	−0.315***	0.120	−0.314***
	(-4.450)	(0.490)	(-4.437)
NEW	2.550***	0.366	2.553***
	(9.720)	(0.410)	(9.739)
CAPIN	−0.722***	0.318*	−0.719***
	(-13.960)	(1.790)	(-13.908)
INTANG	0.006	−0.006	0.006
	(0.690)	(-0.200)	(0.687)
RISK	11.540***	−4.377	11.505***
	(7.130)	(-0.790)	(7.110)
CROSS	0.059***	0.073***	0.059***
	(7.930)	(2.880)	(8.003)
LNGDP	0.007	−0.270**	0.005
	(0.240)	(-2.530)	(0.170)
STAKE	−0.097***	0.056	−0.096***
	(-3.910)	(0.660)	(-3.897)
ENFORCE	0.002	0.027	0.003
	(0.120)	(0.390)	(0.129)
CRI	−0.033*	0.325***	−0.030
	(-1.640)	(4.710)	(-1.505)
Intercept	−3.451***	1.490	−3.352***
	(-10.230)	(1.290)	(-9.650)
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	6545	6545	6545
R-squared	0.523	0.269	0.523
Mediating effects			
Indirect effect – *LNREN* (Model 3) ×*EPU* (Model 2)		0.002*	
z-statistic for indirect effect – *LNREN*×*EPU*			
Direct effect		0.160***	
Total effect		0.163***	
% of total mediated effect (indirect effect/total effect)		1.50%	

Notes: Superscript ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. Numbers in parentheses are t-statistics. DV = dependent variable. Definitions of variables are provided in Appendix B.

energy (*LNREN)* is captured by $\gamma 1$ in Equation (2.2), whereas $\omega 1$ in Equation (2.3) denotes the direct effect of *EPU* on *LNCO2* after controlling for the mediator variable *LNREN*. We considered *LNREN* to be a mediator if: (a) *EPU* was significantly related to *LNCO2* ($\beta 1 \neq 0$) in Equation (2.1); (b) *EPU* was significantly related to *LNREN* ($\gamma 1 \neq 0$) in Equation (2.2); and (c) *LNREN* was significantly related to *LNCO2* after controlling for *EPU* ($\omega 2 \neq 0$). Once these relationships were established, we needed to test whether the average causal mediation effect was statistically significant. To do so, we used a bootstrapped Sobel–Goodman test (Preacher & Hayes, 2004), which indicates whether a mediator can determine the extent to which a treatment variable influences a dependent variable. This test is useful as we simultaneously ran the three equations, Equations (2.1) – (2.3), to assess the potential links between the variables of interest: EPU, renewable energy and carbon emissions.

Table 7 presents the regression results. Model (1) shows the total effect of *EPU* on carbon emissions. Model (2) reports the effect of *EPU* on renewable energy, and Model (3) identifies the direct effect of *EPU* on carbon emissions after controlling for renewable energy. The results for Model (1) show that the coefficient of *EPU* is statistically significant and positive ($\beta = 0.163$, p-value<0.01), suggesting that *EPU* is positively associated with carbon emissions. Further, the coefficient of *EPU* in Model (2) is negative and statistically significant ($\beta = -0.304$, p-value<0.01), suggesting that *EPU* is negatively associated with the mediator variable, *LNREN*. In Model (3), the coefficient of *LNREN* is negative and statistically significant ($\beta = -0.008$, p-value<0.05), while the coefficient of *EPU* is positive and statistically significant ($\beta = 0.160$, p-value<0.01). However, the *EPU* coefficient has shrunk in size compared to the *EPU* coefficient in Model (1). Moreover, the coefficient of *EPU* is still significant after controlling for the mediator in Model (3), with this indicating partial mediation. Overall, these results show that renewable energy partially mediates the relationship between *EPU* and carbon emissions.

We then tested the statistical significance of the mediation test. The mediation-related statistics are shown at the bottom of Table 6. As the results show, the direct and total effects of *EPU* on carbon emissions are 0.160 and 0.163, respectively. The indirect effect, as shown through the mediation, is negative and statistically significant ($\beta = 0.002$, p-value<0.10) and the mediated portion of *LNREN* attributed to *EPU* is 1.50% of the total effect. Fig. 1 presents these results graphically. Although the mediation effect is smaller, the results indicate that investments into renewable energy weakens the effect that policy uncertainty has on carbon emissions at the firm level. This is consistent with our arguments on the 'real options to delay'.

6. Does economic policy uncertainty affect firm valuations through carbon emissions? (H2)

To test the second hypothesis (H2), we developed the following set of equations to conduct the mediation test:

$$TOBINQ_{i,t+1} = \beta_0 + \beta_1 EPU_{j,t} + \sum Controls_{i,t} + \sum INDUSTRY_{i,t} + \sum YEAR_{i,t} + \varepsilon_{i,t} \tag{3.1}$$

$$LNCO2_{i,t} = \gamma_0 + \gamma_1 EPU_{j,t} + \sum Controls_{i,t} + \sum INDUSTRY_{i,t} + \sum YEAR_{i,t} + \varepsilon_{i,t} \tag{3.2}$$

$$TOBINQ_{i,t+1} = \omega 0 + \omega_1 EPU_{j,t} + \omega_2 LNCO2_{i,t} + \sum Controls_{i,t} + \sum INDUSTRY_{i,t} + \sum YEAR_{i,t} + \varepsilon_i \tag{3.3}$$

where *TOBINQ* is Tobin's Q and is used to measure firm value; *LNCO2* is the natural logarithm of the carbon emissions; and *EPU* is economic policy uncertainty, which is the treatment variable. Other variables are defined in Appendix B.

Beginning with Equation (3.1), the impact of *EPU* on *TOBINQ* is captured by $\beta 1$ in Equation (3.1), whereas $\omega 1$ in Equation (3.3) denotes the direct effect of *EPU* on *TOBINQ* after controlling for the mediator variable *LNCO2*. We considered *LNCO2* to be a mediator if: (a) *EPU* was significantly related to *TOBINQ* ($\beta 1 \neq 0$) in Equation (3.1); (b) *EPU* was significantly related to *LNCO2* ($\gamma 1 \neq 0$) in Equation (3.2); and (c) *LNCO2* was significantly related to *TOBINQ* after controlling for *EPU* ($\omega 2 \neq 0$). We again employed the bootstrapped Sobel–Goodman test (Preacher & Hayes, 2004) to evaluate whether the average causal mediation effect was statistically significant.

