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The impact of environmental performance on stock prices in the green and innovative context

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ABSTRACT

This study examines the impact of environmental performance on firms' stock prices, considering the moderating effect of the green and innovative environmental context by country. Renewable energy policies, green technologies, and foreign trade form this environmental context of interest for the reduction of carbon emissions. Using a sample of 2638 firm-year observations for the firms listed in the main stock index of 16 European countries over the period of 2005–2017, we find that environmental performance is value-relevant, except during the worst years of a crisis, when it is not significant. Two elements of the green technological framework, namely, renewable energy policies and the potential transmission effect of technology through foreign trade, are valued by investors as offsetting factors of the positive effect exerted by carbon performance on the firm's value. This is consistent with the slow and costly adoption of greener technologies. However, registered green patents appear to be a turning point, showing a significant positive effect on the relationship between firms' environmental performances and their market values. Again, the crisis period interferes with deepening the negative effect of renewable energy policies and cancelling out the effect of green patents and foreign trade. On one hand, our results highlight the market's role in making inefficiencies visible and showing the potential future losses of green and innovative policies; on the other hand, the hampering interference of crisis periods must be considered by policymakers.

1. Introduction

The European Union Emissions Trading System (EU ETS) remains the world's largest carbon market, and it is the flagship of the ambitious climate action for the EU. The legislative framework was revised in 2018 to align the EU's 2030 emission targets with the Paris Agreement. Among its key features, the third phase (2013–2020) aims for the deployment of innovative renewable energy technologies, whereas the fourth phase (2021–2030) intends to promote innovation and investment in low-carbon technologies across industrial and power sector firms (EC, 2020b). As a consequence, the EU promotes and supports renewables, energy efficiency, and the governance of EU members' green policies (EC, 2020a).

To date, researchers have analyzed the effect of renewable energy policies on carbon emissions by country across different world regions (i.e., Bölük and Mert, 2014, and Dogan and Seker, 2016, in the EU). Eco-innovation has resulted from a variety of factors, such as government regulation inducing/enforcing firms to adopt low-carbon policies, cost savings derived from energy efficiency, and customer requirements regarding greener products and processes (Horbach et al., 2012). In fact, there are only two ways of cutting down on carbon emissions: reducing the carbon intensity (units of carbon by units of energy consumed), or reducing the energy intensity (energy usage per monetary unit of gross domestic product), and both ways require technology advances (Popp, 2011). Along this line, public scrutiny has pushed listed firms in carbon-intensive sectors to develop green technologies (De Haas and Popov, 2019). However, there is an alternative way to access green technologies: through international trade with, and foreign investments from, highly developed economies (Popp, 2011). In summary, green technologies, renewable energy policies, and foreign trade form a macroeconomic framework of potential interest for the reduction of carbon emissions.

On one hand, this work belongs to the research stream that analyzes how the environmental aspects of listed firms affect those firms' market values, in which contentious results indicate that the drivers of this relationship remain an open research topic. The previous literature has

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focused on the role of the environmental aspects of firms as an additional value-relevant factor in explaining their stock prices (i.e., event studies and Ohlson models). Specifically, this work is framed into the inputs-to-equity-valuation theory (Holthausen and Watts, 2001), and tests the value relevance (effect on the market value) of carbon performance through Ohlson's (1995) model. Following such a model, carbon performance takes part in the "other information" added to the bottom-line value drivers provided by the firm's financial statements (Clarkson et al., 2015; Matsumura et al., 2014). On the other hand, the literature has also considered macro-factors, such as renewable energy used by country, foreign direct investment (FDI), or export-import trade, in order to explain the aggregated carbon emissions by country. A well-developed line of research has tested the Environmental Kuznets Curve (EKC) hypothesis (Grossman and Krueger, 1995), mainly in developing countries, but more recently also in developed countries (Mert and Bölük, 2016; Mert et al., 2019). How the green and innovative context evolves and affects environmental performance can be attributed to the scale effect, the composition effect, and the technique effect[1] (Bo, 2011; Liobikiene and Butkus, 2018). Thus, for example, foreign trade can create scale and composition effects, but it can also transfer the technology-creating technique effect. Renewable energy use is a paradigmatic example of both composition and technique effects, whereas green patents are "pure" elements of the technique effect. As a consequence, foreign trade, renewables, and green patents have been identified as relevant variables that effect the EKC relationship (Mert et al., 2019). In this work, advances on both lines of research are gathered, namely, those on the market value relevance of environmental performance, and those referring to the role of the green and innovative context on the EKC relationship. To the best of our knowledge, this work is the first to analyze the green technological framework by country as a moderating factor of the effect of carbon emissions on stock prices.

