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Environmental concerns and financial performance: evidence from the EU regulatory framework

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Abstract: We analyse the impact of carbon and greenhouse gas emissions on firms' accounting and market performance. Over a sample of 115 non-financial firms from 9 European countries during the 2008–2016 period, our results suggest that higher volume of both country-level carbon and greenhouse emissions have, on average, a positive and statistically significant impact on firms' accounting performance. However, no statistical effect is found in terms of stock market performance. The results are more relevant in the case of firms with higher levels of equity and higher levels of intangible assets. We document the existence of an inverse U-shaped relation between country-level greenhouse emissions and firms' performance suggesting that, after a certain point, greenhouse gas emissions negatively affect firms' performance. Our results are robust to different estimation technics and control variables, to the consideration of the financial crisis period, and to the inclusion of financial firms in the sample.

Keywords: carbon emissions; greenhouse gas emissions; accounting performance; market performance; EU.

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1 Introduction

The last decades have witnessed an increasing acceptance of environmental concerns related to climate change, pollution, and deforestation around the globe. The search for solutions to these problems is one of the big current challenges from a political perspective and from the development of new business models and practices. In an attempt to give response to the necessary changes to avoid the worst effects of climate change and emissions, several policies and regulations are being applied. The Emission Trading Scheme (ETS) in the European Union[1] and carbon taxes (or similar pricing mechanisms) in several other countries are examples of these efforts. The ETS "*is a cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively*". The EU ETS is defined under the "cap and trade" principle. The cap is established on the basis of the total amount of emissions by firms inside the system. The logic of this system is that, as the cap is reduced over time, the total emissions will decrease as well. Firms can receive or buy emission allowances that can be traded if needed.[2] The basic reasoning behind this legal framework is to create incentives for firms to invest on renewable and clean energies and to progressively reduceemissions.

A growing body of business and financial literature has examined the efforts of firms to be greener and its effects in terms of corporate performance. The results obtained so far are, however, still inconclusive. For instance, King and Lenox (2001), Cohen and Winn (2007), Dean and McMullen (2007), Esty and Winston (2009), among others, argue that higher environmental quality can be useful for firms to increase profits and to improve competitive advantages. On the other hand, as Wang et al. (2014) show, there is also evidence of a positive correlation between greenhouse gas emissions and corporate financial performance.

Our paper aims to contribute to this field of research by shedding some additional light on the impact of different country-level variables, capturing the relevance of carbon (CO2) and greenhouse gas emissions, on the accounting and stock market performance of firms. We examine a sample of 115 non-financial firms from nine European countries during the 2008–2016 period. Our results indicate that higher volume of both CO2 and greenhouse gas emissions have, on average, a positive and statistically significant impact on sales, as a proxy of firm accounting performance. We find the opposite relation when using a proxy for market performance as dependent variable. This result, however, is not statistically significant at conventional levels. Moreover, our results present evidence on the role that specific firm-level characteristics play to shape the impact of emissions on firms' financial performance. Specifically, our empirical findings show that although, on average, accounting performance is positively related with greenhouse gas emissions, this relation is more relevant for firms with higher levels of equity over total assets and for firms with a large share of intangible assets in their balance sheets. Additionally, our results suggest that CO2 emissions negatively affect the market performance of firms with higher levels of the equity-to-total assets ratio.

Furthermore, in line with recent evidence (e.g. see Trumpp and Guenter, 2015 or Hailemariam et al., 2020) we also find empirical evidence for a non-linear relation between country-level greenhouse gas emissions and firms' accounting performance suggesting that, after a certain point, an increased level of this type of emissions negatively affects accounting performance. Our results are robust to different specifications of the econometric model, to the effect of the Global Financial Crisis (GFC), and to the consideration of financial services providers in our sample of firms.

The rest of the paper is organised as follows. Section 2 presents in more detail the theory behind our empirical study. Section 3 describes the empirical method, the sample, and variables used in the empirical analysis. Section 4 presents the empirical results and robustness tests. Finally, Section 5 concludes.

2 Theoretical background

The nature of the relation between contaminating emissions and financial performance is not yet entirely clear. In an attempt to clarify the relation between emissions and financial performance, several studies have tried to incorporate the influence of external factors such as the role played by financial and economic development and / or the impact of firm-level characteristics in their empirical analysis (see Busch and Lewandowski, 2017, for a complete review). Hence, globally speaking, the literature that analyses this phenomenon can be divided into two different strands.

The first strand of research has focused on analysing the effects of country-level factors, such as the financial and/or economic development and the regulatory framework, on the relation between CO2 performance and firm financial (economic) performance. Among others, the papers by Tamazian et al. (2009) and Tamazian and Rao (2010) empirically examine the link between economic development and environmental quality and the role played by financial development and institutional quality on the above-referred relation. Their results show that both economic and financial development positively affect environmental quality in their sample of BRIC and transitional economies. In the same vein and more recently, Hailemariam et al. (2020) examine the relation between economic growth and CO2 emissions by considering the role of income inequality in CO2 emissions function. Their empirical findings support that an increase in top income inequality is positively associated with CO2 emissions. Moreover, their results reveal a nonlinear relation between economic growth and CO2 emissions, consistent with an environmental Kuznets curve and suggesting the existence of a nonlinear relation (inverse U-shaped) between economic development and environmental quality.

Regarding the impact of regulatory features and, particularly, considering the new regulatory framework in Europe, over a sample of German firms, Oestreich and Tsiakas

(2015) find that, during the first few years of the EU ETS, firms that received free CO2 emission allowances, on average, significantly outperformed firms that did not. Their result may suggest the presence of a large and statistically significant "CO2 premium", which could be mainly explained by the higher cash flows due to the free allocation of CO2 emission allowances that these firms benefited from. Other papers have focused specifically on the effects of movements in the price of CO2 allowances on the returns of European electrical power firms (e.g., Oberndorfer, 2009; Veith et al., 2009; Koch and Bassen, 2013). The main result of this strand of research is the identification of a linear and positive relation between the price of CO2 allowances and stock prices of the European power sector. However, even in such a narrow problem there are contradictory results. Contrary to this evidence, Clarkson et al. (2015), for instance, document that CO2 allowances have no impact on the stock market valuation of firms.

Other papers have dealt with the relevance of the well-known "rebound effect" potentially affecting the results of those policies and mechanisms that aim to reduce the most negative environmental effects of industrialisation. As Freeman (2018) states, the paradox underlying the rebound effect is that, due to secondary effects, improvements in resource efficiency provide smaller reductions in the consumption of energy and/or material resources than are expected. The rebound effect has played, therefore, a role in economic growth, however its negative impact in terms of environmental performance has yet to be properly addressed. According to Font Vivanco et al. (2016), an appropriate policy design is key to avoid additional rebound effects and environmental trade-offs. From their discussion, cap-and-trade systems as well as energy and carbon taxes, when designed appropriately, emerge as the most effective policies in setting a ceiling for emissions and addressing energy use across the economy.

The second strand of the literature focuses on how firm specific characteristics and actions may affect the relation between contaminating emissions and financial performance. Therole of information disclosure for firms' performance has been analysed in Clarkson et al. (2015), Liesen et al. (2017), Shrivastava and Tamvada (2019), and Wang et al. (2019), among others. Shrivastava and Tamvada (2019) classify the greening activities of firms in terms of their tangibility (tangible *vs* intangible) and visibility (external – aimed at outside stakeholders and processes *vs* internal - aimed at inside stakeholders and processes). Furthermore, Shrivastava and Tamvada (2019) examine the impact of the greening activities on the firms' performance considering such characteristics as the firms' age and size. Their results show that while both external and internal greening strategies affect performance for young and small firms (notably effective are external tangible strategies), internal greening strategies (tangible and intangible) are more important for middle-aged firms and large firms. Liesen et al. (2017) focuses on corporate disclosures of greenhouse gas and CO2 emissions. Their results show that greenhouse gas emissions are relevant for investors and, although less evident, the same applies to CO2 emissions. Accordingly, information costs associated with CO2 emissions management and disclosures do not present a burden on corporate financial resources. Increased transparency on disclosures might increase market efficiency and translate into important benefits in terms of investment decisions. Currently, financial markets seem to be inefficient in pricing publicly available information on CO2 disclosure and performance and, according to Clarkson et al. (2015), the valuation impact of CO2 emissions is unlikely to be homogenous across firms or even industries.