Table 8, Models (1)–(3) show the mediating role of carbon emissions in the association between *EPU* and *TOBINQ*. The coefficient of *EPU* in Model (1) is negative and statistically significant ($\beta = -0.149$, p-value<0.01), suggesting that *EPU* is negatively associated with *TOBINQ*. This result for this international sample of firms is consistent with Yang et al. (2019) who performed the same estimation with a sample of Chinese firms, as well as with Iqbal et al. (2020) who used US firms. Furthermore, the coefficient of *EPU* in Model (2) is positive and statistically significant ($\beta = 0.185$, p-value<0.01), highlighting that *EPU* is positively associated with the mediator variable *LNCO2*. In Model (3), the coefficient of *LNCO2* is negative and statistically significant ($\beta = -0.209$, p-value<0.01), while the coefficient of *EPU* is also negative and statistically significant ($\beta = -0.110$, p-value<0.01). However, the *EPU* coefficient has shrunk in size compared to the *EPU* coefficient in Model (1), and the size of the *LNCO2* coefficient is larger. Further, the coefficient of *EPU* is still

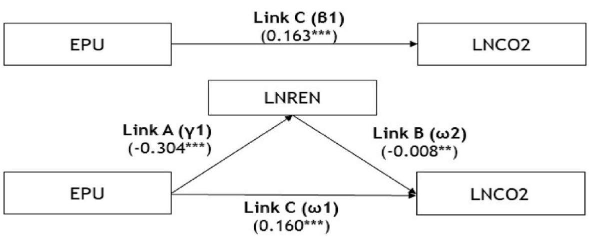

Fig. 1. Paths between carbon emissions, renewable energy and EPU.

significant after controlling for the mediator in Model (3), with partial mediation indicated here. Overall, these results point to the mediating role of carbon emissions in the relationship between *EPU* and *TOBINQ*.

We then tested the statistical significance of the mediation test, reporting the mediation-related statistics at the bottom of Table 8. The direct and total effects of *EPU* on *TOBINQ* are −0.149 and −0.110, respectively. Finally, the mediation effect (i.e., the indirect effect) is negative and statistically significant ($\beta = -0.039$, p-value<0.01), with the mediated portion of *TOBINQ* attributed to *EPU* being 25.92% of the total effect. Hence, H2 is supported: carbon emissions do mediate the relationship between EPU and firm value. Fig. 2 presents these results graphically.

7. Robustness analyses

7.1. Heckman's (1979) Two-stage analysis

Given that firms voluntarily disclose carbon emissions information to the Carbon Disclosure Project (CDP), the main results, as presented in Table 5, could suffer from self-selection bias. It is possible that these firms differ in some systemic way to those firms who do not disclose this information. For this reason, we tested Equation (1) with Heckman's (1979) two-stage analysis. The first stage models a firm's decision to report carbon emissions to the CDP, for which we augmented our sample with firms choosing not to disclose data to the CDP over the sample period. The following model was used for the first-stage probit regression and to generate the inverse Mills ratio (*IMR*):

$$Pr\ (DISC\_CDP=1)_{i,t} = \beta_0 + \beta_1 PROPDISCL_{i,t} + \beta_2 DISC\_CDP\_LAG_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 ROA + \beta_5 MB_{i,t} + \beta_6 LEV_{i,t} + \beta_7 FAGE_{i,t} + \beta_8 FOREIGN_{i,t} + \beta_9 CAPIN_{i,t} + \beta_{10} RISK_{i,t} + \beta_{11} INSTOWN_{i,t} + \beta_{12} ANALYST_{i,t} + \beta_{13} ENVPERF_{i,t} + \beta_{14} LNGDP_{i,t} + \beta_{15} CRI_{i,t} + \beta_{16} STAKE_{i,t} + \beta_{17} ENFORCE_{i,t} + \sum Year_{i,t} + \sum Industry_{i,t} + \varepsilon_{i,t} \quad (4)$$

In Equation (4), the dependent variable, *DISC_CDP*, is a dummy variable coded to 1 if the firm disclosed carbon emissions information to the CDP, and 0 if it did not. We selected the independent variables following the prior literature on CDP disclosures (Daradkeh et al., 2023; Matsumura et al., 2014). We also included two variables to satisfy exclusion restrictions in the first-stage analysis, as stated in Equation (4): *PROPDISCL* and *DISC_CDP_LAG*. Following Daradkeh et al. (2023), *PROPDISCL* reflects industry pressure to disclose carbon emissions information to the CDP. We therefore measured *PROPDISCL* as the proportion of firms in an industry that disclose carbon emissions information to the CDP and expect a positive sign for its coefficient. *DISC_CDP_LAG* captures the disclosure of carbon emissions information in the previous year as a firm's decision to disclose carbon emissions information to the CDP tends to be sticky. We also expect a positive sign for this coefficient. Appendix B provides definitions of all the variables.

Table 9, Panel A reports the regression results of the first-stage model. We find that, as expected, the coefficients of *PROPDISC* and *DISC_CDP_LAG* are statistically significant and positive. The model has a pseudo-R^2 value of 73.50% and partial R^2 values (unreported) for *PROPDISC* and *DISC_CDP_LAG* of 9.86% and 51.20%, respectively, which are statistically significant at the 1% level. Hence, these results support *PROPDISC* and *DISC_CDP_LAG* as reasonably exogenous variables. Table 9, Panel B, Model (1) shows the second-stage regression results. The coefficient of *EPU* is statistically significant and positive ($\beta = 0.165$, p-value<0.01), while the coefficient of the inverse Mills ratio (*IMR*) is statistically insignificant, suggesting that sample selection bias is not a significant concern. We find similar results using both firm- and country-fixed effects, as reported in Table 9, Panel B, Models (2) and (3).

7.2. Alternative specifications and proxies

In our main analysis, we examined the contemporaneous associations between EPU and carbon emissions. To test for robustness, we examined the impact of policy uncertainty in previous years on the current year's carbon emissions. More specifically, we examined the effects of the previous three years' EPU on the current year's carbon emissions. Table 10, Panel A reports the regression results. Model (1) reports the one-year lag of EPU, while Models (2) and (3) report the two- and three-year lags, respectively. The *EPU* coefficient is positive and statistically significant, confirming the robustness of the results in Table 5.

We also use carbon emissions intensity *(CO2TR)* as an alternative measure, with this considered to be a relative measure of carbon emissions. Carbon emissions intensity *(CO2TR)* is computed as the total amount of carbon emissions scaled by a firm's total sales revenue. Table 10, Panel B reports the regression results from Models (1)–(3). The *EPU* coefficients are again statistically significant and positive across all specifications of the regression models except for Model (1), thus corroborating our main findings.

Further, we tested industry-adjusted carbon emissions as another proxy of carbon emissions. More specifically, we computed the industry–year median of carbon emissions within a country and deducted that from total carbon emissions produced by each firm. Table 10, Panel C, Models (1)–(4) report the regression results. The coefficients of *EPU* are positive and statistically significant across all models, corroborating our main findings that EPU increases the level of carbon emissions.

7.3. Analysing the US effect

Our sample is dominated by firms from the US (29.53%), and, interestingly, data on the individual components of policy uncertainty, i.e., news stories, government spending, the consumer price index [CPI], and tax components, are available for US firms. This gave us the opportunity to test the impact of various components of policy uncertainty on firm-level carbon emissions. Table 11 reports the regression results, with Model (1) showing the impact of overall EPU while Models (2)–(5) estimate the effects of the four

Table 8
Mediation regression results of association between economic policy uncertainty (EPU), carbon emissions and firm valuation.