The objective of reducing carbon emissions by governmental authorities is a cause and effect of growing social concern. The governmental concern has resulted in tighter environmental regulation, whereas social concern is reflected in higher stakeholder and investor pressures on listed firms to improve their environmental performance. This is why other economic and technological factors with potential impacts on environmental performance should receive investors' attention, thus reinforcing or offsetting the baseline effects of the environmental performance on the stock prices.

The relevance of the topic is still vivid considering its undeniable impact on social progress and sustainability. The reduction in carbon emissions is a clear proxy for environmental performance, and in the EU such a carbon performance is analyzed as a market value driver in a new scenario, in which the reporting of carbon emissions is mandatory for EU ETS participants (Clarkson et al., 2015).

This paper contributes to the discussion of how environmental performance affects stock prices by analyzing the most salient listed European firms[2] in 16 countries for the 2005–2017 period, thereby including the last international financial crisis[3] suffered in Europe. This research introduces renewable energy, green patents, and foreign trade as the main elements of the green technological scenario in order to test how they moderate the effect of a reduction in emissions on stock prices in the well-known theoretical framework of the Ohlson model. In every case, the types of countries included in the sample explain this moderation effect according to the EKC.

We find a positive, significant incremental relationship between the environmental performance and the stock price, which intensifies in an advanced technological context, proxied by the presence of registered green patents in the country, supporting the EKC relationship. However, the increasing use of renewable energy and significant international trade negatively impact the market value relevance of the environmental performance. These results complement previous findings on the adverse impact of renewables over economic indicators in the short run (Akadiri et al., 2019) and others that identify a deterioration of the emission levels caused by FDI inflows in the EU (Mert et al., 2019). It is remarkable how the green and innovative context is assessed by the market in a very different way during the crisis time included in the period under analysis. According to the results found, during crisis periods the adoption of renewable energy is seen as costlier, whereas international trade and green patents are not value-relevant in any direction.

The results obtained are of interest for governmental authorities in their role as regulators and policymakers, for firm managers and stakeholders (especially when firms are higher emitters), for stock market participants, and for other groups interested in firms' commitment to environmental goals. According to the main contributions of this paper, participants of the stock market are able to assess not only the firm's environmental performance, but also the role that different elements of the green and innovative context play in increasing or reducing the value relevance of such environmental performance. Hence, the main implication concerns energy policymakers and governments, who must regulate the information to be issued to allow the market to adequately assess all environmental factors with current and potential effects on the listed firms. Furthermore, policymakers and governments should incorporate the market as a relevant piece of environmental policies, taking advantage of market capacity in order to assess the future potential sources of gains (or losses), as well as its ability to exert pressure on the listed firms to pursue environmental goals. Finally, the results achieved in the green and innovative context have further implications for policymakers. Specifically, they must play a proactive role in designing energy and research policies that should facilitate the development of, access to, and effective application of clean technologies, with special attention to upstream energy innovations to reach the turning point of financial value creation. This proactive role becomes critical during crisis periods.

This paper's structure is as follows: section 2 is devoted to a literature review and hypotheses formulation, section 3 displays the data and methodology, section 4 presents the main results, and section 5 concludes the study.