In a more recent paper, Wang et al. (2019) investigate the stock market response to firm disclosure of positive environmental information. Their results, obtained over a sample of 327 media releases related to positive environmental activities of firms in the New York Stock Exchange from January 2005 to December 2014, indicate that announcements of future firms' environmental activities lead to the largest favourable stock market reactions. There is no guaranteed link, however, from this type of information to environmental outcomes.

Using nonlinear estimates, the results obtained by Lewandowski (2017) support the idea that it pays to be green for firms with superior CO2 performance but not in the case of firms with inferior CO2 performance. Moreover, this author also shows that improvements in CO2 performance appear to be linearly related to financial performance but negatively related to stock market performance. In other words, it seems that, according to his results, even though enhancements in CO2 performance may result in increasing profitability, firms face a penalty from investors when they improve their CO2 performance. These contradictory findings help to understand why firms have been slow to respond with effective action to tackle climate change, in spite of growing regulatory pressure.

The impact of management tools to reduce contaminating emissions were also addressed in Hörisch et al. (2015). Considering a sample of the largest firms of five industrialised countries, the results show a positive impact of the implementation of internal management tools on the reduction of the environmental impact per unit of revenues generated. Following this line, Shrivastava and Tamvada (2019) extend this analysis and refine the managerial actions of firms. In the attempt to provide more light on the determinants of corporate green practices, Liu (2018) specifically introduces the role of board gender diversity and demonstrates that firms with greater board gender diversity are less often sued for environmental infringements. However, CEO gender is linked to reduced environmental litigation only in those firms with low female board representation.

To the best of our knowledge, however, there is no empirical evidence on the effects of country-level measures of CO2 and greenhouse gas emissions on firms' accounting and market performance and on how this influence could be shaped by the individual firm- level characteristics in terms of size, equity level, and tangibility of assets. Given the existent debate about the association between emissions and financial performance, we aim to contribute to shed light on its understanding by examining the existence of potential non-linear relations and the extent to which the global financial crisis 2007/2008 may affect the sign of this relation.

3 Empirical analysis

3.1 Sample

We use several main data sources. Firm-level information comes from the ORBIS Database (Bureau Van Dijk). It contains comprehensive information on financial statements, ratings, and intelligence of firms across the globe. Whenever they are available, we use consolidated balance-sheet and income-statement data. We delete any unconsolidated group entries to avoid double counting and only include the unconsolidated data of firms for which this is the only type of information available in ORBIS.[3] Initially, we selected non-financial firms from the most important European stock market indexes: CAC 40, DAX (DEUTSCHER AKTIENINDEX), FTSE MIB

INDEX, IBEX 35, and EURO STOXX 50. This allowed us to have an initial sample of 150 firms from 12 different industries. Given that we use lagged values for the firm-level explanatory variables, we eliminate those firms for which we do not have data for more than three consecutive years. We also exclude firms with negative asset and equity value. Moreover, we consider only firms that have no missing data for all the variables needed for our baseline empirical specification. Given all these data constraints, our final sample is made up of an unbalanced panel for a maximum of 115 firms in nine European countries during the 2008–2016 period. This makes a maximum of 775 firm-year observations in our sample.

Emissions data comes from the European Environment Agency (EEA) and Eurostat Statistics. Macroeconomic data are obtained from the International Financial Statistics of the International Monetary Fund (IMF). Panel A of Table 1 shows the list of countries and the number of firms and observations per country. In Panel B we show the distributionof firms and observations per industry.

3.2 Methodology

We use the following panel data estimation to analyse the impact of the different country-level variables, capturing the relevance of both CO2 and greenhouse gas emissions, on the corporate performance of firms:

$$\begin{aligned} PERFORMANCE_{i,j,k,t} = {} & \beta_0 + \beta_1 EMISSIONS_{kt} + \beta_2 FIRM_{ijkt-1} \\ & + \beta_3 COUNTRY_{jt} + \pi_j + \sigma_k + \varphi_t + \mu_i + \varepsilon_{ijt} \end{aligned} \quad (1)$$

where i, j, k, and t refer to the firm, country, industry, and year, respectively. Our dependent variable, $PERFORMANCE_{ijk}$, measures the annual firm-level performance at both accounting- and stock market-level perspective. In particular, we define two measures of firms' performance:

1 the annual ratio of total sales-to-total assets ($PERFORMANCE\_ACC_{ijkt}$)

2 the stock market performance, proxied by the average ratio of the market price of the stock and the accounting profits per share ($PERFORMANCE\_MKT_{ijkt}$).

The consideration of these two alternative dependent variables aims to check whether and how the impact of country-level emissions on firms' performance could differ when considering two different dimensions of firm-level performance: accounting and market perspective.

$EMISSIONS_{kt}$ is a vector of variables that measure the relevance of emissions in each country and year. It is composed of two different variables: carbon dioxide emissions (*DIOXIDEkt*) and greenhouse gas emissions ($GREENHOUSE_{kt}$).

We include additional firm- ($FIRM_{ijkt-1}$) and country- ($COUNTRY_{jt}$) level control variables. As firm-level control variables, we include asset size ($SIZE_{ijkt-1}$), capitalisation ($EQUITY_{ijkt-1}$), and tangibility of firm's assets ($TANGIBILITY_{ijkt-1}$). As country-level variables, we include the natural logarithm of GDP per capita ($LOGGDPpc_{jt}$) and the annual growth of inflation rate ($\Delta INFLATION_{jt}$).

π_j, σ_k, φ_t are the set of industry, country, and year dummies fixed effects to control for characteristics that are specific to each country, each industry, and each year. These specific controls allow us to capture any unobserved firm-invariant effects that are specific to each country, each industry, and each year and that are not included in the regression. μ_i is a firm-specific effect, which is assumed to be constant for firm *i* over *t*. This firm-fixed effect accounts for firm heterogeneity with the intercept terms varying over individual firms. The inclusion of this firm fixed effect allows us to take into account other specific firm-level characteristics, such as corporate governance mechanisms, liquidity, or brand image, that potentially affect performance. ε_{ijkt} is a white-noise error term.

Table 1 Countries, firms and observations

PANEL A: Firms and observations per country		
Country	*#Firms*	*#Observations*
Belgium	2	14
Czech Republic	1	7
Germany	22	154
Spain	29	184
Finland	1	7
France	30	210
Ireland	1	7
Italy	20	137
Netherlands	9	55
Total	115	775
PANEL B: Firms and observations per industry		
Industry	*#Firms*	*#Observations*
Mining and quarrying	5	35
Manufacturing	59	405
Electricity, gas, steam and air conditioning supply	11	77
Water supply; sewerage, waste management and remediation activities	1	7
Construction	6	42
Wholesale and retail trade; repair of motor vehicles and motorcycles	6	38
Transportation and storage	6	37
Accommodation and food service activities	3	21
Information and communication	13	84
Real state activities	2	14
Professional, scientific and technical activities	1	7
Other services activities	2	8
Total	115	775

Panel A reports the number firms and observations included in the analysis from each country. In Panel B, we present the numberof firms and observations per industry (NACE Rev.2 classification). Our final sample consists of 116 firms from 9 European countries during the 2008–2016 period.

One potential problem inherent to our empirical analysis is the presence of endogeneity concerns among the firm-level variables. To address this potential econometric problem, we lagged the set of firm-level explanatory variables by one year. Thereby, we increase the reliability and robustness of our results with regard to the direction of the relation between environmental variables and financial performance. To further reduce the endogeneity concerns, we run specific model specifications in which the initial value of each dependent variable is included as an additional explanatory variable.[4]

3.3 Variables

We now describe in detail the proxies for our main variables of interest –firms' performance and emissions– and the set of control variables at both firm- and country-level. Tables 2 and 3 report the overall descriptive statistics and the correlation matrix for the main variables.

