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Financial markets implications of the energy transition: carbon content of energy use in listed companies

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Abstract

Decarbonization is often misunderstood in financial studies. Furthermore, its implications for investment opportunities and growth are even less known. The study investigates the link between energy indicators and Tobin's Quotient (TQ) in listed companies globally, finding that the carbon content of energy presents a negative yet modest effect on financial performance. Furthermore, we investigated the effect carbon prices in compliance markets have on TQ for exempted and non-exempt firms, finding that Energy efficiency measures yield greater effects in the latter group. Conversely, it is also true that carbon prices marginally reduce TQ more in non-exempt firms. This implies that auction-mechanisms create burdens that companies are eager to relinquish by reducing emissions. However, reducing GHG yields positive effects on TQ only as long as it results in energy efficiency improvements.

Keywords: Energy efficiency, Decarbonization, Transition cost, Corporate financial performance, Corporate environmental performance

JEL Classification: O13, O16, G32

Introduction

Transitioning to a low-carbon society requires the diffusion of technologies capable of substantially changing the energy system. The mitigation costs affect other industries as well. By looking at direct and indirect CO2 equivalent emissions, Mining, Manufacturing, and Construction are carbon-intensive sectors and require innovating their energy and production structures. Capital is needed to support such innovation. The financial sector is participating by incorporating green standards and excluding brown-based businesses from their investment portfolios. Such changes in investment decisions present uncertain implications for listed companies worldwide. Among other factors implicating uncertainties, we also see the strengthening of climate regulation to comply with a 2 degrees Celsius scenario, the increased competition from green products and services, and changes in reputation. These uncertainties and risks regarding the shift toward a climate-neutral economy have implications in the financial sector and are categorized as transition risks (Bank of England et al. 2017; Task Force on Climate-related

Financial Disclosures & TSFD 2017). While regulation could foster innovation and environmental sustainability, achieving such objectives under profitable premises is preferable (Porter and van der Linde 1995). Otherwise, governments need to consider forms of compensation to increase the political acceptability of more stringent regulations (Trebilcock 2014). Understanding the effect of decarbonization on investment opportunities and comparing the effects at corporate level presents relevant policy and managerial implications.

Assessing the effects of decarbonization policies in listed companies presents a twofold problem. Emissions are voluntarily disclosed, meaning that we have partial information on decarbonization per se. Using companies from worldwide samples instead of national ones increases the number of companies within the studies, compensating for the problem of omissions. Secondly, climate policies are heterogenous globally, meaning that the institutional incentives to decarbonize are unequal across economies. These can be potentially assessed via price signals from Emission Trading Systems (ETSs), which are compliance markets for permits of CO2e emissions. While relevant studies considered the perspective of the investors with respect to carbon intensity (Bolton and Kacperczyk 2021b; Capasso et al. 2020; Ilhan et al. 2020), fewer have assessed how changes in the structure of energy use affect profitability, while considering the institutional pressure to decarbonize. The Corporate Financial Performance (CFP) improvements might be tracked in changes or the relative market value of assets as the Tobin's Q (TQ), if decarbonization relies on structural changes of productive systems. This paper introduces in the financial literature the carbon content of energy (CCE) as an indicator of the carbon intensity of corporate activities. This indicator is the ratio between the sum in tons of CO2e of direct (scope 1) and indirect (scope 2) emissions over the Giga Joules of total energy use. Figure 1 presents the trend over the reference years of this work.

Increases in such a ratio will indicate the augmented dependency on carbon-based practices relative to total energy uses. In our sample, listed companies participating in an ETS presented a lower and decreasing CCE, while those outside had a slowly increasing one. While it is not the purpose of this paper to address a causality link between ETS and reductions in CCE, we will investigate whether carbon prices affect the CFP of listed companies. It is not casual as the ETS has been often enforced in jurisdiction with already mature energy systems, such as EU27, Switzerland and New Zealand. Furthermore, it is possible for corporations to have CCE higher than 0.1 tCO2e/GJ. Along with the indirect emissions from electricity use which might be generated by companies using fossil fuel (which emissions are compounded in Scope 2 emissions), it is necessary to account for the emissions coming from production.

Since carbon pricing operates as a signal for decarbonization, its value is tied to the market value of assets, which functioning requires some form of carbon and energy. It is here investigated whether it is carbon reduction instead of energy efficiency measures, disentangling the role of energy, carbon footprint and CCE. The work adds to the CFP and Corporate Environmental Performance (CEP) literature by balancing the influence of compliance price signals for emission abatement. Furthermore, it is here to compare previous studies targeting TQ with environmental indicators.

This paragraph concludes the first of the six sections that constitute the paper. The following synthesized the literature defining a gap upon which research hypotheses are

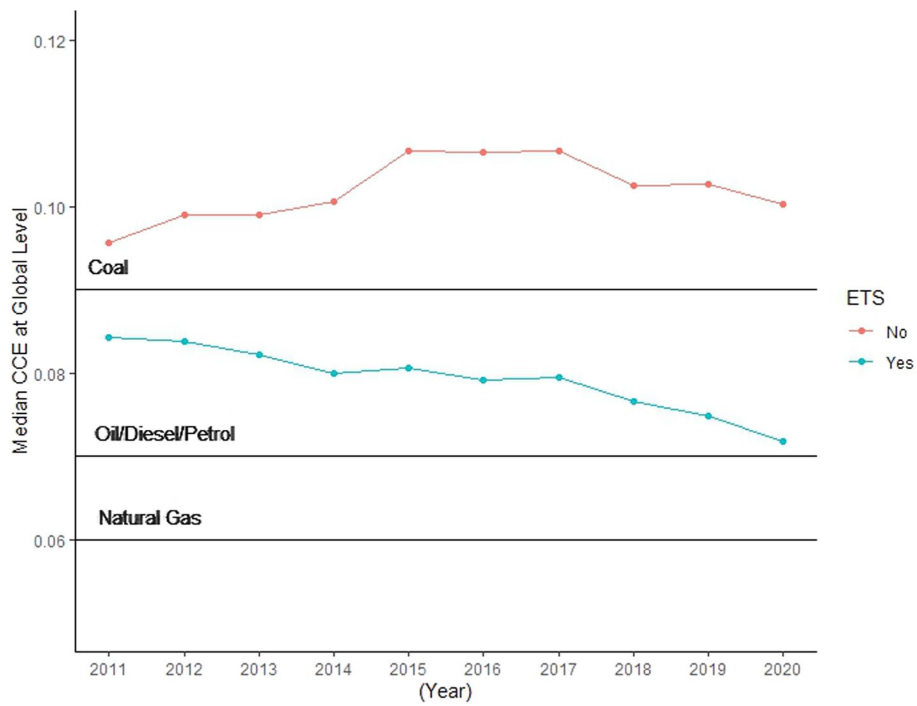

Fig. 1 Median CCE in listed Companies internationally, sampled according to participation in compliance Carbon Markets of Emissions Trading Systems, measured in tCO2e/GJ. Reference for technologies is calibrated from 2016 (New Zeland Ministry for the Environment 2017)

carved. The tests are calibrated using a methodology familiar to the readers of financial literature and the CEP-CFP. The third section takes this role. To our knowledge, the statistical models here are used to test the hypotheses and adopt variables used for the first time in the finance literature. The fourth section describes the target and the independent variables, particularly concerning the carbon pricing signal and the structural difference in CCE among sectors. The results of the works are summarized in the fifth section. However, they will be thoroughly discussed in the sixth section, where comparisons will be made. The innovation produced by the articles is finally summarized in the conclusive section, where it is also pointed out the policy implications and the potential gap left out are addressed.