2. Literature review and hypotheses

2.1. Relationship between the environmental performance and the stock price

Climate change derived from or boosted by greenhouse gas (GHG) emissions is recognized as the source of future economic and social damage, with strong consequences on firms' performance, although the timing and severity of those damages currently can only be estimated (TCFD, 2017). Most industries are concerned about climate-related risks and the transition to a clean-energy economy, while simultaneously new opportunities emerge for those firms focused on leading and facilitating transitions (TCFD, 2020). In the context of still poor information regarding the environmental forces and developments that shape future firms' performances (Hassel et al., 2005; TCFD, 2017, 2020), investors have access to relevant data on firms' environmental performance, such as carbon emissions and allowances (Clarkson et al., 2015). However, the climate-related context is a group of driving forces that are sources of risks and opportunities with a potential financial impact. In this sense,

[1] In our context of carbon emissions, the scale effect takes place when more production generates more carbon emissions; the composition effect occurs when the economy evolves from carbon-intensive to low-carbon activities; and the technique effect arises when new carbon-free or low-carbon technologies are adopted.

[2] All firms listed in the main stock index by country.

[3] The international financial crisis which started in 2007 in the US and extended to other world regions mainly from 2008 onwards, had serious financial and economic effects in Europe, particularly during the period 2008–2010 (EC, 2009).

factors such as trends in the carbon prices, carbon capture developments, trends in energy efficiency/intensity, development, costs and implementation of new technologies, and climate policy developments can act as signposts (TCFD, 2020) of those climate-related forces with potential financial effects, for which information is not issued or is insufficient.

In this setting, an incremental association study under inputs-to-equity-valuation theory (Holthausen and Watts, 2001), such as the Ohlson model, seems appropriate. Ohlson's (1995) model begins from a neoclassical framework and builds a theory of a firm's value, in which prices represent the aggregation of individual investors' expectations of the firm according to the information available on that firm (Holthausen and Watts, 2001). The bottom-line items in financial information, book value and earnings, along with dividends (thanks to the application of the clean surplus relation[4]) form the basis of widely available and meaningful information to reconcile the net stocks of value with value creation and distribution (Barth et al., 2001; Ohlson, 1995). Two features of the Ohlson valuation framework make it appropriate for our current empirical analysis. First, abnormal earnings are assumed to follow an autoregressive process, thus becoming a function of the current abnormal earnings, and therefore of current earnings and dividends, after the clean surplus relation is applied. Second, the model allows for the firm's market value to be affected by "other information", such as environmental information, with a value-relevant effect on future financial figures, but not yet captured by current financial items. This inputs-to-equity-valuation theory represented by the Ohlson framework fits the market-based view and the resource-based view integrated into stakeholder theory. Market prices reflect all available information required for stakeholders (mainly shareholders) to make decisions, including those related to environmental performance (Clarkson et al., 2015; Jaggi et al., 2018). Furthermore, information on the strategic green technological resources that firms can exploit to achieve an environmental performance is part of that "other information" with a potential value relevance (Matsumura et al., 2014).

There is still limited and inconclusive empirical evidence on the reaction of firms' stock prices to their environmental performance. To date, contributions have been concerned with the environmental disclosures of specific performance indicators, such as fines for environmental pollution (Lorraine et al., 2004) and the announcements of environmental awards (Deswanto and Siregar, 2018). Another group of works has analyzed comprehensive indicators, such as environmental performance indices (Radhouane et al., 2018) and green rankings (Yadav et al., 2016; Deswanto and Siregar, 2018). In more recent works, carbon emissions themselves have been used as a performance indicator, first for firms that voluntarily disclose this information (Matsumura et al., 2014; Griffin et al., 2017; Schiemann and Sakhel, 2019), and then for those that report carbon emissions as an obligation (Clarkson et al., 2015).

The empirical research performed on this relationship between the firms' market values and their environmental performances has been dispersed in several research lines with diverse modeling approaches. In particular, event studies analyze the stock price or stock return reaction to new environmental disclosures, generally finding positive reactions to announcements of enhanced environmental performances (i.e., repeated green scores in large US firms, as found by Yadav et al., 2016) and negative reactions to announcements regarding bad environmental performances (i.e., carbon emissions of S&P 500 firms, as found by Griffin et al., 2017). In the EU ETS framework, Brouwers et al. (2018) found that firms' characteristics and industry context are relevant to moderating how the publication of verified emissions affects the market prices.