3.3.1 Key variables: firm financial performance and emissions variables

We define two main dependent variables. The first one is a proxy for firm-level accounting performance, the ratio total sales-to-total assets. The second is a proxy for firm-level market performance, measured as the ratio of stock market valuation over profits. To consider both measures of firms' financial performance allows us to test if there are differences on the effect of emissions based on accounting-based information or stock market-based information. Both variables are calculated using data from ORBIS database (Bureau Van Dijk). As reported in Table 2, Finish firms are the ones that, on average, present better levels of accounting performance (0.9005) measured through the sale-to-total assets ratio ($PERFORMANCE\_ACC_{ijkt}$). The minimum average value of this variable is found in Belgium (0.4159). In terms of market performance, Belgian firms are, precisely, the ones that present the best average value of stock market performance, $PERFORMANCE\_MKT_{ijkt}$, (32.4773); whereas Finland is the country with the lowest average values of this variable (18.7872).

We use *DIOXIDE* and *GREENHOUSE* as the main explanatory variables. Both of them are variables that proxy for environmental concerns at a country-level. The Kyoto Protocol (1997) defines greenhouse gases as a group of gases contributing to global warming and climate change. In particular, nowadays it covers seven types of greenhouse gases divided in two main categories:

C Non-fluorinated gases:

- a Carbon dioxide (CO_2)
- b Methane (CH_4)
- c Nitrous oxide (N_2O).

D Fluorinated gases:

- a Hydrofluorocarbons (HFCs)
- b Perfluorocarbons (PFCs)
- c Sulphur hexafluoride (SF_6)
- d Nitrogen trifluoride (NF_3).

Table 2 Descriptive statistics

	PERFORMANCE_ ACC	*PERFORMANCE_ MKT*	*SIZE*	*EQUITY*	*TANGIBILITY*	*DIOXIDE*	*GREENHOUSE*	*LOGGDPpc*	*ΔINFLATION*
Belgium	0.4159	32.4773	17.7672	0.3517	0.7295	75.7309	84.3928	10.7032	1.7183
Czech Republic	0.4578	26.4302	17.6686	0.4675	0.8012	85.6796	67.7528	9.9240	1.9234
Germany	0.7115	19.5180	17.9626	0.3215	0.5702	682.7698	74.8794	10.6848	1.2589
Spain	0.5665	28.3262	16.8780	0.3058	0.5848	216.212	121.6987	10.3241	1.3478
Finland	0.9005	18.7872	17.4839	0.3634	0.3349	49.5032	91.6914	10.7413	1.6201
France	0.6755	23.2109	17.6923	0.3525	0.6007	247.0951	89.6043	10.6265	1.1578
Ireland	0.8384	21.6785	17.1811	0.4618	0.6779	31.7196	107.5386	10.8923	0.3883
Italy	0.5483	28.8237	16.5379	0.2986	0.5237	285.3409	89.6956	10.4648	1.4466
Netherlands	0.7179	22.9793	17.6067	0.3135	0.5016	165.3669	92.4603	10.8382	1.5212
Mean	0.6316	24.8837	17.3122	0.3237	0.5710	317.7349	94.6315	10.5471	1.3188
Std. Dev.	0.4326	51.4210	1.6137	0.1639	0.2503	185.241	17.0988	0.1755	1.2257
Median	0.6021	15.6995	17.3583	0.3132	0.6232	249.6625	90.18	10.6124	1.2199
Minimum	0.0019	0	11.4097	0.0143	0.0004	27.7675	64.24	9.8742	-4.4799
Maximum	3.0138	925.696	21.7529	0.8251	0.9731	703.346	130.41	11.1547	6.3509

This table reports the main descriptive statistics for firm- and country-level variables included in our basic models. PERFORMANCE_ACC is the firm-level performance from an accounting perspective and it is proxied by the ratio sales-to-assets. PERFORMANCE_MKT is the firm-level performance from a market perspective and it is proxied by the ratio stock market price and profits per share. SIZE, EQUITY, and TANGIBILITY arefirm-level controls trying to capture firm size, proxied by the natural logarithm of firm's total assets; the capitalisation of the firm, proxied by the ratio equity-to-assets; and the tangibility of the firm, proxied by the ratio tangible assets-to-total assets. DIOXIDE and GREENHOUSE are country-level variables that measure CO_2 emissions and greenhouse gas emissions in each country and year. LOGGDPpc and ΔINFLATION are variables included to control for macroeconomic aspects on each country. They are calculated as the natural logarithm of per capita GDP and the annual inflation rate, respectively.

Table 3 Correlations

	PERFORMANCE_ACC	*PERFORMANCE_MKT*	*SIZE*	*EQUITY*	*TANGIBILITY*	*DIOXIDE*	*GREENHOUSE*	*LOGGDPpc*	*ΔINFLATION*
PERFORMANCE_ACC	1.0000								
PERFORMANCE_MKT	–0.0143	1.0000							
SIZE	–0.3797***	–0.0733**	1.0000						
EQUITY	0.2185***	0.1024***	–0.4635***	1.0000					
TANGIBILITY	0.0549*	0.0008	–0.2064***	0.4247***	1.0000				
DIOXIDE	0.0837***	–0.0519	0.1555***	–0.0211	–0.0036	1.0000			
GREENHOUSE	–0.0659*	0.0363	–0.2178***	–0.0409	0.0484	–0.5636***	1.0000		
LOGGDPpc	0.1436***	–0.0468	0.2350***	0.0409	–0.0385	0.3195***	–0.6423***	1.0000	
ΔINFLATION	–0.0128	–0.0456	–0.0292	–0.0015	0.0184	–0.0257	0.0008	0.0002	1.0000

This table reports the correlation matrix among the main variables of interest. *PERFORMANCE_ACC is* the firm-level performance from an accounting perspective and it is proxied by the ratio sales-to-assets. *PERFORMANCE_MKT* is the firm-level performance from a market perspective and it is proxied by the ratio stock market price and profits per share. *SIZE*, *EQUITY*, and *TANGIBILITY* are firm-level controls trying to capture firm size, proxied by the natural logarithm of firm's total assets; the capitalisation of the firm, proxied by the ratio equity-to-assets; and the tangibility of the firm, proxied by the ratio tangible assets-to-total assets. *DIOXIDE* and *GREENHOUSE* are country-level variables that measure CO2 emissions and greenhouse gas emissions in each country and year. LOGGDPpc and Δ*INFLATION* are variables included to control for macroeconomic aspects on each country. They are calculated as the natural logarithm of per capita GDP and the annual inflation rate, respectively.

As EUROSTAT states, it is possible to convert greenhouse gases (other than CO2 naturally) into carbon dioxide (CO2) equivalents, therefore facilitating comparisons and determining their individual and total contributions to global warming. However, we feel that considering both variables in a separated way fits better the three scenarios defined by the GHG Protocol as it helps us understand better the direct effects of CO2 emissions and of greenhouse gases, globally considered.

The *DIOXIDE* variable is obtained from EUROSTAT, and refers to emissions stemming from the burning of fossil fuels and the manufacture of cement. They include CO2 produced during consumption of solid, liquid, and gas fuels as well as gas flaring. The highest and lowest average value of this variable are found in Germany (682.76) and Ireland (31.71), respectively. The *GREENHOUSE* variable contains information about the country-level greenhouse gas emissions. It is defined by the European Environment Agency as "*the trends in total man-made emissions of the "Kyoto basket" of greenhouse gases*". It presents annual total emissions in relation to 1990 emissions and also related to emissions in the Kyoto base year. Both variables are calculated by country and year. During our sample period, Spain is the country with the highest average value of this variable (121.69) and Czech Republic is the country with the lowest average value of greenhouse gas emissions (67.75).

3.3.2 Control variables

We include firm- and macroeconomic-level variables as controls. The firm-specific characteristics used in our empirical models are asset size (*SIZE*), measured as the natural logarithm of firm's total assets; capitalisation (*EQUITY*) computed as the ratio equity-to-total assets; and the degree of asset tangibility (*TANGIBILITY*) proxied by the share of tangible assets over total assets in the balance sheet. Firm size, capitalisation, and asset tangibility are three firm-level characteristics usually connected to financial performance since they are relevant to both financing and investment decisions (Graham et al., 2015; Shrivastava and Tamvada, 2019). During the 2008–2016 period, German firms are the ones that present the highest average value of firm size (17.96). Czech Republic and Ireland present the highest mean values of firms' equity-to-total assets ratio (0.46). The highest mean value for the *TANGIBILITY* variable is found in Czech Republic (0.80). The lowest values of these variables are found in Italy (16.56 for *SIZE*; and 0.29 for the capitalisation ratio) and in Finland (0.33 for the tangibility of assets ratio). The inclusion of *SIZE* as a control variable allows us to consider that large firms tend, on average, to be less likely to fail. *EQUITY* is a proxy for the extent to which a firm is well capitalised or not. High levels of capital may suggest that the firm has relevant growth opportunities and is more profitable than poorer capitalised firms are. Finally, the ratio tangible assets-to-total assets (*TANGIBILITY*) accounts for the relevance of collateral in the firm's balance sheet. Firms with higher levels of collateral are more likely to obtain external resources to finance investments and are perceived as less risky.