Literature and hypotheses

The paper stems from the literature regarding the relationship between CEP and CFP. Since the objective is to assess the effects of changes in non-financial disclosed information, it is here deemed paramount to address the corpus of articles according to the indicators used in the analyses. To our knowledge, there are two main literature sub-streams regarding environmental indicators and their effects on CFP. The first relates the synthetic indicators that compound several sub-indicators concerning environmental degradation, eco-innovation, and internal policies.

The ESG scores are the most used among these indicators: the higher the score, the better the environmental performance. Studies found that a positive relation links ESG to CFP (Devalle et al. 2017; Friede et al. 2015; Landi and Sciarelli 2019), and companies with better scores perform better. These indicators are widely available and used commonly across sectors and years. Furthermore, their intuitive structure and intuitive 0–100 values simplified the interpretation of the results. Furthermore, it allows intuitively constructing portfolios and testing for investors' attention to company performance changes (Gao et al. 2022). These phenomena might be exogenous, such as the Covid pandemic, which increased awareness toward green investments (Rubbaniy et al. 2022), or even endogenous to corporate activities. For instance, companies tend to disclose the set of indicators that favour them in the eyes of investors. This attempt to elude or manipulate the screening is called green-washing and has adverse financial effects in the long term (Cooper et al. 2018). Secondly, the sub-indicators are often changed due to the preference of the investors or the auditors. This implicates the rewriting of assets and equities, which could be negative for the investors of ESG-evaluated companies (Berg et al. 2020). Another relevant limitation of this approach is the veil of ignorance that shrouds the creation of ESG. The score is available, but the weighting mechanism is not disclosed. These methodological limits are accompanied by the limited predicting capabilities of the ESG scores compared to environmental indicators (Guastella et al. 2022).

The second sub-stream of literature relates to the implementation of actual environmental indicators. Quantitative indicators of CEP have been used to regress premiums expected by investors (Bolton and Kacperczyk 2021a, b), credit risk (Capasso et al. 2020; Zhang and Zhao 2022) and speculative potential (Ilhan et al. 2020). These measures comprehend environmental footprints such as carbon emissions, waste production and other measurable externalities. Compared with the previous substream, actual indicators represent realistic performances that often present heterogenous implications, especially according to the institutional system they are immersed in. Delmas et al. (2015) noted that United States-listed companies tend to be negatively affected in the short term by emission reduction. Similar results were found by Bolton and Kacperczyk (2021b), where a positive relationship between carbon revenue intensity positively affects stock returns, especially where environmental policies were more lenient. It has been found in Australian companies that lower environmental performances are linked to higher CFP, motivated by regulation slackness (Wang et al. 2014). On the other hand, several studies found different results using similar data and approaches. Gallego-Alvarez et al. (2015). Mysen (2012) noted that listed companies reduce emissions to attract investors, even when the internal policies are not repaid in better financial performances. Lewandowski (2017) found financial performance gains higher for high emitters who decide to abate, while already carbon-efficient businesses do not benefit from climate mitigation policies. The efficiency of financial markets to quantitative price indicators has been doubted in the short term (Liesen et al. 2017) and the long term (Makridou et al. 2019).

Despite the advancements, the two branches of literature present two relevant gaps. The process of decarbonization has been largely ignored in favor of carbon efficiency and footprint reduction (Brouwers et al. 2018). The studies involving carbon prices found little or no effect on CFP in the early stages of the ETSs when the prices were relatively low (Brouwers et al. 2018; van Emous et al. 2021), meaning that the institutional pressure to decarbonize was quantitatively mild. However, Zha et al. (2022)

noted that prices and policy adequacy had effects in reducing carbon intensity and thus improving CFP. This means that a more sophisticated approach to ETS and CFP and correctly proxying decarbonization might address why actual CEP indicators present heterogenous results.

We addressed these limitations in the literature by adopting new indicators in addition to the previous ones and splitting the samples according to participation in an ETS. Furthermore, the permits' price is here weighted to the volume of GHG covered by the policy instruments. This will imply that if a price is stringent just for a limited number of firms, the effect on listed companies might be necessarily reduced. However, their participation in the compliance market might make a difference. In the first case, we consider the CCE. This indicator is based solely on environmental performances and captures a specific change in the relevance of carbon emissions over the energy intake of a business. A company that electrifies its business activities will see a reduction in CCE as long as indirect emissions are constant: this could not be the case when energy suppliers are browner than the listed company itself. The adoption of renewable and carbon–neutral methods will again reduce CCE. This indicator is, therefore, more suitable for addressing climate-specific changes in the technologies involved by a listed company. If there exists a negative relation between CCE and CFP, then relative reductions in carbon footprints improve CFP.

H1: CCE is negatively related to TQ

Secondly, we redefine participation in the ETS. Companies involved in ETS need to buy permits to compensate for the emissions from their activities. However, not all emissions or sectors are covered, meaning that the actual pressure of the carbon price must be weighted to its relevance in each economy. They have been established in Europe (since 2005), New Zealand (2008), Switzerland (2008), several states in the USA (2010), Korea (2015) and China (2021). In general, ETS prices increase energy costs, which affects all companies that operate in a jurisdiction. Thus, there might be general pressure on companies to reduce their energy intake, which affects their profitability.

H2: weighted ETS decreases TQ

Finally, participation in an ETS requires abatement measures, which reduces the need to compensate for emissions, leaving the company to bank or sell permits in the secondary markets. Firms might collect "carbon rents" from these transactions. Making permits is, therefore, akin to being an asset rather than a liability (André and de Castro 2017; Siegmeier et al. 2018). In addition, the strong version of the Porter hypothesis indicates that environmental regulation fosters profitability, indicating that TQ should be higher in companies dealing with ETS *ceteris paribus* (Bitat 2018). This implies that the weighted ETS price will affect companies obliged to buy permits differently than those that do not need them.

H3: Participation in ETS increases CEP effectiveness on CFP

An intuitive methodology has been developed to address the three hypotheses and provide comparable results for future studies.

Methodology

The hypotheses are tested through one set of models' estimation targeting TQ. The definition of the variable refers to the standard financial literature on CFP (Fu et al. 2021; Lang and Stulz 2017; Suzuki and Chida 2017) and is summarized in Eq. (1).

$$TQ_{i,t} = \frac{M_{i,t} - L_{i,t}^{M}}{B_{i,t} - L_{i,t}^{B}} = \begin{cases} \geq 1, & Undercapitalized \\ < 1, & Overcapitalized \end{cases} \tag{1}$$

The quotient represents the ratio between the market value of a company's assets as equities (M) and liabilities (L^M) over the book value of equities (B) and liabilities (L^B). A hypothetical replacement of the company's assets is possible if the net market value exceeds the net book value. Companies are called undercapitalized when they present a TQ higher than one. If the opposite is true, a company's net market value is insufficient to replace the book value. Companies characterized by a TQ lower than one are referred to as overcapitalized and need to either improve their outlook or reduce the weight of the liabilities. The objective of a company is to keep a TQ of approximately 1 (Bajaj et al. 1998; Stevens 1990; Wernerfelt and Montgomery 1988).