	DV = *TOBINQ*	DV = *LNCO2*	DV = *TOBINQ*
	Model (1)	Model (2)	Model (3)
EPU	−0.149***	0.185***	−0.110***
	(-5.400)	(6.320)	(-4.088)
LNCO2	–	–	−0.209***
			(-18.312)
SIZE	0.117***	0.336***	0.187***
	(13.720)	(37.140)	(20.440)
LEV	0.268***	−0.063	0.255***
	(4.370)	(-0.970)	(4.261)
ROA	7.124***	−3.016***	6.494***
	(41.530)	(-16.580)	(38.016)
SGROWTH	0.098*	−0.074	0.082
	(1.670)	(-1.190)	(1.441)
ENVPERF	−0.001***	90.001	−0.001***
	(-2.900)	(-0.180)	(-3.016)
DIVIDEND	−0.224***	0.090***	−0.205***
	(-7.280)	(2.770)	(-6.829)
FAGE	−0.019**	0.028***	−0.013
	(-1.980)	(2.770)	(-1.398)
NEW	−0.396***	−0.060	−0.409***
	(-6.020)	(-0.860)	(-6.364)
CAPIN	−0.565**	1.909***	−0.166
	(-2.380)	(7.580)	(-0.711)
INTANG	−0.145***	−0.680***	−0.287***
	(-2.910)	(-12.870)	(-5.838)
LIQUIDITY	−0.052***	0.007	−0.051***
	(-5.930)	(0.750)	(-5.914)
RISK	8.119***	10.149***	10.241***
	(5.170)	(6.090)	(6.664)
CROSS	−0.035***	0.066***	−0.022***
	(-4.980)	(8.710)	(-3.105)
LNGDP	0.059**	−0.042	0.050*
	(1.970)	(-1.320)	(1.724)
STAKE	−0.422***	−0.007	−0.423***
	(-18.160)	(-0.280)	(-18.682)
ENFORCE	−0.095***	0.037*	−0.087***
	(-4.750)	(1.770)	(-4.466)
CRI	−0.013	−0.033	−0.020
	(-0.650)	(-1.630)	(-1.032)
Intercept	0.938***	−3.352***	0.237
	(2.860)	(-9.650)	(0.737)
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	6545	6545	6545
R-squared	0.482	0.501	0.507
Mediating effects			
Indirect effect – *LNCO2* (Model 3) × *EPU* (Model 2)		−0.039***	
z-statistic for indirect effect – *LNCO2* × *EPU*		(-6.190)	
Direct effect		−0.110***	
Total effect		−0.149***	
% of total mediated effect		25.92%	

Notes: Superscript ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. Numbers in parentheses are *t*-statistics. Indirect effect z-statistic is bootstrap standard error adjusted. DV = dependent variable. Definitions of variables are provided in Appendix B.

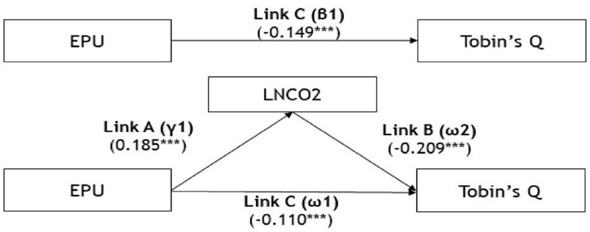

Fig. 2. Paths between carbon emissions, EPU and firm valuation.

Table 9
Heckman's (1979) two-stage model analysis of association between economic policy uncertainty (EPU) and carbon emissions.

Panel A: Heckman's (1979) first-stage probit regression results

	DV = CDP response (*DISC_CDP*)		
	Coefficient	*z*-stat	*p*-value
PROPDISCL	3.013	22.038	0.000
DISC_CDP_LAG	2.737	54.127	0.000
SIZE	0.179	6.862	0.000
ROA	−0.004	−0.094	0.925
MB	0.000	−1.007	0.314
LEV	0.374	2.494	0.013
FAGE	−0.018	−0.669	0.504
FOREIGN	0.217	3.381	0.001
CAPIN	0.318	0.844	0.399
RISK	0.714	0.288	0.774
INSTOWN	0.145	1.652	0.099
ANALYST	0.064	1.524	0.128
ENVPERF	0.008	9.352	0.000
LNGDP	−0.008	−0.100	0.921
CRI	−0.049	−1.083	0.279
STAKE	0.037	0.600	0.549
ENFORCE	0.041	0.704	0.482
Intercept	−4.712	−5.835	0.000
Year Fixed Effects		Yes	
Industry Fixed Effects		Yes	
Observations		12,470	
Pseudo *R*-squared		0.735	
Log likelihood		−2288.83	

Panel B: Heckman's (1979) second-stage regression results

	DV = Carbon Emissions (*LNCO2*)		
	Model (1)	Model (2)	Model (3)
EPU	0.165***	0.124***	0.124**
	(3.683)	(2.837)	(2.053)
SIZE	0.362***	0.344***	0.344***
	(8.794)	(32.488)	(8.471)
MB	−0.030***	−0.030***	−0.030***
	(-3.783)	(-10.434)	(-3.669)
LEV	−0.072	−0.055	−0.055
	(-0.396)	(-0.781)	(-0.301)
ROA	−1.273***	−1.419***	−1.419***
	(-3.921)	(-6.218)	(-4.448)
RDINT	−2.669***	−2.516***	−2.516***
	(-4.909)	(-11.725)	(-4.660)
SGROWTH	−0.061	−0.025	−0.025
	(-0.617)	(-0.392)	(-0.249)
ENVPERF	−0.000	−0.000	−0.000
	(-0.021)	(-0.429)	(-0.173)
FAGE	0.022	0.021**	0.021
	(1.660)	(2.098)	(1.419)
LIQUIDITY	−2.184***	−2.003***	−2.003***
	(-6.839)	(-8.159)	(-5.651)
CFO	−0.329*	−0.354***	−0.354
	(-1.840)	(-4.541)	(-1.562)
NEW	2.635**	2.728***	2.728***
	(2.825)	(9.357)	(3.068)
CAPIN	−0.698***	−0.749***	−0.749***
	(-5.407)	(-14.601)	(-6.496)
INTANG	0.009	0.009	0.009
	(0.327)	(0.793)	(0.302)
RISK	10.699**	10.244***	10.244**
	(2.003)	(5.398)	(2.015)
CROSS	0.057**	0.059***	0.059**
	(2.062)	(7.273)	(2.285)
LNGDP	0.014	−0.108	−0.108
	(0.217)	(-1.019)	(-1.053)
STAKE	−0.093	–	–
	(-1.586)		
ENFORCE	0.009	0.073	0.073

(*continued on next page*)

Table 9 (*continued*)

Panel B: Heckman's (1979) second-stage regression results

	DV = Carbon Emissions (*LNCO2*)		
	Model (1)	Model (2)	Model (3)
	(0.161)	(0.755)	(0.837)
CRI	−0.038*	−0.035	−0.035
	(-1.823)	(-1.446)	(-1.555)
IMR	0.034	0.021	0.021
	(0.981)	(0.732)	(0.559)
Intercept	−2.951***	−1.346	−1.346
	(-5.769)	(-1.129)	(-1.142)
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	No	Yes
Firm Fixed Effects	No	Yes	No
Country Fixed Effects	No	No	Yes
Observations	6290	6290	6290
R-squared	0.524	0.974	0.534

Notes: Superscript ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. Numbers in parentheses are *t*-statistics. Definitions of variables are provided in Appendix B.