Additionally, we also include two macroeconomic variables to control for the potential impact of the business cycle on the performance of firms. In particular, we include the natural logarithm of per capita GDP (*LOGGDPpc*) and the annual variation of the inflation rate (Δ*INFLATION*). Ireland is the country with the highest averaged value of the natural logarithm of GDP per capita (10.89), whereas on the opposite side the Czech Republic presents the lowest average value for this country-level variable (9.92).

The Czech Republic and Ireland are also the countries with the highest (1.92) and lowest (0.38) values of annual inflation rates, respectively.

Table 3 shows the correlation matrix of the main variables. As it becomes clear, our two performance measures present a negative and statistically significant correlation with firm size. Correlation of both variables with the ratio equity-to-total assets is positive for both measures and significant at conventional levels. The variable capturing the accounting performance (sales-to-total assets ratio) presents a positive correlation with the variable tangible assets over total assets. Although positive, the correlation of this variable with market performance is not statistically significant at conventional levels. *PERFORMANCE_ACC* presents a positive and significant correlation with the variable capturing the country-level dioxide emissions. This variable is negatively correlated with the variable *GREENHOUSE*. In terms of market performance, we do not find any statistically significant correlation with any of the two environmental variables.

4 Results

4.1 Financial performance and emissions

In this section, we empirically examine whether and to what extent country-level CO2 and greenhouse gas emissions may affect firm-level accounting and market performance. The results of our baseline model are shown in Tables 4 and 5. In Table 4 we present the ratio sales-to-total assets as a measure of accounting performance (*PERFORMANCE_ACC*). In Table 5, we present the ratio of the market price of the stock over accounting profits as a measure of market performance (*PERFORMANCE_MKT*). Columns (1)–(2) and (4)–(5) of each table show results for fixed and random effects panel data regressions, respectively. Columns (3) and (6) always refer to random effects estimates and include the initial value of the dependent variable as an additional firm-level control.

Focusing on the results of Table 4, we observe that the variables capturing the relevance of both CO2 emissions (*DIOXIDE*) and greenhouse gas emissions (*GREENHOUSE*) present positive and statistically significant coefficients in all the estimates shown. These results are to some extent consistent with those reported in Wang et al. (2014) and indicate that accounting performance is higher in those countries in which the emissions of both CO2 and greenhouse gases are more relevant. According to Wang et al., this evidence suggests that investment projects focused on the reduction of emissions would possibly harm firm competitiveness and, thereby, reduce its performance from an accounting perspective. This positive effect of CO2 emissions on firm accounting performance also has economic significance. Based on the results in column (1) of Table 4, for instance, an increase of one standard deviation in *DIOXIDE* (185.24) would decrease the accuracy of analyst forecasts by 21.4%.

Regarding the firm-level control variables, *SIZE* and *TANGIBILITY* present a negative and statistically significant coefficient in columns (1), (2), (4), and (5), indicating that larger firms and firms with higher levels of tangible assets perform worse than smaller firms and firms with higher relative importance of intangible assets on their balance sheets. We do not find any significant coefficient for the *EQUITY* variable. The initial value of the *PERFORMANCE_ACC* variable shows a positive and statistically significant coefficient in columns (3) and (6), indicating that past accounting performance positively affect current performance. The natural logarithm of the per capita GDP and the annual growth of inflation rate seem not to have any significant impact on accounting performance.

Table 4 Accounting performance and emissions

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
PERFORMANCE_ ACC_2008			0.9866*** (32.53)			0.9870*** (32.21)
$DIOXIDE_{kt}$	0.0005** (1.98)	0.0006** (2.19)	0.0007** (2.53)			
$GREENHOUSE_{kt}$				0.0025** (1.99)	0.0027** (2.05)	0.0028** (2.19)
$SIZE_{ijkt-1}$	–0.0925*** (–4.96)	–0.0772*** (–4.98)	–0.0017 (–0.21)	–0.0952*** (–5.14)	–0.0795*** (–5.16)	–0.0029 (–0.36)
$EQUITY_{ijkt-1}$	0.0064 (0.09)	–0.0299 (–0.42)	–0.0412 (–0.77)	0.0100 (0.14)	–0.0263 (–0.37)	–0.0391 (–0.73)
$TANGIBILITY_{ijkt-1}$	–0.0499 (–0.68)	–0.1509** (–2.14)	–0.0018 (–0.04)	–0.0411 (–0.56)	–0.1405** (–2.01)	0.0048 (0.09)
$LOGGDPpc_{kt}$	–0.0143 (–0.14)	–0.0017 (–0.02)	0.0015 (0.01)	–0.0272 (–0.27)	–0.0155 (–0.15)	–0.0125 (–0.12)
$\Delta INFLATION_{kt}$	0.0000 (0.03)	0.0001 (0.04)	0.0003 (0.14)	0.0001 (0.04)	0.0001 (0.07)	0.0004 (0.17)
Country dummies	NO	YES	YES	NO	YES	YES
Industry dummies	NO	YES	YES	NO	YES	YES
Year dummies	YES	YES	YES	YES	YES	YES
F Test	0.0000	–	–	0.0000	–	–
Wald Test	–	0.0000	0.0000	–	0.0000	0.0000
R^2	0.0996	0.4840	0.9620	0.0997	0.4815	0.9618
# Observations	775	775	775	775	775	775
# Firms	115	115	115	115	115	115
# Countries	9	9	9	9	9	9

This table presents results examining the effect of both dioxide and greenhouse gas emissions on accounting performance. Columns (1) and (4) show fixed effects estimations. Random effects estimations are reported in columns(2), (3), (5), and (6). The dependent variable is the ratio sales-to-total assets. *PERFORMANCE_ACC_2008* is the valueof the sales-to-total assets in 2008. *DIOXIDE* and *GREENHOUSE* are country-level variables that measure CO2 emissions and greenhouse gas emissions in each country and year. *SIZE*, *EQUITY*, and *TANGIBILITY* are firm-level controls trying to capture firm size, proxied by the natural logarithm of firm's total assets; the capitalization of the firm, proxied by the ratio equity-to-assets; and the tangibility of the firm, proxied by the ratio tangible assets-to-total assets. *LOGGDPpc* is the annual real GDP per capita. ΔINFLATION is the annual growth rate of inflation in each country.

*; ** and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Table 5 Market performance and emissions

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
PERFORMANCE_ MKT_2008			0.2700*** (10.18)			0.2712*** (10.22)
$DIOXIDE_{kt}$	–0.0002 (–1.27)	–0.0001 (–1.04)	–0.0002 (–1.07)			
$GREENHOUSE_{kt}$				–0.0012 (–1.48)	–0.0008 (–1.05)	–0.0010 (–1.30)
$SIZE_{ijkt-1}$	0.0098 (0.78)	0.0026 (0.79)	–0.0007 (–0.32)	0.0113 (0.91)	0.0026 (0.82)	–0.0006 (–0.29)
$EQUITY_{ijkt-1}$	0.0782 (1.59)	0.0580** (2.34)	0.0485*** (2.77)	0.0757 (1.54)	0.0578** (2.36)	0.0488*** (2.78)
$TANGIBILITY_{ijkt-1}$	0.0660 (1.34)	–0.0003 (–0.02)	0.0064 (0.42)	0.0645 (1.31)	–0.0013 (–0.06)	0.0061 (0.40)
$LOGGDPpc_{kt}$	0.0408 (0.62)	0.0438 (0.67)	0.0263 (0.42)	0.0467 (0.71)	0.0471 (0.72)	0.0305 (0.48)
$\Delta INFLATION_{kt}$	–0.0015 (–0.86)	–0.0018 (–1.06)	–0.0008 (–0.51)	–0.0015 (–0.84)	–0.0018 (–1.06)	–0.0008 (–0.50)
Country dummies	NO	YES	YES	NO	YES	YES
Industry dummies	NO	YES	YES	NO	YES	YES
Year dummies	YES	YES	YES	YES	YES	YES
F Test	0.0000	–	–	0.0000	–	–
Wald Test	–	0.0000	0.0000	–	0.0000	0.0000
R^2	0.0457	0.1501	0.7350	0.0468	0.1464	0.7353
# Observations	651	651	651	651	651	651
# Firms	113	113	113	113	113	113
# Countries	9	9	9	9	9	9