Three different samples will address the CFP-CEP relation targeting the TQ. One considers the total number of firms used in the sample. The other two are the subsample of firms participating in the ETS of their centre of activity and those not part of an ETS. This information is disclosed in Datastream. The firms in the first subsamples are those with a ratio above one and the second with a below one. This estimation will capture the different effects perceived by the subsamples. The statistical models to be estimated in the first exercise are presented in Eqs.(2, 3, 4).

$$TQ_{i,t} = \beta^1 CCE_{i,t} + \beta^2 ln(Energy/revenue)_{i,t} + ETS_{c,t} + Z_{i,t}\gamma + \varepsilon_{i,t} \tag{2}$$

$$TQ_{i,t} = \beta^1 CCE_{i,t} + \beta^3 ln(Energy)_{i,t} + ETS_{c,t} + Z_{i,t}\gamma + \varepsilon_{i,t} \tag{3}$$

$$TQ_{i,t} = \beta^1 CCE_{i,t} + \beta^4 ln\left(CO2_{i,t}\right) + ETS_{c,t} + Z_{i,t}\gamma + \varepsilon_{i,t} \tag{4}$$

where $\varepsilon_{i,t} = \mu_i + \mu_c + \mu_{GICS} + e_{i,t}$.

The three equations describe a panel data regression where the nation, industrial subsector (as GICS 6), individual, and time effects are considered. The variable CO2 is the sum of Scope 1 and Scope 2 in terms of carbon dioxide equivalents tons over billion dollars of revenues. "Energy" refers to the total energy use of Gigajoules, which a company uses in its activities, compounding direct and indirect energy sources. Finally, the CCE is the ratio of total carbon emissions and energy use. The firms' financial and energetic performances have been matched using ISIN for equities with the index "i" according to the year "t". The models isolate the three indicators due to high levels of correlation. Finally, ETS is the weighted ETS price for each country's jurisdiction. The Z matrix consolidates the control variables determining the TQ. The error term $\varepsilon_{i,t}$ is equal to the sum of two different components. The fixed effects μ_i, μ_c and μ_{GICS} respectively control for unobserved effects from the firm, the country of headquarters and digit 6 GICS sectors. These are meant to isolate the firm-specific and sector-specific factors influencing the target variable that could not be incorporated. The idiosyncratic term $e_{i,t}$ assumed to behave as an IID. The dataset structure presents the possibility of heteroskedasticity and autocorrelation of errors. Heteroskedastic-AutoCorrelated (HAC) robust standard errors have compensated for such issues.

Data

The dataset consists of 2574 listed companies from all available financial markets, observed between 2011 and 2020 on DataStream Eikon. We selected all companies that disclosed environmental and energy indicators in quantitative terms, such as tons or Gigajoule. However, non-financial disclosure is voluntary, i.e. companies do not have to disclose their CEP to anyone. Indeed, it is possible to see that more than 5.85% of companies worldwide disclosed environmental indicators from a potential sample of around 25,740 between 2011 and 2020. This poses the problem of omission bias. Companies could have the incentive to disclose performances only when they are good. Wooldridge (2010) explained that such a bias constitutes a problem only when the dependent variable of a regression could be affected by endogenous omission. Since the CEP is proxied by independent variables, data omission does not constitute a problem. The data on weighted ETS originates from "Our World in Data", and it is calculated by multiplying the available carbon price average for each year by the amount of CO2 equivalent gas covered by the policy in the country's jurisdiction, divided by the total volume of GHG emissions emitted in that country "c" at year "t".

A summary of the dataset is provided in Table 1. The target variable is the logarithm of the TQ in this dataset. Its mean value has been 0.602. this value stands within the interval of the 25th percentile of 0.049 and the 75th percentile of 1.084. Furthermore, the low standard deviation (SD) of 0.841 indicates that the logarithm TQ presents

Table 1 Summary table

Statistic	NxT	Mean	SD	Pctl(25)	Pctl(75)	Dimension	Source
TQ	24,238	0.602	0.841	0.049	1.084	Ratio	Authors' Calculation
Assets	26,413	17.186	2.833	15.142	18.948	Ln(Dollars)	Datastream
Carbon Intensity	16,872	14.881	2.412	13.289	16.476	CO2E Ton/B dollars	Datastream
Energy Intensity	16,069	6.385	2.049	5.004	7.841	Gigajoules/B dollars	Datastream
Energy Footprint	16,137	14.881	2.412	13.289	16.47609	Gigajoules	Datastream
Corporate Leverage	26,270	27.276	20.908	13.270	38.180	%	Datastream
Dividend Payouts	27,280	26.448	27.385	0	45.1	%	Datastream
Operating Profit Margins	26,322	−0.244	1,035.554	5.480	20.780	%	Datastream
Retained Earnings Assets	26,099	53.970	1,497.867	30.952	88.376	%	Datastream
Revenue Growth	26,074	169.024	15,356.510	−1.949	13.737	%	Datastream
ETS	20,277	0.164	0.371	0	0	Dummy 1/0	Datastream
Price	26,074	2.411	3.532	0	3.499	Weighted Carbon price in dollars	Our World in Data*
CCE	15,454	0.152	0.443	0.062	0.134	CO2E Ton/Gigajoules	Authors Calculation

* https://ourworldindata.org/carbon-pricing

a low variability. Capitalization is the dummy variable equal to 1 when the TQ (as it is observed on the financial disclosure, not in logarithmic form) is at least 1 and 0 if it is less than 1. More than 75% of the companies present a TQ of more than 1 in our sample. The study uses as independent variables the total emission of CO2 equivalents, the energy intensity of revenues, the total energy consumed within the year of activity, and finally, the ratio between the logarithm of total CO2 emissions and total energy use: this indicator will be called CCE afterwards. The reason to use natural logarithm transformation is to mitigate the variability within the energy indicators characterized by high skewness. The measure used for energy use within a year is the Giga Joules (Gj). The energy intensity of profits is the Gj over millions of dollars. Finally, carbon intensity in tons per billion dollars. The average listed firm that disclosed energy use presents an energy intensity of 592.884 Gj per million dollars (6.385 in ln), total energy use of 2,902,259 Gj (14.881 in ln), carbon intensity of 2,902,259 tons of GHG per billion dollars (14.881 in ln), and CCE of 0.152 CO2t/ Gj. The mean weighted carbon price was around 2.4 dollars per ton of emissions. SD amounted to 3.5 dollars. The first quartile of the distribution is null due to the large number of countries not having a carbon price in place.

The control variables comprehend accounting, liquidity, and financial indicators suggested by literature (Cao et al. 2019; Hennessy 2004; Lang and Stulz 2017; Smirlock et al. 2016). The first group used the corporate dimension, leverage, ordinary dividend payouts ratio, and institutional ownership. The dimension is measured as the logarithm of total assets. The leverage represents the ratio between debt and assets. The dividend payout ratio represents the number of ordinary dividends given to shareholders over the net revenues minus preferred dividends. Institutional ownership indicates the percentage of company ownership from institutional investors, such as public investment funds or the government. As liquidity indicators, Operating profit margins are used: they represent the percentage of profit a company produces from its operations before subtracting taxes and interest charges from the total revenue. All the control variables in the dataset are measured as percentage points, except for the corporate dimension.