Table 10
Alternative specifications of economic policy uncertainty (EPU) and proxies of carbon emissions.

	Panel A: DV= Carbon emissions (*LNCO2*)			Panel B: DV = Carbon emissions (*CO2TR*)			Panel C: DV = Industry-adjusted carbon emissions			
	One-year lag EPU	Two-year lag EPU	Three-year lag EPU	Current year EPU	Current year EPU	Current year EPU	Current year EPU	One-year lag EPU	Two-year lag EPU	Three-year lag EPU
	Model (1)	Model (2)	Model (3)	Model (1)	Model (2)	Model (3)	Model (1)	Model (2)	Model (3)	Model (4)
EPU	0.136**	0.131**	0.114*	0.036	0.042*	0.063**	0.143***	0.117**	0.160***	0.137***
	(2.828)	(2.280)	(1.902)	(1.052)	(1.859)	(2.329)	(3.157)	(2.660)	(4.442)	(3.043)
Intercept	−2.827***	−2.876***	−2.788***	−0.154	0.652	0.630	−1.240	−1.155	−1.403	−1.344
	(-5.567)	(-5.182)	(-5.289)	(-0.674)	(1.611)	(1.210)	(-1.650)	(-1.388)	(-1.676)	(-1.564)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	No	No	No	No	Yes	No	No	No	No	No
Country Fixed Effects	No	No	No	No	No	Yes	No	No	No	No
Observations	6543	6539	6388	6545	6545	6545	6545	6543	6539	6388
R-squared	0.521	0.521	0.527	0.418	0.922	0.433	0.201	0.200	0.201	0.201

Notes: Superscript ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. Numbers in parentheses are *t*-statistics. Definitions of variables are provided in Appendix B.

components listed above. The results confirm that the overall *EPU* coefficients and the four different components are positive and statistically significant with the exception of tax components. Overall, we find that the different components positively affect carbon emissions, therefore corroborating the main results from the full sample.

7.4. Alternative samples

Beyond the US (29.53%), our sample also includes a high proportion of firms from Japan (15.03%) and the UK (14.55%). To confirm that our study's findings are not influenced by any specific country, we re-ran our baseline regression models after excluding each of the following groups, one at a time: (1) US firms; (2) Japanese firms; (3) UK firms; and (4) firms in countries with less than 10, 20, 30, 50 and 100 observations. We have not reported the regression results here for the sake of brevity. However, the untabulated results indicate that the tenor of our findings remains unchanged. In addition, we also used weighted least squares (WLS) as an alternative model specification to confirm that our findings were not influenced by an uneven distribution of observations across countries. This involves treating a country's weight as equal to the number of observations for that country. The un-tabulated results again suggest that our findings remain robust.

Table 11
Regression results of association between economic policy uncertainty (EPU) and carbon emissions for US firms.

	DV = Carbon emissions (*LNCO2*)				
	Overall Index	News component	Gov. Spending component	CPI component	Tax component
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
EPU	0.463*	0.470**	0.348*	0.333**	−0.001
	(1.883)	(2.025)	(1.921)	(2.072)	(-0.023)
SIZE	0.351***	0.352***	0.351***	0.351***	0.351***
	(9.814)	(9.818)	(9.802)	(9.805)	(9.805)
MB	−0.016***	−0.017***	−0.017***	−0.016***	−0.017***
	(-3.091)	(-3.092)	(-3.111)	(-3.083)	(-3.095)
LEV	−0.088	−0.088	−0.089	−0.089	−0.085
	(-0.484)	(-0.482)	(-0.487)	(-0.486)	(-0.463)
ROA	−1.545***	−1.551***	−1.542***	−1.539***	−1.531***
	(-3.082)	(-3.101)	(-3.074)	(-3.066)	(-3.059)
RDINT	−1.510***	−1.521***	−1.510***	−1.510***	−1.518***
	(-2.632)	(-2.654)	(-2.645)	(-2.639)	(-2.665)
SGROWTH	−0.207	−0.205	−0.203	−0.210	−0.206
	(-1.602)	(-1.592)	(-1.576)	(-1.622)	(-1.597)
ENVPERF	−0.001	−0.001	−0.001	−0.001	−0.001
	(-0.568)	(-0.565)	(-0.564)	(-0.565)	(-0.561)
FAGE	0.025	0.025	0.025	0.025	0.025
	(0.781)	(0.775)	(0.771)	(0.768)	(0.779)
LIQUIDITY	−2.274***	−2.276***	−2.256***	−2.272***	−2.268***
	(-3.501)	(-3.504)	(-3.470)	(-3.495)	(-3.488)
CFO	−0.231	−0.237	−0.223	−0.228	−0.230
	(-0.823)	(-0.844)	(-0.790)	(-0.811)	(-0.817)
NEW	3.752***	3.752***	3.745***	3.755***	3.744***
	(4.211)	(4.209)	(4.200)	(4.210)	(4.194)
CAPIN	−0.806***	−0.810***	−0.803***	−0.805***	−0.806***
	(-5.140)	(-5.165)	(-5.113)	(-5.131)	(-5.136)
INTANG	0.061**	0.062**	0.060**	0.061**	0.061**
	(2.345)	(2.362)	(2.307)	(2.326)	(2.344)
RISK	−4.080	−4.210	−3.844	−3.952	−3.968
	(-0.957)	(-0.987)	(-0.905)	(-0.929)	(-0.931)
Intercept	−3.712***	−3.711***	−3.137***	−3.214***	−1.729***
	(-3.269)	(-3.451)	(-3.836)	(-3.944)	(-4.637)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	No	Yes	Yes
Observations	1933	1933	1933	1933	1933
R-squared	0.692	0.692	0.692	0.692	0.692

Notes: Superscript ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. Numbers in parentheses are *t*-statistics. Definitions of variables are provided in Appendix B.