This table presents results examining the effect of both dioxide and greenhouse gas emissions on market performance. Columns (1) and (4) show fixed effects estimations. Random effects estimations are reported in columns (2), (3), (5), and (6). The dependent variable is proxied by the ratio stock market price and profits per share. *PERFORMANCE_MKT_2008* is the value of the dependent variable in 2008. *DIOXIDE* and *GREENHOUSE* are country-level variables that measure CO_2 emissions and greenhouse gas emissions in each country and year. *SIZE*,*EQUITY*, and *TANGIBILITY* are firm-level controls trying to capture firm size, proxied by the natural logarithm of firm's total assets; the capitalisation of the firm, proxied by the ratio equity-to-assets; and the tangibility of the firm,proxied by the ratio tangible assets-to-total assets. *LOGGDPpc* is the annual real GDP per capita. Δ*INFLATION* isthe annual growth rate of inflation in each country. *; ** and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

In Table 5, we present the empirical findings obtained when we use market performance as our dependent variable. In this case, our results support some evidence on a potential negative association between emissions and stock market performance suggesting that, contrarily to what happens with the accounting performance, capital markets seem to react negatively to higher levels of both CO_2 and greenhouse gas emissions at a country-level. This, in fact, may support the view defended in the recent paper by Wang et al.

(2019), according to which the stock market reacts positively when a firm announces policies and/or measures related to reduce contaminating emissions. However, we should be cautious with these results, as we do not obtain statistically significant coefficients at conventional levels for both *DIOXIDE* and *GREENHOUSE* variables.

In relation to the coefficients for the firm-level control variables, we only find a positive and statistically significant coefficient for the lagged value of the *EQUITY* variable in almost all the estimates of Table 5, indicating that those firms with higher levels of capital over total assets perform significantly better in the stock market than those poorer capitalised. We obtain again a positive coefficient for the initial value of the dependent variable (*PERFORMANCE_MKT_2008*) that is included in the regression shown in columns (3) and (6) to reinforce the results by mitigating potential endogeneity problems. We do not find any significant coefficient for the macro-level variables *LOGGDPpc* and Δ*INFLATION*.

In sum, it seems that CO2 emissions and greenhouse gas emissions do not affect accounting and market performance in the same way. In particular, our results show that emissions only have a positive and significant impact when we consider accounting performance as the dependent variable. Although negative, we do not find any significant result regarding the effect of such variables on market performance. If we understand accounting performance as a reflection of the near past and present economic activities, the perception of a positive relation between contamination levels and positive performance is worrisome, to the extent that it may lead to managerial short-termism. On the other hand, if we understand market performance as a reflection of all public information including expectations about future performance, it is comforting to observe that this positive relation is not found. Implicitly, we believe that investors have interiorised that uncapped emissions are unsustainable and contaminating activities should not be rewarded.

4.2 *Financial performance and emissions: the role of firm-level characteristics*

To better understand the relation between contaminating emissions and financial performance, we now examine whether and to what extent the effect the characteristics of the firm in terms of size, financing structure and tangibility of the assets in the balance sheet could shape the relation between emissions and financial performance. To develop this analysis, we define interaction terms between our proxies of country-level emissions and each of the firm-level characteristics. The results obtained are presented in Table 6. In Panel A, we report the results obtained for accounting performance (*PERFORMANCE_ACC*) and in Panel B, we report the results obtained for market performance (*PERFORMANCE_MKT*).

Results in columns (1)–(3) of Panel A indicate that the above-referred positive effect of CO2 emissions on accounting performance remains invariant, although this effect is not homogeneous across firms. In particular, our empirical findings are consistent with a more important influence of CO2 emissions in the case of smaller firms, firms with lower levels of equity financing, and firms with a lower share of tangible assets on their balance sheets. These results, however, are not statistically significant at conventional levels. Results in column (5) suggest that the effect of greenhouse gas emissions on firms' accounting performance is particularly relevant in the case of better capitalised firms. The individual coefficient of *EQUITY* presents a negative and statistically significant coefficient, however, the interaction term with the *GREENHOUSE* variable is positive and significant. This result is consistent with the positive role of being located in a "less-green country", with more greenhouse gas emissions, in which better capitalised firms are able to generate a higher accounting performance. According to the estimation results presented in column (6), firms with higher levels of intangible assets perform relatively better in countries with higher levels of greenhouse gas emissions. This result is consistentwith the evidence of Shrivastava and Tamvada (2019). These authors state that green product innovation (green intangible assets) may be crucial for firms' performance. Specifically their results indicate that these types of investments are more relevant for entrepreneurial firms than incumbents. Hence, investments in intangible assets in countries with higher levels of emissions could promote better accounting results than for firms oriented to investments on tangible assets.

Table 6 Financial performance and emissions: the role of firm-level characteristics

PANEL A: Accounting performance						
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
PERFORMANCE_ ACC_2008	0.9851*** (32.24)	0.9874*** (33.15)	0.9864*** (32.28)	0.9881*** (32.80)	0.9838*** (32.01)	0.9884*** (32.17)
$DIOXIDE_{kt}$	0.0017** (2.35)	0.0008*** (2.72)	0.0008** (2.38)			
$GREENHOUSE_{kt}$				0.0057 (1.12)	0.0011 (0.81)	0.0048*** (2.77)
$DIOXIDE_{kt}$ * $SIZE_{ijkt-1}$	–0.0005 (–1.45)					
$DIOXIDE_{kt}$ * $EQUITY_{ijkt-1}$		–0.0002 (–1.00)				
$DIOXIDE_{kt}$ * $TANGIBILITY_{ijkt-1}$			–0.0000 (–0.34)			
$GREENHOUSE_{kt}$ * $SIZE_{ijkt-1}$				–0.0001 (–0.58)		
$GREENHOUSE_{kt}$ * $EQUITY_{ijkt-1}$					0.0060*** (2.62)	
$GREENHOUSE_{kt}$ * $TANGIBILITY_{ijkt-1}$						–0.0033* (–1.70)
$SIZE_{ijkt-1}$	0.0164 (1.09)	–0.0017 (–0.22)	–0.0022 (–0.28)	0.0150 (0.48)	–0.0047 (–0.58)	–0.0022 (–0.28)
$EQUITY_{ijkt-1}$	–0.0482 (–0.89)	0.0338 (0.36)	–0.0415 (–0.77)	–0.0371 (–0.69)	–0.6385*** (–2.71)	–0.0402 (–0.74)
$TANGIBILITY_{ijkt-1}$	–0.0079 (–0.15)	0.0018 (0.04)	0.0240 (0.26)	0.0071 (0.14)	0.0108 (0.21)	0.3393 (1.64)
$LOGGDPpc_{kt}$	–0.0026 (–0.03)	0.0055 (0.05)	0.0013 (0.01)	–0.0114 (–0.11)	0.0054 (0.05)	–0.0140 (–0.13)
$\Delta INFLATION_{kt}$	0.0004 (0.17)	0.0003 (0.13)	0.0004 (0.16)	0.0004 (0.15)	0.0001 (0.06)	0.0000 (0.01)

Table 6 Financial performance and emissions: the role of firm-level characteristics (continued)