In the attempt to create the widest dataset possible, several observations were missing when pooling disclosing companies across time. Listed companies voluntarily disclose their energy indicators; most companies started to disclose their performances after 2015. This means it is currently difficult to assess the level of exposure to transition risk homogenously across sectors, nations, and time. The collected sample represents 5.96% of listed companies globally and 30.1% of global market capitalization. Regarding energy indicators, this dataset represented 16.71% of the global energy use of 512.228 Ej (E = 1000G) and 19.82% of global CO2 equivalent emissions in 2019. Statistically, the omission bias will not affect the estimation as it does not represent the target variable but the independent ones. A second problem noted in the energy-carbon issue is the high level of correlation. A summary table of correlation between variables is presented in Table 2.

Energy intensity and total use are highly correlated (35.9%): this level could indicate that major energy-intensive companies tend to be also dependent on energy use to generate revenues. Similarly, total CO2 equivalent emissions are highly related to

Table 2 Correlation table

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
TQ (1)	1	−0.256	−0.152	−0.140	−0.139	−0.017	0.182	0.061	−0.061	−0.012	−0.020	0.00004
Assets (2)	−0.256	1	0.319	−0.047	0.110	−0.050	−0.010	−0.060	0.072	−0.008	−0.314	−0.130
Carbon intensity (3)	−0.152	0.319	1	0.745	0.434	0.132	−0.050	−0.218	0.017	−0.034	−0.125	−0.329
Energy Intensity (4)	−0.140	−0.047	0.745	1	0.359	0.214	−0.090	−0.009	−0.040	−0.025	−0.119	−0.237
Energy Footprint (5)	−0.139	0.110	0.434	0.359	1	0.029	−0.041	−0.050	0.003	0.004	−0.024	−0.035
Corporate Leverage (6)	−0.017	−0.050	0.132	0.214	0.029	1	−0.098	0.074	−0.113	−0.016	0.074	−0.020
Dividend Payouts (7)	0.182	−0.010	−0.050	−0.090	−0.041	−0.098	1	0.127	0.096	−0.009	−0.061	−0.011
Operating Profit Margins (8)	0.061	−0.060	−0.218	−0.009	−0.050	0.074	0.127	1	0.012	0.124	−0.016	0.100
Retained Earnings Assets (9)	−0.061	0.072	0.017	−0.040	0.003	−0.113	0.096	0.012	1	−0.002	0.009	−0.015
Revenue Growth (10)	−0.012	−0.008	−0.034	−0.025	0.004	−0.016	−0.009	0.124	−0.002	1	−0.037	0.003
Price (11)	−0.020	−0.314	−0.125	−0.119	−0.024	0.074	−0.061	−0.016	0.009	−0.037	1	0.045
CCE (12)	0.00004	−0.130	−0.329	−0.237	−0.035	−0.020	−0.011	0.100	−0.015	0.003	0.045	1

both energy indicators. The carbon intensity correlates to energy intensity for 74.5% and total energy use for 43.4%. The dominance of carbon-based energy use explains these values used in listed companies that disclose energy use.

Table 3 Panel data regression, fixed effects

	Dependent variable								
	TQ								
	Total sample			**Non-ETS firms**			**ETS firms**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
CCE	−0.201***	−0.197***	−0.199***	−0.121***	−0.121***	−0.121***	−0.120***	−0.120***	−0.120***
	(0.033)	(0.031)	(0.035)	(0.020)	(0.026)	(0.022)	(0.033)	(0.025)	(0.027)
Energy intensity	−0.232***			−0.229***			−0.239***		
	(0.030)			(0.030)			(0.030)		
Energy footprint		−0.090***			−0.093***			−0.089***	
		(0.024)			(0.024)			(0.024)	
Carbon footprint			−0.070***			−0.074***			−0.066***
			(0.011)			(0.011)			(0.011)
Price	−0.005**	−0.006***	−0.006***	−0.005**	−0.005***	−0.005***	−0.005**	−0.007***	−0.007***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Assets	−0.217***	−0.106***	−0.121***	−0.213***	−0.108***	−0.124***	−0.229***	−0.081***	−0.094***
	(0.026)	(0.015)	(0.016)	(0.026)	(0.015)	(0.016)	(0.026)	(0.015)	(0.016)
Corporate leverage	0.006***	0.005***	0.005***	0.006***	0.005***	0.006***	0.005***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Dividend payouts	0.003***	0.003***	0.003***	0.003***	0.003***	0.003***	0.002***	0.002***	0.002***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Operating profit margins	0.012***	0.011***	0.011***	0.011***	0.010***	0.010***	0.018***	0.017***	0.017***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Retained earnings assets	0.00003	0.00003	0.00003	0.00004	0.00004	0.00004	−0.001***	−0.001***	−0.001***
	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)	(0.00004)
Revenue growth	0.00001***	0.00000***	0.00001***	0.00001***	0.00000***	0.00001***	−0.001***	−0.001***	−0.001***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
Constant	3.846***	2.676***	2.839***	3.842***	2.761***	2.945***	3.266***	2.081***	2.166***
	(0.353)	(0.291)	(0.289)	(0.353)	(0.291)	(0.289)	(0.353)	(0.291)	(0.289)
Observations	11,690	11,690	11,690	9,277	9,277	9,277	2,413	2,413	2,413
R^2	0.441	0.419	0.425	0.443	0.423	0.428	0.548	0.524	0.530
Adjusted R^2	0.435	0.413	0.418	0.436	0.415	0.421	0.529	0.505	0.511
F statistic	71.855***	65.778***	67.207***	57.829***	53.216***	54.439***	29.851***	27.182***	27.784***

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Results

The fixed effect panel data were estimated using Ordinary Least Squares, and the results are reported in Table 3. Nine regressions are reported, of which the first three refer to the total sample. The second trio employs a subsample of companies not participating in an ETS, and finally, the last trio to those currently covered. The fixed effects explained in the methodology section are used in all estimated models together. Furthermore, the slight variations in observations might be due to the varying number of disclosing firms. While this affected the balance of the panels, these variations did not affect the results dramatically.

The first model condensates the effect on TQ enacted by the CCE and the energy intensity of revenues. Both effects are statistically significant, with the former having a value of −0.201 and the latter of −0.232. The value of the CCE effect on TQ remains similar for the complete sample exercise. These results should interpret as elasticities, meaning that one base point increase of the independent variable yields a percentage variation of TQ equal to the estimated effects. The following two indicators considered are energy footprint and carbon intensity. The former presents an elasticity of −0.090, while the latter −0.070. The elasticity of the ETS price across the model amounted to −0.006. Overall, the controls were statistically significant. The R squares of the models varied from 41.9% to 44.1%. The F test was statistically significant in all three models, indicating that the null hypothesis of misspecification was rejected.