8. Conclusion

In this paper, we examined how the uncertainty surrounding economic policies influences carbon emissions at the firm level using 6545 firm-year observations from 22 countries over the period 2007 to 2018. The results indicate that firms in countries with high levels of policy uncertainty emit more carbon, with investment in renewable energy weakening this relationship. Such an examination is new in this research area. And yet, beyond novelty, this research makes an important contribution to the field because of the joint decisions firms are facing in the transition to a low carbon economy. In addition, this study highlights the previously unexplored negative consequences that not reducing emissions due to policy uncertainty has on firm value.

The study's findings yield important implications for investors, regulators, and management, given the unprecedented global attention given to policies on climate change and carbon emissions at the firm level. Our work focuses on an important country-level factor, that being the role of economic policy uncertainty in driving a firm's carbon footprint. The insights revealed should be highly beneficial to retail and institutional investors and their understanding of the effects of sustainability on a firm's value. Moreover, our findings should be of interest to regulators attempting to manage the uncertainty surrounding their policies as they encourage firms to adopt climate change strategies. Governments and policy makers must create environments conducive to firms acting to reverse the effects of climate change, such as shifting from fossil fuel to renewable energy in their production processes. Uncertainty around government economic policies only adds further damage the environment. Finally, our findings may be of interest to managers as they tackle the risks and opportunities associated with climate change. This may be the most important item on the agenda for businesses facing the dilemma of 'doing well by doing good'. Specifically, our insights should encourage managers to play the long game of investing in carbon reduction mechanisms so as to maintain firm value over the long term.

As with other research, this study has some limitations. We examined 22 countries for which EPU data were available. Future research could extend the sample by including more countries to validate our findings. We used carbon emissions information that is voluntarily disclosed by firms to CDP; thus, firms that have not responded to the CDP questionnaire were excluded from our sample. While we took steps to minimise self-selection bias and endogeneity concerns, future research could investigate a larger data sample gathered via other communication channels. Despite these limitations, our findings contribute to the emerging body of literature on EPU and carbon emissions by investigating the potential causes of firm reluctance to invest in emissions reduction initiatives and their subsequent effects on firm valuation.

Data availability

Data will be made available on request.

Appendix. A Summary of studies on EPU and carbon emissions

No.	Authors (Year)	Research question	Theory	Period	Sample	Country	Method	Findings
Panel A: Single country studies								
1	Jiang et al. (2019)	Does EPU matter for carbon emissions?	Real options theory, social-political theory, signal transmission theory	1985–2017	Country level, 391 observations	US	Granger causality in quantiles	EPU significantly influences carbon emissions when the growth of carbon emissions is in a higher or lower growth period.
2	Wang et al. (2020)	To examine the effects of EPU on the level of carbon emissions	Environmental Kuznets curve (EKC) theory	1960–2016	Country level, yearly data	US	Autoregressive-distributed lag (ARDL) model	EPU is positively associated with carbon emissions over the long term.
3	Adedoyin and Zakari (2020)	To examine the role of EPU in the relationship between energy consumption and carbon emissions.	Environmental Kuznets curve (EKC) theory	1985–2017	Country level, 33 observations	UK	ARDL model and Granger causality	EPU decreases carbon emissions in the short term but increases them over the long term, with one-way causality running from carbon emissions to EPU.
4	Abbasi and Adedoyin (2021)	Do energy use and EPU affect carbon emissions?	Environmental Kuznets curve (EKC) hypothesis	1970–2018	Country level, not available (N/A)	China	Dynamic ARDL model	EPU positively but insignificantly influences carbon emissions.
5	Yu et al. (2021)	How EPU affects the emission intensity of manufacturing firms	Real options to delay	2008–2011	86,071 firms in 2008 to 196,620 in 2011	China	Fixed effects regression	Provincial EPU increases firm-level carbon intensity through the channels of fuel mix and energy intensity.
6	Syed and Bouri (2022)	To examine the impact of EPU on carbon emissions.	Environmental Kuznets curve (EKC) hypothesis	1985–2019	Country level, monthly data	US	Bootstrap ARDL model	EPU increases carbon emissions and worsens environmental conditions in the short term but decreases carbon emissions and improves environmental quality over the long term.

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No.	Authors (Year)	Research question	Theory	Period	Sample	Country	Method	Findings
7	Liu and Zhang (2022)	How does EPU affect carbon emissions?	Real options theory and environmental Kuznets curve (EKC) hypothesis	2003–2017	Country level, 450 observations	Regional China	Fixed effects regression	EPU has a negative effect on carbon emissions, but this effect is insignificant for the central and western regions of China.
Panel B: Cross-country studies								
8	Pirgaip and Dinçergök (2020)	To explore the causal relationships between EPU, energy consumption and carbon emissions.	Environmental Kuznets curve (EKC) theory	1998–2018	Country level, N/A	G7 countries	Bootstrap Granger causality	Different causality relationships for different G7 countries. For example, unidirectional causality runs from EPU (carbon emissions) to carbon emissions (EPU) in Canada, Germany and the US (Italy).
9	Adams et al. (2020)	To examine the effect of energy consumption, EPU and geopolitical risks on carbon emissions.	Environmental Kuznets curve (EKC) theory	1996–2017	Country level, yearly data	10 resource-rich countries	Pooled mean group–autoregressive distributed lag (PMG-ARDL) model, and Dumitresu–Hurlin (DH) causality	EPU is significantly associated with carbon emissions in the long term, with bi-directional causality between EPU and carbon emissions.
10	Zakari, Adedoyin, and Bekun (2021)	To investigate the impact of energy use and EPU on carbon emissions.	Delayed consumption and environmental Kuznets curve (EKC) hypothesis	1985–2017	Country level, yearly data	22 OECD countries	PMG-ARDL model	EPU has a positive impact on carbon emissions, with one-way causality between carbon emissions and EPU.
11	Anser et al. (2021)	To explore the impact of EPU on carbon emissions in the top ten carbon emitter countries.	Environmental Kuznets curve (EKC) hypothesis; consumption hypothesis vs. investment hypothesis	1990–2015	Country level, yearly data	10 top carbon-emitting countries	PMG-ARDL model	EPU decreases carbon emissions in the short term but increases them over the long term.
12	Iqbal, Chand and Ul Haq (2023)	To explore the impact of EPU on carbon emissions	Real options to delay	2000–2021	Country-level, yearly data	US, UK, China, Pakistan and India	ARDL model	Economic growth and policy uncertainty contribute to increasing levels of carbon emissions
13	Benlemlih and Yavaş (2023)	To examine the relationship between EPU and carbon emissions	Regulatory and risk management perspective	2004–2019	1436 listed firms	23 countries	Fixed effects regression	EPU increases carbon emissions at the firm level, with this effect moderated by the board and country characteristics