PANEL A: Accounting performance						
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Country dummies	YES	YES	YES	YES	YES	YES
Industry dummies	YES	YES	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES	YES	YES
Wald Test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R^2	0.9611	0.9632	0.9617	0.9613	0.9615	0.9616
# Observations	775	775	775	775	775	775
# Firms	115	115	115	115	115	115
# Countries	9	9	9	9	9	9
PANEL B: Market performance						
PERFORMANCE_ MKY_2008	0.2698*** (10.17)	0.2683*** (10.12)	0.2702*** (10.18)	0.2721*** (10.12)	0.2679*** (10.06)	0.2711*** (10.19)
$DIOXIDE_{kt}$	–0.0002 (–1.12)	–0.0001 (–0.72)	–0.0001 (–0.89)			
$GREENHOUSE_{kt}$				–0.0007 (–0.42)	–0.0013 (–1.62)	–0.0010 (–1.20)
$DIOXIDE_{kt} * SIZE_{ijkt-1}$	4.97e-06 (0.48)					
$DIOXIDE_{kt} * EQUITY_{ijkt-1}$		–0.0001* (–1.66)				
$DIOXIDE_{kt} * TANGIBILITY_{ijkt-1}$			–0.0003 (–0.55)			
$GREENHOUSE_{kt} * SIZE_{ijkt-1}$				–0.0000 (–0.21)		
$GREENHOUSE_{kt} * EQUITY_{ijkt-1}$					0.0010 (1.33)	
$GREENHOUSE_{kt} * TANGIBILITY_{ijkt-1}$						0.0000 (0.04)
$SIZE_{ijkt-1}$	–0.0023 (–0.57)	–0.0013 (–0.58)	–0.0007 (–0.34)	0.0012 (0.14)	–0.0012 (–0.55)	–0.0006 (–0.29)
$EQUITY_{ijkt-1}$	0.0502*** (2.80)	0.0893*** (2.96)	0.0477*** (2.71)	0.0493*** (2.78)	–0.0573 (–0.70)	0.0487*** (2.78)
$TANGIBILITY_{ijkt-1}$	0.0064 (0.42)	0.0078 (0.51)	0.0188 (0.69)	0.0061 (0.40)	0.0086 (0.56)	0.0035 (0.05)
$LOGGDPpc_{kt}$	0.0273 (0.43)	0.0326 (0.52)	0.0266 (0.42)	0.0307 (0.49)	0.0373 (0.59)	0.0305 (0.48)
$\Delta INFLATION_{kt}$	–0.0009 (–0.53)	–0.0009 (–0.57)	–0.0008 (–0.49)	–0.0008 (–0.51)	–0.0009 (–0.56)	–0.0008 (–0.49)

Table 6 Financial performance and emissions: the role of firm-level characteristics (continued)

PANEL B: Market performance						
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Country dummies	YES	YES	YES	YES	YES	YES
Industry dummies	YES	YES	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES	YES	YES
Wald Test	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R^2	0.7345	0.7464	0.7364	0.7366	0.7519	0.7356
# Observations	651	651	651	651	651	651
# Firms	113	113	113	113	113	113
# Countries	9	9	9	9	9	9

This table presents results examining if firm-level characteristics shape the impact of both dioxide and greenhouse gas emissions on accounting and market performance. Panel A reports the results using the ratio sales-to-total assets as the dependent variable. The dependent variable in Panel B is proxied by the ratio stock market price and profits per share. *PERFORMANCE_ACC_2008* and *PERFORMANCE_MKT_2008* are defined as the value of the sales-to-total assets ratio in 2008 (or earliest available) and the value of the market performance variable in 2008 (or earliest available), respectively.*DIOXIDE* and *GREENHOUSE* are country-level variables that measure CO2 emissions and greenhouse gas emissions in each country and year. *SIZE*, *EQUITY*, and *TANGIBILITY* are firm-level controls trying to capture firm size, proxied by thenatural logarithm of firm's total assets; the capitalisation of the firm, proxied by the ratio equity-to-assets; and the tangibilityof the firm, proxied by the ratio tangible assets-to-total assets. *LOGGDPpc* is the annual real GDP per capita. Δ*INFLATION*is the annual growth rate of inflation in each country. *; ** and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Consistently with the results reported in Table 5, we do not find any direct effect of both CO2 and greenhouse gas emissions on firms' market performance. In column (2) of Panel B, however, we find a small negative coefficient for the interaction term *DIOXIDE*EQUITY* suggesting that, although higher levels of own capital positively affects market performance, market reaction seems to be less positive in the case of firms allocated in countries that allow higher levels of CO2 emissions.

4.3 Financial performance and emissions: testing non-linear relations

As previously commented, there are no generally accepted conclusions in the related literature for the relation between emissions and firms' performance. Given this, some previous papers have proposed testing the existence of a non-linear relation between emissions and performance. Based on an international sample of firms analysed during the 2008–2012 period, Trumpp and Guenter (2015) find empirical evidence of an U-shaped relation between CO2 performance and profitability as well as between waste intensity and profitability. They find a very similar result for the relation between environmental and stock market performance, but only in the particular case of manufacturing firms. Hailemariam et al. (2020) finds a concave relation between national income and CO2 emissions, reinforcing the idea of an environmental Kuznets curve hypothesis, which suggests a nonlinear relation between economic development and quality of the environment.

Given this controversial result and the lack of conclusive findings, in this section, we specifically search for additional evidence on a potential non-linear relation between both types of emissions and financial performance.[5] As in previous tables, we present the results obtained for alternative estimation models. The empirical findings are shown in Table 7. In columns (1), (4), and (7), we run fixed effects panel regressions. Results in the remaining columns are obtained from random effects methodology. As can be seen in columns (4)–(9), we obtain evidence on the existence of an inverse U-shaped relation between greenhouse gas emissions and firms' accounting performance. This result suggests that being located in a country with higher levels of contaminating emissions has a positive impact on accounting performance, however, this positive impact becomes negative when a given level of greenhouse gas emissions is crossed. Lewandoski (2017) finds an opposite result when focusing on the relation between firm-level emissions and financial performance. His results suggest that performance tends to be more positive for firms with superior CO2 performance but negative for firms with inferior CO2 performance. Thus, it seems that it pays for firms to engage in climate change mitigation only when a given level of contaminating emissions has been exceeded. In our case, we focus on country-level variables proxying for the relevance of emissions, and our findings are consistent with the general idea that after a critical level of greenhouse gas emissions the performance of firms will decrease, on average. However, while below that critical level, firms enjoy higher levels of sales-to-total assets ratio.

At this point, it is important to remark that this result is obtained only when we consider greenhouse gas emissions as our main explanatory variable. We do not find non-linear relation between CO2 emissions and financial performance. This finding may underline some potential characteristics regarding the existence of an explicit regulatory framework for emissions. Firms operating in a country with higher levels of greenhouse gas emissions seem to experience, on average, a positive impact on performance that, at a certain point, becomes negative. This suggests that firms have incentives to contaminate less, which are not directly related with the regulatory framework and may be potentially associated with perceived long-term benefits of investing in greener production technologies. The results are similar when we both CO2 and greenhouse gas emissions are simultaneously included as explanatory variables (Columns (7) to (9)).

Regarding the control variables, we again find negative coefficients for the lagged values of *SIZE* in almost all estimates presented in Table 7. With respect to *EQUITY* and *TANGIBILITY*, we also find them to be negatively related to accounting performance. However, we only find statistically significant results for *TANGIBILITY* in columns (2), (5), and (8). We do not find any statistically significant coefficient for the macroeconomic variables *LOGGDPpc* and Δ*INFLATION*.

4.4 Financial performance and emissions: the effect of the global financial crisis

This section, examines whether the recent period of Global Financial Crisis significantly affected the impact of emissions on financial performance. Crisis periods are periods of considerable uncertainty characterised by particularly relevant distress episodes and it seems reasonable to assume that the performance of firms may be affected, furthermore contaminating emissions might play a more important role to understand firm- growth pattern during these years.