The second estimation round refers to the sample of firms not involved in an ETS. The CCE's elasticity amounted to −0.121 in all three models. On the other hand, the energy intensity of revenues yielded an elasticity of −0.229. The one from Energy footprint amounted to −0.093. Finally, Carbon intensity's was estimated to be −0.074. One percentage variation of weighted ETS amounted to −0.005 base points increases of TQ, averaging between the values of the 4–6 model. All three models present a high value of the F test, indicating the statistical robustness of the model. The R squared varied from a maximum of 44.5% in Model 4 to a minimum of 42.5% in Model 5.

Finally, three statistical Models, 7–8–9, target the TQ from firms participating in ETS. The estimate of the CCE elasticity was equivalent to −0.120, while the one of Energy intensity was −0.239. The effects of the Carbon intensity and Energy footprint are statistically significant, respectively −0.066 and −0.089. The carbon price, in this case, yielded an elasticity of −0.007. The F test rejected in all cases the null hypothesis of model missspecification, and the R squared equaled 54.8% (Model 7), 52.4% (Model 8) and 53% (Model 9).

Discussion

While transitioning to a new energy system, listed companies would be affected by various risks, possibly hindering their financial performance. Governments in various institutions are establishing forms of permit trading to support companies engaging in decarbonization activities. The results of these institutional pressures should be visible in the relative value of assets proxied by TQ. The results of the estimation models presented robust evidence for the three hypotheses elaborated in the second section. First, the estimations show that CCE increases are met by reductions in TQ. This finding

Table 4 Estimated effects in terms of TQ SDs

Variable	Total sample (%)	In ETS (%)	Outside ETS (%)
Price	−2	−2.49	−2.09
CCE	−57.12	−72.2	−51.54
Energy Intensity	−60.65	−74.41	−56.61
Carbon Intensity	−17.32	−20.61	−17.02

Table 5 Literature Results in terms of TQ SDs

Study	van Emous et al. (2021)	Brouwers et al. (2018)	Wang et al. (2014)	Delmas et al. (2015)
Variable	CO2 Growth	Carbon Intensity	Carbon Footprint	Carbon Footprint
Sample	Firms from 53 countries 2004–2019	EU ETS over the period 2005–2012	Australia 2010	US 2004 to 2008
Effect	2.78%	−40.93%	39.39%	−98.55%

supports the H1. In other words, decarbonizing the total energy improves the relative market value of assets. Another interpretation could be that increasing reliance on carbon-based energy systems increases liabilities over the market value of assets, hindering company's financial performance.

The cost of permits generates a cost for non-abating firms within the ETS. However, the effects can be observed outside the sample. This could be related to two factors of listed companies. Their multinational production structure makes any listed companies indirectly related to energy production in major ETS jurisdictions, meaning that the value of ETS permit's prices might affect even non-ETS TQ. Indeed, the effect is minor for such companies. A robustness check of this effect is provided by comparing the effects of the subsamples in terms of SDs. This value is calculated by multiplying the elasticity estimate by the SD of the variable in the subsample and then dividing it by the SD of the subsample's TQ. The results are reported in Table 4.

The SD of the estimation slightly changes from the total sample due to missing observations. For instance, the effect of the increase equivalent to one SD of carbon prices (3.821) is reflected in a reduction of 2% of TQ SD. This is higher for ETS companies, with a perceived SD of 4.209. Non-ETS companies presented an SD of ETS prices equal to 3.693, a reduction comparable to 2.09% of TQ SD. Similar discrepancies were found for the CCE, Energy Intensity and Carbon Intensity. Energy intensity presents a slightly larger effect than CCE, and greater than Carbon intensity for all samples. This might indicate that decarbonization efforts might pay better under energy efficiency measures rather than corporate mitigation policies.

We found evidence for H2 indeed, but we also for H3. The negative effects could be intended conversely as improvements in the case of decarbonization. The results indeed indicate that listed companies participating in ETS perceive greater burdens from carbon prices. Still, companies also perceive greater benefits from reducing carbon intensity, particularly CCE and Energy intensity. Even accounting for an increase comparable to the one occurring in the EU ETS between 2021 and 2022 (a rise of about 50 euros in less than one year, comparable here to less than 10 SD), would still not be enough to be compared to a reduction in one SD of energy intensity or CCE in ETS companies. In Table 5, there are collected various references where effects are calculated similarly, providing comparability with our results. The subsamples in our case are comparable to (Brouwers et al. 2018).

The role of institutional signals for decarbonization is relevant. Despite some outliers, sparse studies supported this hypothesis despite some outliers. It can be inferred which studies are dealing indirectly too climate policies by the location of listed firms and the timeframe of the available citations. For instance, the study of Delmas et al. (2015) is in line with our results. However, the lack of any climate policy in the US and the counterevidence made by van Emous et al. (2021) stirs the solidity of the former's results. In addition, Brouwers et al. (2018) carbon intensity increases were negatively related to TQ, with an order of magnitude greater than in our study. Yet, he focused on companies dealing with the European ETS. In our case, the subsample was diluted by companies participating in other ETS, where carbon prices have been substantially lowering at the time of observation. As a final example, Wang et al. (2014) found that carbon intensity was positively related to TQ in Australia, a highly dependent on climate-intensive energy systems.

The reduction of CCE is probably one of the most comprehensive corporate measures of decarbonization available in literature. It considers not only the weight of direct emissions, but also the ones from the energy system. This is quite relevant, as corporations are often multinationals dealing with various energy systems, located in different jurisdictions. Multinationals can organize their business activities in places where climate policies are less stringent and demand more Energy (thermal or electric it might be). This phenomenon is called carbon leakage (Jakob 2021). It is here briefly discussed the case when this happens. The relocation of industrial activity to avoid costly transitions implies that indirect emissions increase compared to a scenario of no carbon leakage. The company buys electricity from an energy provider that does not abide to decarbonization, meaning that it can be more polluting than one abiding to ETS for instance.

When this relocation and increase in global pollution occurs, it is problematic from a policy perspective, but also from a corporate one. When looking at the total carbon intensity in terms of net revenues, it is possible to see greater dependence on emissions if revenues do not grow more than the total carbon footprint. It is environmentally concerning when looking at what corporations are using, which is Energy. Polluting more for a slight increase in energy consumption might be a redundant corporate policy, even hypocritical if the goal was to reduce emissions in the jurisdiction applying climate policies. Thus, boards interested in actually decarbonizing their businesses should be interested in how much the energy they are acquiring from external providers is clean. Reducing indirect emissions is as relevant as reducing direct emissions for the sake of decarbonization.

The economic measure to evaluate carbon is provided by taxes or as evaluated in this paper, by ETSs. Carbon prices are one aspect that requires further assessment. In our study, we could not match each ISIN with an account in the various ETS systems. Since the accounts from each market are disjointed, this would require a specific effort to match multiple financial and non-financial statements. Focusing on one market could be more efficient. This gap could be filled by matching the European Transaction Log companies to corporate financial performance. Very little is known about the actual value of each firm's trading position and the utility in owning permits. Chinese pilots have been found to be effective instruments to reduce stock crash risk (Xie et al. 2023), meaning that they have a hedging potential. Our results of a negative effect of ETS participation may originate in the price level. The additional ETS 2 in European Union will increase covered emissions, reducing the number of excluded companies, potentially driving up permits' demand and shifting them from liability to assets.