For the research stream using the Ohlson valuation framework, some studies have included carbon performance as "other information", revealing a market value reduction for most carbon-intensive firms in Australia (Chapple et al., 2013), a negative effect of carbon emissions on market values in the US (Griffin et al., 2017), and non-homogeneous negative effects across firms and sectors in European firms (Clarkson et al., 2015). In fact, carbon emissions shortfalls are a factor underlying the negative effect on firm value, but they are mitigated for the best carbon performers in their industries and for firms in less competitive sectors. However, the macroeconomic energy context has been left out of consideration to date in this research stream.

In short, when the influence on stock prices is positive, market-based measures are able to capture reputational benefits from the environmental performance, reduced risk perceptions, and the firms' meeting of stakeholders' needs (Dixon-Fowler et al., 2013), but a negative or less positive influence can capture penalties derived from the firms' climate change-related risk profiles reflected in carbon emissions (Matsumura et al., 2014). These penalties can include the costs of new regulatory compliance to reduce emissions and costs from more severe climate parameters affecting the firms' production processes. In addition, relevant transaction costs refer to the implementation of new systems, monitoring, verification, and reporting of carbon emissions, as well as allowance trading (Jaraitė et al., 2010).

To establish the baseline model, we check the sign of the relationship between the firm's carbon performance and its price, because the result found in the literature is mostly positive, but not unanimous. Therefore, according to most previous empirical results in European and other geographical contexts, the general hypothesis is as follows:

H1. Environmental performance positively affects the firms' stock prices.

2.2. Relationship between green tech policies, foreign trade, and carbon emissions

The nexus between economic growth and carbon emissions has been tested on several occasions, finding contradictory results, since typical economic indicators (mainly gross domestic product, hereinafter GDP) have shown positive, negative, and even no relationship with emissions. These inconclusive results have been resolved by the previous literature with the EKC popularized by Grossman and Krueger (1995), according to which pollution increases in the first stages of economic development, up to a certain point. Before this threshold, the scale effect prevails, but after this threshold, economic growth softens environmental pollution due to the prevailing composition and technique effects (Bo, 2011; Grossman and Krueger, 1995; Liobikiene and Butkus, 2018), with technological components playing a crucial role. Considering this point, renewable energy is an explanatory variable in the second part of the curve and should be included in any study focusing on developed countries. The results obtained for the EU by Dogan and Seker (2016) support both the existence of the EKC (for the relationship between carbon emissions and GDP) and the mitigating effect of renewable energy on carbon emissions. In fact, the positive relationship between renewable energy and environmental performance is one of the most conclusive links found in the EU according to current empirical research (Alola et al., 2021; Musa et al., 2021). Furthermore, López-Menéndez et al. (2014) found that European countries fulfilling at least the 20% target of renewable energy sources better support the EKC hypothesis.

[4] The clean surplus relation means that all changes in a firm's assets and liabilities not related to dividends, shares issued, or shares repurchased pass through the income statement and take part of the firm's net income. As a consequence, the book value of a firm at the end of a period equals the book value at the beginning of the period plus the earnings obtained minus the dividends paid during the period, with these dividends being the net of the capital contributions. A restatement of the Ohlson (1995) model after considering the clean surplus relation allows the substitution of abnormal earnings by earnings and dividends as explanatory variables. The resulting model explains the firm's price with the book value, earnings, dividends, and other information not reflected in the firm's financial statements.

Under the EU ETS, the production of carbon-free electricity from renewable energy sources liberated emission allowances, producing two effects: displacement of carbon emissions from clean electricity suppliers to the remaining ETS participants (cap-and-trade system), and a reduction of allowance prices (Van den Bergh et al., 2013). On one hand, the deployment of renewable energy sources is a costly investment for the power sector and for the support schemes developed according to country-wide renewable energy policies (Owen, 2006), which could represent higher tariffs for firms as electricity users. On the other hand, the lower prices of carbon allowances are good news for bad environmental performers (less expensive access to additional pollution), but bad news for good environmental performers (lower reward for more-than-required reduction of emissions). Therefore, for participants in the EU ETS, a negative impact is expected on the firm's market price. In contrast, when renewable energy production systems are established, electricity prices would benefit from low marginal generation costs, thus offsetting the aforementioned negative effect. Suffice it to mention the "20-20-20 plan"[5] to illustrate how far EU renewable energy production is from being established. In this setting, the second hypothesis is formulated as follows.