Table 7 Accounting performance and emissions: testing non-linear relations

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
PERFORMANCE_ACC_2008			0.9868*** (32.66)			0.9862*** (32.42)			0.9869*** (32.69)
$DIOXIDE_{kt}$	0.0007 (1.02)	0.0007 (1.00)	0.0006 (0.93)				–0.0013 (–1.12)	–0.0011 (–0.93)	–0.0011 (–0.90)
$DIOXIDE\_SQUARED_{kt}$	–1.86e-07 (–0.22)	–9.50e-08 (–0.11)	9.63e-08 (0.11)				6.46e-07 (0.66)	6.51e-07 (0.64)	7.67e-07 (0.77)
$GREENHOUSE_{kt}$				0.0180*** (3.30)	0.0189*** (3.38)	0.0201*** (3.63)	0.0257*** (3.15)	0.0250*** (2.95)	0.0248*** (2.98)
$GREENHOUSE\_SQUARED_{kt}$				–0.0007*** (–2.91)	–0.0007*** (–2.98)	–0.0008*** (–3.20)	–0.0009*** (–3.12)	–0.0009*** (–2.98)	–0.0009*** (–3.06)
$SIZE_{ijkt–1}$	–0.0928*** (–4.96)	–0.0769*** (–4.97)	–0.0015 (–0.19)	–0.0920*** (–4.99)	–0.0773*** (–5.03)	–0.0020 (–0.25)	–0.0947*** (–5.08)	–0.0766*** (–5.02)	–0.0020 (–0.25)
$EQUITY_{ijkt–1}$	0.0069 (0.10)	–0.0305 (–0.43)	–0.0416 (–0.78)	–0.0041 (–0.06)	–0.0393 (–0.56)	–0.0455 (–0.85)	–0.0048 (–0.07)	–0.0458 (–0.64)	–0.0467 (–0.87)
$TANGIBILITY_{ijkt–1}$	–0.0494 (–0.67)	–0.1532**(– 2.17)	–0.0019 (–0.04)	–0.0514 (–0.71)	–0.1500**(– 2.15)	–0.0025 (–0.05)	–0.0418 (–0.57)	–0.1604**(– 2.27)	–0.0000 (–0.00)
$LOGGDPpc_{kt}$	–0.0163 (–0.16)	–0.0024 (–0.02)	0.0024 (0.02)	–0.0159 (–0.16)	–0.0039 (–0.04)	–0.0009 (–0.01)	–0.0241 (–0.23)	–0.0069 (–0.06)	–0.0022 (–0.02)
$\Delta INFLATION_{kt}$	0.0000 (0.04)	0.0001 (0.05)	0.0003 (0.13)	–4.44e-10 (–0.00)	0.0000 (0.02)	0.0003 (0.11)	–0.0000 (–0.02)	–6.36e-06 (–0.00)	0.0002 (0.08)

Table 7 Accounting performance and emissions: testing non-linear relations (continued)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
Country dummies	NO	YES	YES	NO	YES	YES	NO	YES	YES
Industry dummies	NO	YES	YES	NO	YES	YES	NO	YES	YES
Year dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
F Test (p-value)	0.0000	–	–	0.0000	–	–	0.0000	–	–
Wald Test (p-value)	–	0.0000	0.0000	–	0.0000	0.0000	–	0.0000	0.0000
R^2	0.0997	0.4845	0.9620	0.1114	0.4842	0.9620	0.1136	0.4865	0.9621
# Observations	775	775	775	775	775	775	775	775	775
# Firms	115	115	115	115	115	115	115	115	115
# Countries	9	9	9	9	9	9	9	9	9

This table presents results examining the effect of both dioxide and greenhouse gas emissions on accounting performance. Columns (1), (4), and (7) show fixed effects estimations. Random effects estimations are reported in columns (2), (3), (5), (6), (8), and (9). The dependent variable is the ratio sales-to-total assets. *PERFORMANCE_ACC_2008* is the value of the sales-to-total assets in 2008. *DIOXIDE* and *GREENHOUSE* are country-level variables that measure CO2 emissions and greenhouse gas emissions in each country and year. *DIOXIDE_SQUARED* and *GREENHOUSE_SQUARED* are the squared values of the aforementioned variables. *SIZE*, *EQUITY*, and *TANGIBILITY* are firm-level controls tryingto capture firm size, proxied by the natural logarithm of firm's total assets; the capitalisation of the firm, proxied by the ratio equity-to-assets; and the tangibility of the firm, proxied by the ratio tangible assets-to-total assets. *LOGGDPpc* is the annual real GDP per capita. Δ*INFLATION* is the annual growth rate of inflation in each country. *; ** and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

To empirically test this idea we define the dummy variable *GFC* that takes a value of 1 for the years 2008 to 2011 (both included) and 0, otherwise. We define the interaction terms *DIOXIDE*GFC* and *GREENHOUSE*GFC* to assess if and to what extent the impact of both types of emissions on firm-level performance differs during the crisis. Results are reported in Table 8. As in previous cases, we obtain positive signs for the individual coefficients of the variables *DIOXIDE* and *GREENHOUSE*, indicating that higher levels of CO2 emissions and greenhouse gas emissions positively affect firms' performance measured in accounting terms. Moreover, the crisis dummy variable (*GFC*) shows a negative and statistically significant coefficient in columns (1)–(3) indicating that during the years of crisis the performance of our sample of firms was worse than during the non-crisis years. Regarding the interaction terms, we obtain statistical results at conventional levels in columns (4)–(6). In particular, the coefficient of the interaction term *GREENHOUSE*GFC* presents a negative sign that suggests that, although in general terms, higher levels of country emissions of greenhouse gases positively impact financial performance, this effect was offset during the crisis years. We do not obtain, however, any statistically significant coefficient for the interaction term *DIOXIDE*GFC* in columns (1)–(3). The rest of control variables behave similarly to the previous tables of results.

Table 8 Accounting performance and emissions: effect of the Global Financial Crisis

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
PERFORMANCE_ ACC_2008			0.9859*** (32.70)			0.9878*** (32.55)
$DIOXIDE_{kt}$	0.0010*** (3.86)	0.0010*** (4.04)	0.0011*** (4.40)			
$GREENHOUSE_{kt}$				0.0048*** (4.04)	0.0050*** (4.10)	0.0054*** (4.42)
GFC_t	–0.0518*** (–3.14)	–0.0531*** (–3.20)	–0.0511*** (–3.05)	0.0450 (1.19)	0.0454 (1.19)	0.0566 (1.47)
$DIOXIDE_{kt}*GFC_t$	0.0002 (0.72)	0.0002 (0.76)	0.0003 (0.91)			
$GREENHOUSE_{kt}*GFC_t$				–0.0010** (–2.46)	–0.0010** (–2.46)	–0.0011*** (–2.64)
$SIZE_{ijkt-1}$	–0.0851*** (–4.55)	–0.0734*** (–4.66)	0.0003 (0.04)	–0.0873*** (–4.69)	– 0.0754*** (–4.81)	–0.0003 (–0.05)
$EQUITY_{ijkt-1}$	–0.0005 (–0.01)	–0.0281 (–0.41)	–0.0467 (–0.88)	0.0124 (0.18)	–0.0163 (–0.24)	–0.0391 (–0.73)
$TANGIBILITY_{ijkt-1}$	–0.0745 (–1.01)	–0.1575** (–2.23)	–0.0140 (–0.27)	–0.0576 (–0.79)	–0.1411** (–2.01)	–0.0057 (–0.11)
$LOGGDPpc_{kt}$	–0.0140 (–0.14)	–0.0042 (–0.04)	0.0027 (0.03)	–0.0361 (–0.35)	–0.0273 (–0.26)	–0.0220 (–0.21)
$\Delta INFLATION_{kt}$	–0.0003 (–0.13)	–0.0003 (–0.11)	–0.0000 (–0.00)	–0.0005 (–0.19)	–0.0004 (–0.17)	–0.0001 (–0.06)

Table 8 Accounting performance and emissions: effect of the Global Financial Crisis (continued)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Country dummies	NO	YES	YES	NO	YES	YES
Industry dummies	NO	YES	YES	NO	YES	YES
Year dummies	NO	NO	NO	NO	NO	NO
F Test	0.0000	–	–	0.0000	–	–
Wald Test	–	0.0000	0.0000	–	0.0000	0.0000
R^2	0.0711	0.4849		0.0731	0.4805	0.9622
# Observations	775	775	775	775	775	775
# Firms	115	115	115	115	115	115
# Countries	9	9	9	9	9	9

This table presents results examining the effect of both dioxide and greenhouse emissions on accounting performance.Columns (1) and (4) show fixed effects estimations. Random effects estimations are reported in columns (2), (3), (5), and (6). The dependent variable is the ratio sales-to-total assets. *PERFORMANCE_ACC_2008* is the value of the sales-to-total assets in 2008. *DIOXIDE* and *GREENHOUSE* are country-level variables that measure CO2 emissions and greenhouse gas emissions in each country and year. *GFC* is a dummy variable that takes value 1 for the years 2008to 2011, both included. *SIZE*, *EQUITY*, and *TANGIBILITY* are firm-level controls trying to capture firm size, proxiedby the natural logarithm of firm's total assets: the capitalisation of the firm, proxied by the ratio equity-to-assets; and the tangibility of the firm, proxied by the ratio tangible assets-to-total assets. *LOGGDPpc* is the annual real GDP per capita. Δ*INFLATION* is the annual growth rate of inflation in each country. *; ** and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

4.5 Financial performance and emissions: the role of financial firms

Following an important set of previous papers, we have not considered financial firms in our sample and we mainly focused on the industrial sector. Busch et al. (2012), argue that direct emissions reported by banks are based not on their own operations, but rather on the emission levels of the financial assets that they manage in their balance sheets. Therefore, those assets will be already affecting the amount of both CO2 and greenhouse gas emissions coming from the assets in the balance sheet of non-financial firms. Similarly, financial services providers are usually excluded from the samples of analysis given the specific regulations affecting their activity.