Theoretical aspects could be investigated further in a future article as well. Advancements in investment theory under the sustainable paradigm should be necessary for this field. One possible road was studied recently. It investigated a Green Q-theory, studying the implications of adopting emission reduction policies in oil and gas companies (Faria et al. 2022). While the paper stated that emission reduction negatively affected the company's financial performance, there is no reference to emission trading. A possible gap could be the implication of carbon trading (under voluntary or compliance premises) for q-theory. Further empirical assessments could involve matching accounts from the European Transaction Log and the listed companies participating in the ETS to assess whether carbon price variations induced TQ variations. Similar approaches could be repeated across ETS around the world. The Chinese trading system is yet to be empirically investigated as well.

Conclusion

This paper investigated within the discussion of transition risk, which are the effects on growth opportunities proxied by the target variable TQ due to corporate decarbonization policies. From this general research question, the role of carbon pricing was also assessed. Three hypotheses were defined according to the core elements in the literature. One related to the negative relation carbon intensity. The second is the effect of carbon pricing on the target variable and whether participation in ETS made a difference. According to our results, decarbonization is related to increases in growth opportunities. However, the cost of weighted ETS prices was negatively related to growth. This means that although decarbonization frees listed companies from the necessity to surrender permits and sell them, they are a cost to corporate activities. The test on the third hypothesis presented a positive synthesis from the previous two. Companies involved in the ETS present greater utility in decarbonizing compared to those exempted. This means that the policy instrument is a facilitator of reaching climate objectives.

Previous studies addressed sparsely the role of emission trading systems and their role in increasing the effects of decarbonization. The number of indicators used in this study allowed the comparison of the results with other studies, and we found that this work is in line with previous studies. It is worth noting, however, that it is possible to find outliers and exceptions that need to be addressed carefully in future studies. Our work opened a new gap regarding the quantitative effects of carbon pricing and the implications of high prices over CFP. Our results occurred in years where compensation costs for climate-forcing activities were relatively low compared to recent price peaks, such as the EU ETS. Indeed, we cannot say from our models whether the negative effects of participation in the ETS are related to the policy structure or the level of prices. Future studies need to investigate further the role of ETS permits as assets or liabilities for listed companies.

Appendix

Geographical differences

The geographical differences occurring in CCE are determined not by the place of the financial market under consideration but instead by the dominant technologies in place within that nation. While it is not known here which is the causal relationship between the two variables, listed companies represent the collection of firms capable of acquiring capital from different channels to fund technological advancements. This potential is not limitless, and divergences will occur inevitably. For instance, the median CCE in the EU is radically lower than the CCE of listed companies in India or China. Except for Poland, this is potentially due to the systematic differences in technologies involved by listed companies. A synthetic portrait of the geographical differences is presented in Fig. 2.

No clear north–south divergence emerges. For instance, Brazil has a median CCE of 0.035 CO2t/Gj, while the United States of 0.096 CO2t/Gj. Similarly, the former performance is lower than neighbouring Argentina and European Poland. The indicator is affected by the type of company listed in one country and which of these firms is disclosing the performance. From a systematic point of view, these biases should not be

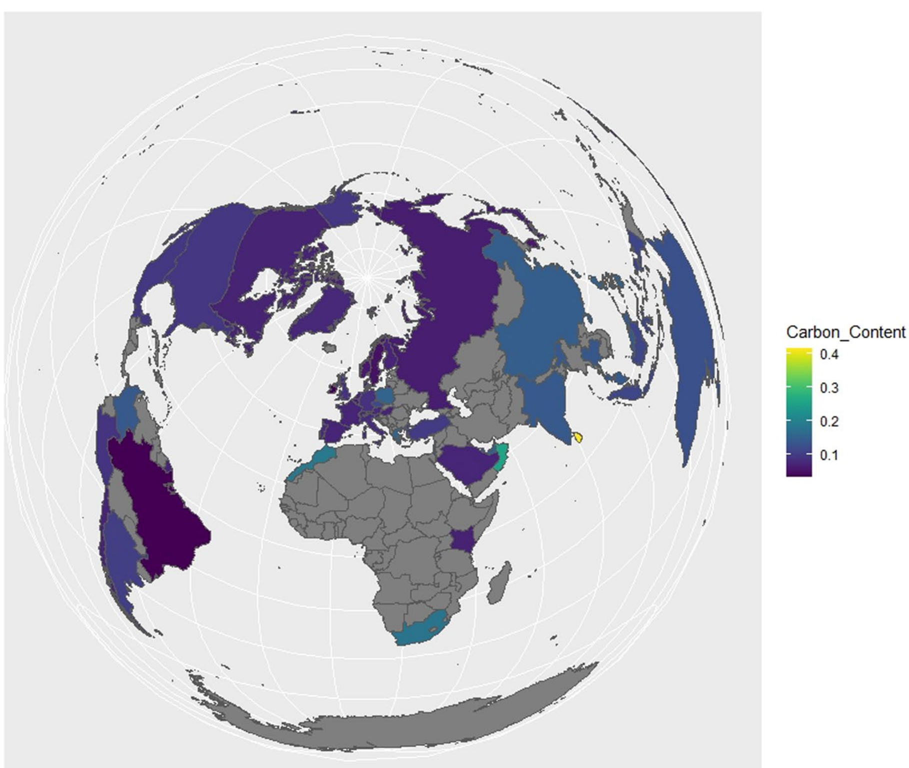

Fig. 2 Median Carbon Content of Energy of listed Companies according to Country, 2011–2020 period

endogenous. A limitation presented by this indicator is the exclusion of state-owned companies. It is possible to find high emitters such as Aramco among these companies. The result of such exclusion is that the median CCE of Saudi Arabia is comparable to a European Nation, while its CO2 emission per capita is more like the US. The US financial markets condensate the most significant historical polluters internationally (Griffin and Heede 2017; Heede 2014). However, this occurrence should not wholly explain the divergence in CCE between Saudi Arabia and the US. It is explained by American companies compounding the tail of CCE distribution. US and probably Saudi Arabia companies tend to be more carbon-intensive than European ones. For instance: companies tend to disclose energy indicators far less, probably due to the role of the government in the economy, which leads to less non-financial disclosure available for the sample.

Sectoral differences

As previously stated, heterogeneity emerges at the national and sectoral levels, while the variability of observation occurs due to an omission of non-financial disclosure. It is reported in Table 6 the differences across GICS 2 sectors across three major countries: the United States, Germany, and China. Coming from three different continents, these are among the most industrialized and have the greatest internal markets on the planet. It emerges that the Chinese median CCE of listed companies is higher than US ones, which is higher than those in Germany. This was expected, given the consolidated history of climate policy in Germany against the previous two nations. Secondly, the Chinese economy was opened to financial markets recently and adopted climate mitigation strategies again recently. Outside the GICS 2 sector of Materials, Germany presents a CCE across almost half of the Chinese sector. Thus, it is unusual the low median CCE in the Energy sector of China for a nation that generates 62.2% of its electricity through Coal (Newell and Raimi 2020). The reason for such performance is probably due to the level of participation of the Chinese government in the ownership of Energy companies (Yi-chong 2012). The energy sectors in US and Germany are entirely privately owned.