Appendix B. Definitions of variables

Variables		Explanation
Panel A: Dependent variables		
CO2	Carbon emissions	Total carbon emissions in CO_2-e metric tons.
LNCO2	Carbon emissions	The natural logarithm of total carbon emissions in CO_2-e metric tons.
CO2TR	Carbon emissions intensity	Total carbon emissions in CO_2-e metric tons scaled by total revenue.
Panel B: Independent variables		
EPU_TOTAL	Economic policy uncertainty	Twelve (12) monthly average of economic policy uncertainty.
EPU	Economic policy uncertainty	The natural logarithm of the monthly average of economic policy uncertainty.
Panel C: Additional variables of interest		
LNREN	Renewable energy	The natural logarithm of the total amount of renewable energy consumption.
TOBINQ	Firm value	The sum of the market value of common equity plus the book value of total debt scaled by total assets.
Panel C: Firm-level variables		
SIZE	Firm size	The natural logarithm of the market value of equity.
MB	Market-to-book	The ratio of market value to book value of equity.
LEV	Leverage	The ratio of total debt scaled by total assets.
ROA	Profitability	The ratio of net profit before extraordinary items scaled by total assets.
SGROWTH	Sales growth	Growth of sales revenue.
ENVPERF	Environmental performance	The environmental pillar score from the ASSET4 database.
FAGE	Firm age	The natural logarithm of the total number of years since the firm first appeared in the Worldscope database.
CFO	Cash flow	The ratio of cash flow from operations to total assets.
NEW	Asset newness	The ratio of net property, plant and equipment to gross property, plant and equipment.
CAPIN	Capital intensity	Capital expenditure scaled by total revenue.
INTANG	Intangible	The ratio of total intangible assets to total assets.
LIQUIDITY	Share turnover	The average monthly trading volume relative to total shares outstanding.
RISK	Firm risk	The standard deviation of daily stock returns over the years.
CROSS	Cross listing	The number of stock exchanges where the firm is listed.
DISC_CDP	CDP response	An indicator variable taking the value of 1 if the firm responds to the CDP questionnaire, and 0 otherwise.
PROPDISCL	Industry pressure	The ratio of the number of firms with publicly available CDP responses to the total number of firms in an industry.
DISC_CDP_LAG	Prior year's CDP response	An indicator variable taking the value of 1 if the firm responds to the CDP questionnaire in the last year, and 0 otherwise.
INSTOWN	Institutional investor	The percentage of ownership held by institutional owners.
ANALYST	Analysts' coverage	The natural logarithm of the total number of analysts covering a firm.
RDINT	Research and development	Total research and development (R&D) expenditure divided by total revenue.
CSI	Carbon-sensitive industry	An indicator variable that takes a value of 1 if the firm operates in a carbon-sensitive industry, and 0 otherwise.
Panel D: Country-level variables		
LNGDP	Gross domestic product	The natural logarithm of the gross domestic product (GDP) per capita.
CRI	Climate change risk	The country-level Global Climate Change Risk Index score from Germanwatch & Climate Action Network (2019). A higher score indicates lower country-level global climate change risk.
ENFORCE	Enforcement	The principal component of "rule of law", "regulatory quality" and "control of corruption" variables derived from the Worldwide Governance Indicators (World Bank, 2020).
STAKE	Stakeholder orientation	An indicator variable taking the value of 1 if the firm operates in a code law country, and 0 otherwise.
ETS	Emissions trading scheme	An indicator variable taking the value of 1 if the firm operates in a country participating in a national ETS, and 0 otherwise.
CCPI	Climate change performance	Country-level Climate Change Performance Index score from Germanwatch & Climate Action Network (2019). A higher CCPI score indicates higher country-level climate change performance.

Appendix C. National emissions trading schemes (ETSs)

Country	Name of Scheme	Implementation year	Scope
Australia	Carbon pricing mechanisms	2012, 2013	National
Brazil	–	–	–
Canada	Québec Cap-and-Trade System	2012	Regional
Chile	–	–	–
China	Shenzhen pilot system	2013	Regional
Colombia	–	–	–

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Country	Name of Scheme	Implementation year	Scope
France	European Union (EU) ETS	2005	National
Germany	EU ETS	2005	National
Greece	EU ETS	2005	National
India	–	–	–
Ireland	EU ETS	2005	National
Italy	EU ETS	2005	National
Japan	Tokyo Cap-and-Trade Program	2010	Regional
Mexico	–	–	–
Netherlands	EU ETS	2005	National
Russia	–	–	–
Singapore	–	–	–
South Korea	Korea Emissions Trading Scheme	2015	National
Spain	EU ETS	2005	National
Sweden	EU ETS	2005	National
United Kingdom	EU ETS	2005	National
United States	California Emissions Trading Scheme	2013	Regional
	Regional Greenhouse Gas Initiative (RGGI)	2009	Regional

References

Abbasi, K. R., & Adedoyin, F. F. (2021). Do energy use and economic policy uncertainty affect CO_2 emissions in China? Empirical evidence from the dynamic ARDL simulation approach. *Environmental Science and Pollution Research, 28*(18), 23323–23335.

Abdouli, M., & Hammami, S. (2017). Investigating the causality links between environmental quality, foreign direct investment and economic growth in MENA countries. *International Business Review, 26*(2), 264–278.

Adams, S., Adedoyin, F., Olaniran, E., & Bekun, F. V. (2020). Energy consumption, economic policy uncertainty and carbon emissions: Causality evidence from resource rich economies. *Economic Analysis and Policy, 68*, 179–190.

Adedoyin, F. F., & Zakari, A. (2020). Energy consumption, economic expansion, and CO_2 emission in the UK: The role of economic policy uncertainty. *The Science of the Total Environment, 738*, Article 140014.

Ameer, R., & Othman, R. (2012). Sustainability practices and corporate financial performance: A study based on the top global corporations. *Journal of Business Ethics, 108*(1), 61–79.

Anser, M. K., Apergis, N., & Syed, Q. R. (2021). Impact of economic policy uncertainty on CO_2 emissions: Evidence from top ten carbon emitter countries. *Environmental Science and Pollution Research, 28*(23), 29369–29378.

Atif, M., Hossain, M., Alam, M. S., & Goergen, M. (2021). Does board gender diversity affect renewable energy consumption? *Journal of Corporate Finance, 66*, 1–29.

Baker, S. R., Bloom, N., & Davis, S. J. (2016). Measuring economic policy uncertainty. *Quarterly Journal of Economics, 131*(4), 1593–1636.

Ball, R., Kothari, S. P., & Robin, A. (2000). The effect of international institutional factors on properties of accounting earnings. *Journal of Accounting and Economics, 29*(1), 1–51.

Barnett, M. L., & Salomon, R. M. (2006). Beyond dichotomy: The curvilinear relationship between social responsibility and financial performance. *Strategic Management Journal, 27*(11), 1101–1122.

Bekhet, H. A., & Othman, N. S. (2017). Impact of urbanization growth on Malaysia CO_2 emissions: Evidence from the dynamic relationship. *Journal of Cleaner Production, 154*, 374–388.

Benlemlih, M., & Yavaş, Ç. V. (2023). Economic policy uncertainty and climate change: Evidence from CO_2 emission. *Journal of Business Ethics*, 1–27.