There are papers, however, that do take into account the potential impact of financial firms when developing their empirical analysis (Wang et al., 2014; Luo and Tang, 2014; Trumpp and Guenther, 2015; Clarkson et al., 2015; Delmas et al., 2015; Lewandowski, 2017). Therefore, in this section, we explicitly examine the potential relevance of firms from the financial sector by using a larger sample of firms including banks, insurance firms, and other financial services providers.[6] Table 9 reports the results obtained when our sample is increased with the inclusion of financial firms. Findings for the relation between CO2 emissions and accounting performance, and between greenhouse gas emissions and accounting performance are shown in columns (1)–(3) and in columns (4)–(6), respectively. As it can be seen, the results are very similar to those reported in

Table 4 and, therefore, it can be stated that the inclusion of financial services providers in our sample of firms seem to not affect our basic set of results.[7]

Table 9 Accounting performance and emissions: the role of financial firms

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
PERFORMANCE_ACC_2008			1.0020*** (36.32)			1.0021*** (36.29)
$DIOXIDE_{kt}$	0.0006** (2.29)	0.0006** (2.31)	0.0006** (2.40)			
$GREENHOUSE_{kt}$				0.0025** (2.08)	0.0026** (2.05)	0.0026** (2.15)
$SIZE_{ijkt-1}$	–0.0592*** (–3.58)	–0.0570*** (–4.36)	–0.0015 (–0.25)	–0.0612*** (–3.71)	–0.0583*** (–4.48)	–0.0019 (–0.30)
$EQUITY_{ijkt-1}$	–0.0347 (–0.51)	–0.0500 (–0.75)	–0.0420 (–0.85)	–0.0344 (–0.51)	–0.0497 (–0.75)	–0.04108 (–0.84)
$TANGIBILITY_{ijkt-1}$	–0.1205* (–1.73)	–0.1983*** (–3.02)	0.0314 (0.69)	–0.1125 (–1.62)	–0.1915*** (–2.92)	0.0349 (0.77)
$LOGGDPpc_{kt}$	0.0004 (0.00)	0.0073 (0.07)	0.0018 (0.02)	–0.0127 (–0.13)	–0.0056 (–0.06)	–0.0107 (–0.11)
$\Delta INFLATION_{kt}$	–0.0004 (–0.16)	–0.0003 (–0.14)	–0.0001 (–0.05)	–0.0003 (–0.13)	–0.0002 (–0.11)	–0.0000 (–0.02)
Country dummies	NO	YES	YES	NO	YES	YES
Industry dummies	NO	YES	YES	NO	YES	YES
Year dummies	YES	YES	YES	YES	YES	YES
F Test	0.0000	–	–	0.0000	–	–
Wald Test	–	0.0000	0.0000	–	0.0000	0.0000
R^2	0.0791	0.6196	0.9701	0.0780	0.6192	0.9336
# Observations	857	857	857	857	857	857
# Firms	136	136	136	136	136	136
# Countries	9	9	9	9	9	9

This table presents results examining the effect of both dioxide and greenhouse emissions on accounting performanceover a European sample of non-financial and financial firms. Columns (1) and (4) show fixed effects estimations. Random effects estimations are reported in columns (2), (3), (5), and (6). The dependent variable is the ratio sales- to-total assets. *PERFORMANCE_ACC_2008* is the value of the sales-to-total assets in 2008. *DIOXIDE* and *GREENHOUSE* are country-level variables that measure CO2 emissions and greenhouse gas emissions in each country and year. *SIZE*, *EQUITY*, and *TANGIBILITY* are firm-level controls trying to capture: firm size, proxied bythe natural logarithm of firm's total assets; the capitalisation of the firm, proxied by the ratio equity-to-assets; and the tangibility of the firm, proxied by the ratio tangible assets-to-total assets. *LOGGDPpc* is the annual real GDP percapita. Δ*INFLATION* is the annual growth rate of inflation in each country. *; ** and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

5 Conclusions

This paper analyses the effect of both CO_2 and greenhouse gas emissions on the financial performance of firms. Our results show differences between accounting and market performance and when between CO_2 emissions and greenhouse gas emissions.

Our results show a positive relation between the levels of both CO_2 and greenhouse gas emissions and accounting performance, and no relation with market performance. The qualitative nature of our results does not change when we define different econometric specifications of our empirical model, when we consider the effect of the GFC period, and when we use a larger sample of firms including financial firms. These results have important implications for firms and policymakers. The fact that we report a positive relation between CO_2 and greenhouse emissions and accounting performance is worrying, because it shows that nowadays there may be still some scope to increase profits at the expense of the environment. It also indicates that firms currently may find it difficult to make significant efforts to reduce emissions, without bearing a direct 'cost' in terms of corporate competitiveness and financial performance. On a positive note, since we do not report a similar relation in terms of market performance, this indicates that investors have already assumed the unsustainability of a contaminated environment and discount it.

The EU environmental policy is well advanced, it cannot be considered as lax by any means and the cap and trade scheme has a clear objective of penalising contaminating behaviours, providing economic incentives to make economy activities greener. However, the positive relation between the level of emissions and accounting performance and the fact that no relation is found in terms of market performance shows that there is still scope for EU policymakers to act. Particularly, to work out stronger encouragements to reduce CO_2 consumption and emissions through higher penalties for contaminating activities (e.g., more expensive allowances) and more incentives to achieve an effective decarbonisation of the economy.

Our results also reveal particularities when we consider the financing structure and the asset composition of firms. In particular, our empirical findings suggest that the relation between accounting performance and greenhouse gas emissions is more relevant for firms with higher levels of equity financing and for firms with more intangible assets in their balance sheets. Additionally, our results suggest that CO_2 emissions negatively affect the market performance of firms with higher levels of the equity-to-total assets ratio.

Although in regulatory terms, there is no relevant difference between CO_2 emissions and other greenhouse gases due to the use of CO_2 equivalents, our results show that to consider emissions of greenhouse gases individually is important in this type of studies. With respect to linear relations, the use of CO_2 or greenhouse emissions does not generate any differences in the results, concerning the direction and the significance level of the relation between contaminating emissions and financial performance. However, when we test for relations of a different nature, the inclusion of greenhouse gases reveals a relation that would go undetected if we had focus only on CO_2 emissions. Our results show an inverted U relation when testing for greenhouse emissions that is not present when we test for CO_2 emissions solely.

The data and methodologies employed in this paper do not allow us to uncover the economic rationale underlying the decrease in financial performance for higher levels of greenhouse emissions. However, it would be important that following research would focus on this point, given its importance as a further tool to work out a better system of incentives for the economy to become greener.

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Notes

[1]It operates in 31 countries (all 28 EU countries plus Iceland, Liechtenstein and Norway).

[2]The limited number of available allowances ensures that they are assigned a value in the market.

[3]All data are expressed in US dollars.

[4]We consider the value of each dependent variable in 2008 (initial year of our sample period) or earliest available.

[5]Given that in the basic set of results, we have obtained only statistically significant findings when using the accounting-based performance dependent variable, in this analysis we run the estimates on the annual ratio sales-to-total assets.

[6]In particular, we have a sample of a maximum of 136 firms and 857 observations in our time window.

[7]Notice that we have reported the baseline regressions testing the relation between emissions and accounting performance over the full sample of firms. Results for the association between emissions and market performance are also similar to those reported in Table 5 and are available from the authors upon request.