The previous two subsections presented aspects of the CCE of listed markets. While the sample presents limitations, it is possible to glimpse the performances across nations and sectors. Among the limitations, the omission of environmental performances is one major. From a statistical point of view, this should not affect the analysis result, as the bias affects the independent variable rather than the dependent. Secondly, the bias

Table 6 CCE in GICS 2 sectors, median of listed companies, reference: 2020

GICS 2	Communication services	Consumer discretionary	Consumer staples	Energy	Financials
United States	0.106	0.094	0.081	0.083	0.098
Germany	0.070	0.090	0.063	0.054	0.082
China	0.178	0.153	0.106	0.080	0.170
GICS 2	**Health care**	**Industrials**	**Information technology**	**Materials**	**Real estate**
United States	0.084	0.086	0.109	0.072	0.076
Germany	0.082	0.084	0.074	0.092	0.069
China	0.137	0.115	0.166	0.140	0.172

seems to be specific to an educated guess to the level of participation of the state in one sector. Energy and Utilities are strategic areas where state control is higher. Thus, disclosure coming from listed companies is necessarily vacant. It is unclear what effect the opening to international markets might have on environmental performance.

Market concentration

Figure 3 presents the concentration of GHG emissions in disclosing firms. The lower the curve, the higher the concentration. Of the three, the Chinese subsample presents the highest concentration.

We calculated in Table 7 the average CCE of energy use according to the time and nation available from listed companies. While this is not representative of the dynamic of the entire economy, it gives a picture of the performance of the biggest and most competitive firms.

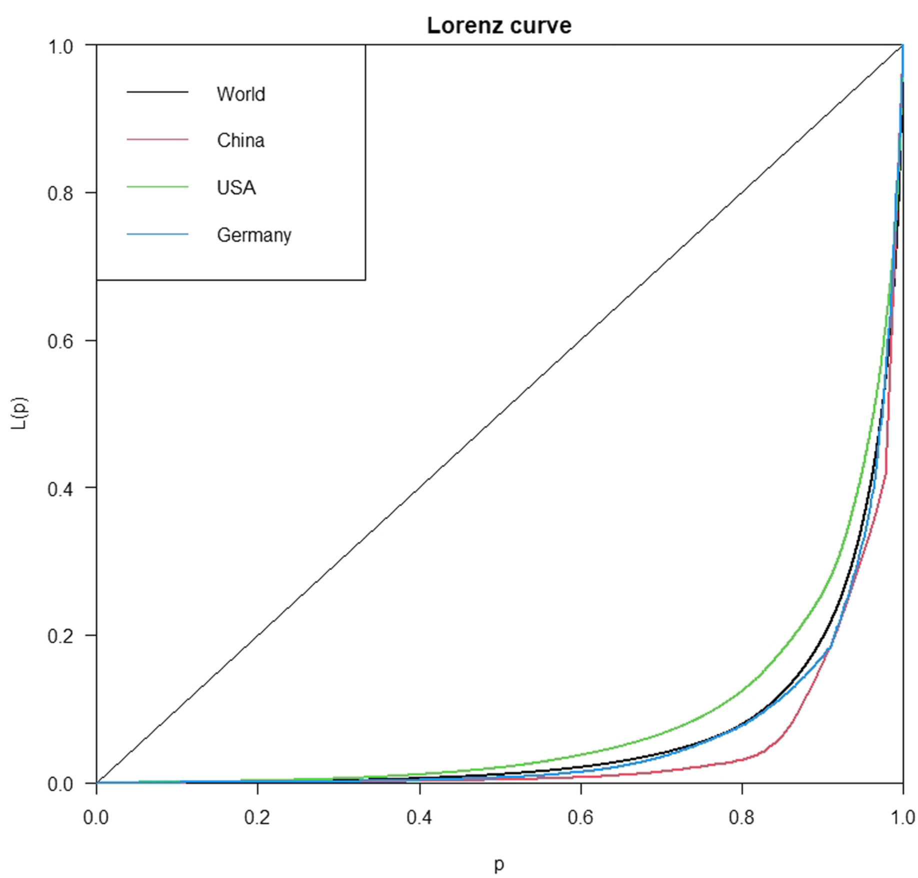

Fig. 3 Lorenz Curve for CO2 total emission of listed companies in reference markets, 2020

Table 7 Median CCE for the Period 2011–2020, calculated across sectors and time within the country

Country	CCE of energy use tCO2/Gj	Country	CCE of energy use tCO2/Gj
Argentina	0.104	Mexico	0.094
Australia	0.128	Morocco	0.189
Austria	0.079	Netherlands	0.072
Belgium	0.066	New Zealand	0.068
Brazil	0.033	Norway	0.060
Canada	0.071	Oman	0.254
Chile	0.073	Peru	0.092
China	0.146	Philippines	0.154
Colombia	0.138	Poland	0.155
Czech Republic	0.119	Portugal	0.081
Denmark	0.076	Qatar	0.143
Finland	0.072	Russia	0.065
France	0.074	Saudi Arabia	0.073
Germany	0.087	Singapore	0.117
Greece	0.157	Slovenia	0.084
Hungary	0.072	South Africa	0.180
India	0.138	South Korea	0.060
Indonesia	0.115	Spain	0.073
Ireland	0.035	Sri Lanka	0.415
Israel	0.130	Sweden	0.051
Italy	0.082	Switzerland	0.078
Japan	0.067	Taiwan	0.153
Kenya	0.070	Thailand	0.137
Kuwait	0.073	Turkey	0.100
Luxembourg	0.080	United Arab Emirates	0.152
Malaysia	0.143	United Kingdom	0.090
		United States of America	0.093

Abbreviations

CCE	Carbon content of energy
CEP	Corporate environmental performance
CFP	Corporate financial performance
ETS	Emission trading system
HAC	Heteroskedastic-autocorrelated consistent
SD	Standard deviation
TQ	Tobin's quotient