Bernanke, B. S. (1983). Irreversibility, uncertainty, and cyclical investment. *Quarterly Journal of Economics, 98*(1), 85–106.

Blyth, W., Bradley, R., Bunn, D., Clarke, C., Wilson, T., & Yang, M. (2007). Investment risks under uncertain climate change policy. *Energy Policy, 35*(11), 5766–5773.

Bonaime, A., Gulen, H., & Ion, M. (2018). Does policy uncertainty affect mergers and acquisitions? *Journal of Financial Economics, 129*(3), 531–558.

Busch, T., & Lewandowski, S. (2018). Corporate carbon and financial performance: A meta-analysis. *Journal of Industrial Ecology, 22*(4), 745–759.

CDP. (2008). Carbon disclosure project report 2008: Global 500. Available at: https://www.cdproject.net/Documents/cdp_global_500_report_2008.pdf. (Accessed 25 May 2023).

Clarkson, P. M., Li, Y., Pinnuck, M., & Richardson, G. (2015). The value relevance of greenhouse gas emissions under the European Union carbon emissions trading scheme. *European Accounting Review, 24*(3), 551–580.

Clarkson, P. M., Li, Y., Richardson, G. D., & Vasvari, F. P. (2011). Does it really pay to be green? Determinants and consequences of proactive environmental strategies. *Journal of Accounting and Public Policy, 30*(2), 122–144.

Dahlmann, F., Branicki, L., & Brammer, S. (2019). Managing carbon aspirations: The influence of corporate climate change targets on environmental performance. *Journal of Business Ethics, 158*(1), 1–24.

Daradkeh, H., Shams, S., Bose, S., & Gunasekarage, A. (2023). Does managerial ability matter for corporate climate change disclosures? *Corporate Governance: An International Review, 31*(1), 83–104.

de Villiers, C., Naiker, V., & van Staden, C. J. (2011). The effect of board characteristics on firm environmental performance. *Journal of Management, 37*(6), 1636–1663.

DeFond, M. L., Lim, C. Y., & Zang, Y. (2016). Client conservatism and auditor–client contracting. *The Accounting Review, 91*(1), 69–98.

Dhaliwal, D. S., Li, O. Z., Tsang, A., & Yang, Y. G. (2014). Corporate social responsibility disclosure and the cost of equity capital: The roles of stakeholder orientation and financial transparency. *Journal of Accounting and Public Policy, 33*(4), 328–355.

Dixit, R. K., & Pindyck, R. S. (2012). *Investment under uncertainty*. Princeton University Press.

Drobetz, W., El Ghoul, S., Guedhami, O., & Janzen, M. (2018). Policy uncertainty, investment, and the cost of capital. *Journal of Financial Stability, 39*, 28–45.

Duong, H. N., Nguyen, J. H., Nguyen, M., & Rhee, S. G. (2020). Navigating through economic policy uncertainty: The role of corporate cash holdings. *Journal of Corporate Finance, 62*, Article 101607.

Fei, Q., Rasiah, R., & Shen, L. J. (2014). The clean energy growth nexus with CO_2 emissions and technological innovation in Norway and New Zealand. *Energy & Environment, 25*(8), 1323–1344.

Freeman, R. E. (2010). *Strategic management: A stakeholder approach*. Cambridge University Press.

Friedl, B., & Getzner, M. (2003). Determinants of CO_2 emissions in a small open economy. *Ecological Economics, 45*(1), 133–148.

Friedman, M. (2007). The social responsibility of business is to increase its profits. In *Corporate ethics and corporate governance* (pp. 173–178). Springer.

Fuss, S., Szolgayova, J., Obersteiner, M., & Gusti, M. (2008). Investment under market and climate policy uncertainty. *Applied Energy, 85*(8), 708–721.