H2. In the context of a larger share of renewable energy, environmental performance negatively affects stock prices.

In the past, one of the obstacles to developing clean innovation was the lack of incentives (Jaffe et al., 2005) and the absence of policy interventions (Acemoglu et al., 2012). However, social and economic development is currently affected and clearly enhanced by technological innovation (Alonso-Martínez, 2018). Specifically, patent data have been previously used to measure innovations in green technologies (Johnstone et al., 2010), and technology innovations have proven to be correlated with pollution reduction. Lanjouw and Mody (1996) examined the relationship between the number of 'environmental' patents granted and environmental policy stringencies (expenditures for reducing pollution) at the macrolevel in different countries, finding correlations between abatement costs and environmental patenting activity. These findings are even more remarkable in the case of international patents since, as proxies of technology transfer, they foster the use of environmentally-friendly technologies (Noailly and Ryfisch, 2015). However, technology diffusion is gradual (Popp, 2011), and the high level of environmentally-friendly technology in developed EU countries could require a spillover period to be generalized. In addition, the cost savings derived from materials and energy innovations cannot be quickly obtained, since the process requires organization, control, and coordination (Horbach et al., 2012).

Empirical evidence has found that stock markets play a relevant role in encouraging carbon-intensive sectors to develop greener technologies (EKC technique effect) in order to cut their carbon emissions (Paramati et al., 2017; De Haas and Popov, 2019) and in reallocating investment (EKC compositions effect) toward less polluting sectors (De Haas and Popov, 2019). Therefore, in our sample consisting of firms listed in the most salient index by country, the market price is expected to reflect a positive effect in response not only to carbon performance, but also to the interaction of a better performance in the context of developed green patents. These arguments lead us to propose the following hypothesis.

H3. In the context of significant green patent development, environmental performance positively affects stock prices.

Countries with higher levels of FDI inflows can benefit from the transfer of cleaner technologies (Paramati et al., 2017) and could be pushed or forced to use resources in a more environmentally friendly way, thus reducing pollution as a consequence (Dinda, 2004; Bo, 2011). Conversely, international trade would expand the economic scale, including pollution, even if the global result of technique and composition effects on carbon emissions has been negative, and FDI could be a vehicle for exporting pollution to more environmentally-tolerant countries (Bo, 2011). When studies include both developing and developed countries, the effect of FDI inflows has shown opposite signs; for instance, a clear, decreasing effect on carbon emissions in developing countries, but an opposite sign in developed countries (Paramati et al., 2017). Along this line, a negative impact of FDI on carbon emissions was found in the EU, which could be attributed to environmental restrictions imposed on investors (Omri et al., 2014).

Regarding trade openness, unidirectional causality from this factor to carbon emissions has been identified in EU countries (Dogan and Seker, 2016). After analyzing six macro-regions, Al-Mulali and Sheau-Ting (2014) found that this long-term, positive relationship is addressed by highly developed countries and countries where trading activities represent a relevant share of the GDP. However, Al-Mulali et al. (2015) identified trade openness as a reduction factor of carbon emissions in the long term in 23 European countries. Along this line, in Central and East European economies, considered transition countries by Andonova (2003), international trade works as a diffusor of clean technologies.

Considering the nature of our sample, European firms listed in developed stock markets in countries with a high level of technology, we do not expect the positive effect of a cleaner-technology transfer or the benefits of tighter environmental regulations of foreign countries. Accordingly, the fourth hypothesis is:

H4. In the context of trade openness, environmental performance negatively affects or does not affect stock prices.