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References

André FJ, de Castro LM (2017) Scarcity climate rents under a carbon price with oligopoly competition. Oxf Econ Pap 69(2):470–495. https://doi.org/10.1093/oep/gpw073
Bajaj M, Chan Y-S, Dasgupta S (1998) The relationship between ownership, financing decisions and firm performance: a signaling model. Int Econ Rev 39(3):723–744. https://doi.org/10.2307/2527397
Bank of England, Scott M, Huizen JV, Jung C (2017) The Bank of England's response to climate change. Bank of England Q Bull 98–109
Berg F, Fabisik K, Sautner Z (2020) Rewriting history II: the (un)predictable past of ESG ratings. SSRN Electron J. https://doi.org/10.2139/ssrn.3722087
Bitat A (2018) Environmental regulation and eco-innovation: the Porter hypothesis refined. Euras Bus Rev 8(3):299–321. https://doi.org/10.1007/s40821-017-0084-6
Bolton P, Kacperczyk M (2021a) Global pricing of carbon-transition. Risk. https://doi.org/10.3386/w28510
Bolton P, Kacperczyk M (2021b) Do investors care about carbon risk? J Financ Econ. https://doi.org/10.1016/j.jfineco.2021.05.008
Brouwers R, Schoubben F, Van Hulle C (2018) The influence of carbon cost pass through on the link between carbon emission and corporate financial performance in the context of the European Union Emission Trading Scheme. Bus Strateg Environ 27(8):1422–1436. https://doi.org/10.1002/bse.2193
Cao D, Lorenzoni G, Walentin K (2019) Financial frictions, investment, and Tobin's q. J Monet Econ 103:105–122. https://doi.org/10.1016/j.jmoneco.2018.08.002
Capasso G, Gianfrate G, Spinelli M (2020) Climate change and credit risk. J Clean Prod 266:121634. https://doi.org/10.1016/j.jclepro.2020.121634
Cooper SA, Raman KK, Yin J (2018) Halo effect or fallen angel effect? Firm value consequences of greenhouse gas emissions and reputation for corporate social responsibility. J Account Public Policy 37(3):226–240. https://doi.org/10.1016/j.jaccpubpol.2018.04.003
Delmas MA, Nairn-Birch N, Lim J (2015) Dynamics of environmental and financial performance: the case of greenhouse gas emissions. Organ Environ 28(4):374–393
Devalle A, Fiandrino S, Cantino V (2017) The Linkage between ESG performance and credit ratings: a firm-level perspective analysis. Int J Bus Manag 12(9):53. https://doi.org/10.5539/ijbm.v12n9p53
Faria JR, Tindall G, Terjesen S (2022) The green Tobin's q: theory and evidence. Energy Econ 110:1033. https://doi.org/10.1016/j.eneco.2022.106033
Friede G, Busch T, Bassen A (2015) ESG and financial performance: aggregated evidence from more than 2000 empirical studies. J Sustain Financ Investment 5(4):210–233. https://doi.org/10.1080/20430795.2015.1118917
Fu X, Li MC, Molyneux P (2021) Credit default swap spreads: market conditions, firm performance, and the impact of the 2007–2009 financial crisis. Empir Econ 60(5):2203–2225. https://doi.org/10.1007/s00181-020-01852-0
Gallego-Alvarez I, Segura L, Martinez-Ferrero J (2015) Carbon emission reduction: the impact on the financial and operational performance of international companies. J Clean Prod 103:149–159
Gao Y, Zhao C, Sun B, Zhao W (2022) Effects of investor sentiment on stock volatility: new evidences from multi-source data in China's green stock markets. Financ Innov 8(1):77. https://doi.org/10.1186/s40854-022-00381-2
Griffin P, Heede CR (2017) The carbon majors database. CDP Carbon Majors Rep 2017:14
Guastella G, Mazzarano M, Pareglio S, Spani RC (2022) Do environmental and emission disclosure affect firms' performance? Euras Bus Rev. https://doi.org/10.1007/s40821-021-00195-9
Heede R (2014) Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010. Clim Change 122(1–2):229–241. https://doi.org/10.1007/s10584-013-0986-y
Hennessy CA (2004) Tobin's Q, Debt Overhang, and Investment. J Financ 59(4):1717–1742. https://doi.org/10.1111/j.1540-6261.2004.00677.x
Ilhan E, Sautner Z, Vilkov G (2020) Carbon Tail Risk. Rev Financ Stud. https://doi.org/10.1093/rfs/hhaa071
Jakob M (2021) Why carbon leakage matters and what can be done against it. In: One Earth, vol 4, Issue 5. Cell Press, pp 609–614. https://doi.org/10.1016/j.oneear.2021.04.010
Landi G, Sciarelli M (2019) Towards a more ethical market: the impact of ESG rating on corporate financial performance. Soc Responsibil J 15(1):11–27. https://doi.org/10.1108/SRJ-11-2017-0254
Lang LHP, Stulz RM (2017) Tobin ' s q, corporate diversification, and firm performance. J Polit Econ 102(6):1248–1280
Lewandowski S (2017) Corporate carbon and financial performance: the role of emission reductions. Bus Strateg Environ 26(8):1196–1211. https://doi.org/10.1002/bse.1978
Liesen A, Figge F, Hoepner A, Patten DM (2017) Climate change and asset prices: Are corporate carbon disclosure and performance priced appropriately? J Bus Financ Acc 44(1–2):35–62. https://doi.org/10.1111/jbfa.12217
Makridou G, Doumpos M, Galariotis E (2019) The financial performance of firms participating in the EU emissions trading scheme. Energy Policy 129:250–259. https://doi.org/10.1016/j.enpol.2019.02.026
Mysen T (2012) Sustainability as corporate mission and strategy. Eur Bus Rev 24(6):496–509. https://doi.org/10.1108/09555341211270519
New Zeland Ministry for the Environment (2017) Measuring emissions: a guide for organisations

Newell RG, Raimi D (2020) Global energy outlook comparison methods: 2020 update. Resources for the Future
Porter ME, van der Linde C (1995) Toward a new conception of the environment-competitiveness relationship. J Econ Perspect 9(4):97–118
Rubbaniy G, Khalid AA, Rizwan MF, Ali S (2022) Are ESG stocks safe-haven during COVID-19? Stud Econ Financ 39(2):239–255. https://doi.org/10.1108/SEF-08-2021-0320
Siegmeier J, Mattauch L, Edenhofer O (2018) Capital beats coal: how collecting the climate rent increases aggregate investment. J Environ Econ Manag 88:366–378. https://doi.org/10.1016/j.jeem.2017.12.006
Smirlock BM, Gilligan T, Marshall W (2016) American Economic Association Tobin's q and the Structure-Performance Relationship Author (s): Michael Smirlock, Thomas Gilligan and William Marshall Source. Am Econ Rev 74(5):1051–1060
Stevens JL (1990) Tobin's q and the structure-performance relationship: comment. Am Econ Rev 80(3):618–623
Suzuki K, Chida R (2017) Contribution of R&D capital to differences in Tobin's q among Japanese manufacturing firms: Evidence from an investment-based asset pricing model. J Jpn Int Econ 43:38–58. https://doi.org/10.1016/j.jjie.2016.12.001
Task Force on Climate-related Financial Disclosures, & TSFD (2017) Recommendations of the task force on climate-related financial disclosures
Trebilcock MJ (2014) Dealing with losers: the political economy of policy transitions. Oxford University Press
van Emous R, Krušinskas R, Westerman W (2021) Carbon emissions reduction and corporate financial performance: the influence of country-level characteristics. Energies 14(19):6029. https://doi.org/10.3390/en14196029
Wang L, Li S, Gao S (2014) Do greenhouse gas emissions affect financial performance?—an empirical examination of Australian public firms. Bus Strateg Environ 23(8):505–519
Wernerfelt B, Montgomery CA (1988) Tobin's q and the importance of focus in firm performance. Am Econ Rev 78(1):246–250
Wooldridge JM (2010) Econometric analysis of cross section and panel data. MIT Press, Cambridge
Xie Z, Yang M, Xu F (2023) Carbon emission trading system and stock price crash risk of heavily polluting listed companies in China: based on analyst coverage mechanism. Financ Innov 9(1):71. https://doi.org/10.1186/s40854-023-00475-5
Yi-chong X (2012) The political economy of state-owned enterprises in China and India. Palgrave Macmillan
Zha G, Li Y, Tang Q (2022) Impacts of emissions trading scheme initiatives on corporate carbon proactivity and financial performance. J Risk Financ Manag 15(11):526. https://doi.org/10.3390/jrfm15110526
Zhang Z, Zhao R (2022) Carbon emission and credit default swaps. Financ Res Lett 50:103286. https://doi.org/10.1016/j.frl.2022.103286

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