Germanwatch, & Climate Action Network. (2019). The climate change performance index. Available at: https://www.climate-change-performance-index.org/downloads. (Accessed 30 May 2023).
Griffin, P. A., Lont, D. H., & Sun, Y. (2017). The relevance to investors of greenhouse gas emission disclosures. *Contemporary Accounting Research, 34*(2), 1265–1297.
Gujarati, D. (2003). *Basic econometrics* (4th ed.). New York, NY: McGraw-Hill.
Gujarati, D. N., & Porter, D. C. (2009). *Basic econometrics*. New York, NY: McGraw-Hill Irwin.
Gulen, H., & Ion, M. (2016). Policy uncertainty and corporate investment. *Review of Financial Studies, 29*(3), 523–564.
Hassel, L., Nilsson, H., & Nyquist, S. (2005). The value relevance of environmental performance. *European Accounting Review, 14*(1), 41–61.
Hassett, K. A., & Sullivan, J. (2015). Policy uncertainty and the economy: A review of the literature. In *In: Proceedings of 'exploring the price of policy uncertainty' conference*. Washington, DC: Becker-Friedman Institute and the Urban Institute Center for Global Development. April 7-8.
Heckman, J. J. (1979). Sample selection bias as a specification error. *Econometrica, 47*(1), 153–161.
Holtz-Eakin, D., & Selden, T. M. (1995). Stoking the fires? CO_2 emissions and economic growth. *Journal of Public Economics, 57*(1), 85–101.
Horváthová, E. (2012). The impact of environmental performance on firm performance: Short-term costs and long-term benefits? *Ecological Economics, 84*, 91–97.
Iqbal, M., Chand, S., & Haq, Z. U. (2023). Economic policy uncertainty and CO_2 emissions: A comparative analysis of developed and developing nations. *Environmental Science and Pollution Research, 30*, 15034–15043. https://doi.org/10.1007/s11356-022-23115-4
Iqbal, U., Gan, C., & Nadeem, M. (2020). Economic policy uncertainty and firm performance. *Applied Economics Letters, 27*(10), 765–770.
Jia, J., & Li, Z. (2020). Does external uncertainty matter in corporate sustainability performance? *Journal of Corporate Finance, 65*, Article 101743.
Jiang, Y., Zhou, Z., & Liu, C. (2019). Does economic policy uncertainty matter for carbon emission? Evidence from US sector level data. *Environmental Science and Pollution Research, 26*(24), 24380–24394.
Jory, S. R., Khieu, H. D., Ngo, T. N., & Phan, H. V. (2020). The influence of economic policy uncertainty on corporate trade credit and firm value. *Journal of Corporate Finance, 64*, Article 101671.
Julio, B., & Yook, Y. (2012). Political uncertainty and corporate investment cycles. *The Journal of Finance, 67*(1), 45–83.
Jung, J., Herbohn, K., & Clarkson, P. (2018). Carbon risk, carbon risk awareness and the cost of debt financing. *Journal of Business Ethics, 150*(4), 1151–1171.
Kolk, A., Levy, D., & Pinkse, J. (2008). Corporate responses in an emerging climate regime: The institutionalization and commensuration of carbon disclosure. *European Accounting Review, 17*(4), 719–745.
Kumarasiri, J. (2016). Policy uncertainty continues to hamper carbon emissions management. *The Conversation*. Available at: https://theconversation.com/policy-uncertainty-continues-to-hamper-carbon-emissions-management-68565. (Accessed 25 May 2023).
Lee, S. Y. (2012). Corporate carbon strategies in responding to climate change. *Business Strategy and the Environment, 21*(1), 33–48.
Lee, K. H., & Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *Journal of Cleaner Production, 108*, 534–542.
Ling, C. H., Ahmed, K., Binti Muhamad, R., & Shahbaz, M. (2015). Decomposing the trade–environment nexus for Malaysia: What do the technique, scale, composition, and comparative advantage effect indicate? *Environmental Science and Pollution Research, 22*(24), 20131–20142.
Liu, Y., & Zhang, Z. (2022). How does economic policy uncertainty affect CO_2 emissions? A regional analysis in China. *Environmental Science and Pollution Research, 29*(3), 4276–4290.
Lys, T., Naughton, J. P., & Wang, C. (2015). Signaling through corporate accountability reporting. *Journal of Accounting and Economics, 60*(1), 56–72.
Makni, R., Francoeur, C., & Bellavance, F. (2008). Causality between corporate social performance and financial performance: Evidence from Canadian firms. *Journal of Business Ethics, 89*(3), 409–422.
Matsumura, E. M., Prakash, R., & Vera-Muñoz, S. C. (2014). Firm-value effects of carbon emissions and carbon disclosures. *The Accounting Review, 89*(2), 695–724.
Menegaki, A. (2008). Valuation for renewable energy: A comparative review. *Renewable and Sustainable Energy Reviews, 12*(9), 2422–2437.
Palmer, K., Oates, W. E., & Portney, P. R. (1995). Tightening environmental standards: The benefit–cost or the no-cost paradigm? *The Journal of Economic Perspectives, 9*(4), 119–132.
Pevzner, M., Xie, F., & Xin, X. (2015). When firms talk, do investors listen? The role of trust in stock market reactions to corporate earnings announcements. *Journal of Financial Economics, 117*(1), 190–223.
Pindyck, R. S. (1990). *Irreversibility, uncertainty, and investment*. Cambridge, MA: National Bureau of Economic Research (NBER).
Pirgaip, B., & Dinçergök, B. (2020). Economic policy uncertainty, energy consumption and carbon emissions in G7 countries: Evidence from a panel Granger causality analysis. *Environmental Science and Pollution Research, 27*(24), 30050–30066.
Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers, 36*(4), 717–731.
Qian, W., & Schaltegger, S. (2017). Revisiting carbon disclosure and performance: Legitimacy and management views. *The British Accounting Review, 49*(4), 365–379.
Richmond, A. K., & Kaufmann, R. K. (2006). Is there a turning point in the relationship between income and energy use and/or carbon emissions? *Ecological Economics, 56*(2), 176–189.
Rjiba, H., Jahmane, A., & Abid, I. (2020). Corporate social responsibility and firm value: Guiding through economic policy uncertainty. *Finance Research Letters, 35*, Article 101553.
Sha, Y., Kang, C., & Wang, Z. (2020). Economic policy uncertainty and mergers and acquisitions: Evidence from China. *Economic Modelling, 89*, 590–600.
Simnett, R., Vanstraelen, A., & Chua, W. F. (2009). Assurance on sustainability reports: An international comparison. *The Accounting Review, 84*(3), 937–967.
Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World Development, 32*(8), 1419–1439.
Syed, Q. R., & Bouri, E. (2022). Impact of economic policy uncertainty on CO_2 emissions in the US: Evidence from bootstrap ARDL approach. *Journal of Public Affairs, 22*(3), Article e2595.
Task Force on Climate-related Financial Disclosures (TCFD). (2017). Recommendations of the Task Force on climate-related financial disclosures. Available at: https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf. (Accessed 5 May 2023).
The Guardian. (2016). The world passes 400ppm carbon dioxide threshold permanently. Available at: https://www.theguardian.com/environment/2016/sep/28/the-world-passes-400ppm-carbon-dioxide-threshold-permanently. (Accessed 10 July 2023).
Tsang, A., Xie, F., & Xin, X. (2019). Foreign institutional investors and corporate voluntary disclosure around the world. *The Accounting Review, 94*(5), 319–348.
United Nations Framework Convention on Climate Change (UNFCCC). (2015). COP 21: Report of the conference of the parties on its twenty-first session, held in Paris from 30 november to 13 december 2015. Available at: http://unfccc.int/resource/docs/2015/cop21/eng/10.pdf. (Accessed 30 May 2023).
United Nations (UN). (2021). What is renewable energy?. Available at: https://www.un.org/en/climatechange/what-is-renewable-energy. (Accessed 30 May 2023).
Wang, Q., Xiao, K., & Lu, Z. (2020). Does economic policy uncertainty affect CO_2 emissions? Empirical evidence from the United States. *Sustainability, 12*(21), 9108.
World Bank. (2020). The worldwide governance indicators. Available at: http://info.worldbank.org/governance/wgi/index.asp. (Accessed 5 June 2023).
World Business Council for Sustainable Development (WBCSD), & World Resources Institute (WRI). (2004). The greenhouse gas protocol – a corporate accounting and reporting standard. Available at: http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf. (Accessed 30 May 2023).
Wu, J., Zhang, J., Zhang, S., & Zou, L. (2020). The economic policy uncertainty and firm investment in Australia. *Applied Economics, 52*(31), 3354–3378.
Xu, Z. (2020). Economic policy uncertainty, cost of capital, and corporate innovation. *Journal of Banking & Finance, 111*, 1–15.
Yang, Z., Yu, Y., Zhang, Y., & Zhou, S. (2019). Policy uncertainty exposure and market value: Evidence from China. *Pacific-Basin Finance Journal, 57*, Article 101178.
Young, S. L., & Makhija, M. V. (2014). Firms' corporate social responsibility behavior: An integration of institutional and profit maximization approaches. *Journal of International Business Studies, 45*(6), 670–698.
Yu, J., Shi, X., Guo, D., & Yang, L. (2021). Economic policy uncertainty (EPU) and firm carbon emissions: Evidence using a China provincial EPU index. *Energy Economics, 94*, Article 105071.

Zakari, A., Adedoyin, F. F., & Bekun, F. V. (2021). The effect of energy consumption on the environment in the OECD countries: Economic policy uncertainty perspectives. *Environmental Science and Pollution Research, 28*(37), 52295–52305.

Zhang, M., Wang, Q., Zhou, D., & Ding, H. (2019). Evaluating uncertain investment decisions in low-carbon transition toward renewable energy. *Applied Energy, 240*, 1049–1060.

Zhou, Z., Zhang, L., Lin, L., Zeng, H., & Chen, X. (2020). Carbon risk management and corporate competitive advantages: "Differential promotion" or "cost hindrance". *Business Strategy and the Environment, 29*(4), 1764–1784.