3. Data and methodology

3.1. Data description

The sample of this empirical analysis consists of all firms listed in the main stock index in 16 European countries (United Kingdom, France, Spain, Germany, Italy, Sweden, Finland, Netherlands, Poland, Norway, Austria, Portugal, Denmark, Ireland, Greece and Belgium) during the 2005–2017 period. We consider firm-level characteristics extracted from Compustat and match them with carbon emissions data extracted from the Source Emissions database provided by the European Commission. Additional data related to energy, technology, and foreign trade are extracted from the OECD and the World Bank, all for the same period.

3.2. Methodology and model

Panel data analysis through a well-developed dynamic estimator, such as the Generalized Method of Moments (GMM), is proposed to control any potential data endogeneity. Specifically, the two-step GMM estimator is efficient in controlling the correlation of errors over time, addressing the potential omitted variable bias and the heteroscedasticity across companies. GMM uses the explanatory variables as instruments in all equations, alleviating causality identification. This methodology requires inclusion of the lags of dependent and explanatory variables to partially solve the possible problem of causal inference. Following Munjal et al. (2018) and Castro et al. (2021), we use lags from t-2 to t-5 of all explanatory variables, including the lag of the dependent variable, in order to consider the number of instruments. We check the validity and adequacy of the model by employing the Hansen test and the second-order autocorrelation test (AR2) in order to control the strength of instruments and the lack of residual serial correlation, respectively

[5] The European Commission published a Communication in 2007 entitled "Limiting global climate change to 2 °C. The way ahead for 2020 and beyond", in which the EU's unilateral commitment was established to reach three objectives by 2020: a 20% decrease in carbon emissions (with respect to 1990); a 20% increase in energy savings; and a 20% share of renewables out of the total energy supply.

(Blundell and Bond, 1998; Arellano and Bover, 1995). The second-order autocorrelation test is more accurate and robust than the first-order autocorrelation test (Arellano and Bond, 1991).

The main objective of this study is to analyze the impact of the environmental performance on the stock prices of European firms listed in the main stock index by country. To achieve this goal, we propose the following Model (1):

$$PRICE_{it} = a_0 + a_1 ENV\_PER_{it} + a_2 BVPS_{it} + a_3 PERF_{it} + a_4 DIV_{it} + a_5 SIZE_{it} + a_6 AGE_{it} + a_7 GROWTH_{it} + a_8 INF_t + a_9 GDP_t + \sum_{k=1}^{m} S_k + \sum_{t=2005}^{2017} Y_t + \varepsilon_{it} \quad (1)$$

where $PRICE_{i,t}$ is the stock price of firm i at the end of year t and ENV_PER_{it} is the carbon environmental performance of firm i in year t. Following Trumpp et al. (2015) and Trumpp and Guenther (2017), *ENV_PER* is calculated as the total verified carbon emissions (with the changing sign) to the total sales.

As part of the Ohlson (1995) valuation framework, book value per share (BVPS), net income divided by total assets (PERF), and dividends per share (DIV) are used to explain the firm value coming from financial information. Environmental performance is the piece of non-financial information (Ohlson's "other information") of interest. Then we add some variables to control for other factors affecting the market value of firms, and therefore provide "other information" to Ohlson's model. The firm's size (SIZE) – specified as in Jaggi et al. (2018) – is a widely recognized differential factor in market valuation theories. The firm's age (AGE) and growth (GROWTH) – computed as in Kim et al. (2020) – have been included to control for the life cycle stage of the firm, because this factor has been found to be unanimously determinant for the environmental strategy adopted by the firm (Elsayed and Paton, 2009; Primc and Čater, 2016). Inflation (INF) and GDP growth (GDP) are macroeconomic factors that control for the stage of the economic cycle by country (Qureshi et al., 2020; Ziaei, 2015). Finally, to capture unobserved sector effects, we add a set of industry dummies based on the 38 sectors of Fama and French (S_k). The variables are described in the Appendix.[6]

Considering that our sample period ranges from 2005 to 2017, we tested the hypotheses for both crisis (from 2008 to 2010) and non-crisis periods. In European countries, weaknesses in both sovereigns and banks led to a vicious cycle and imposed, among other significant effects, financial institution bailouts, credit restrictions on businesses and citizens, and sharp decreases in stock prices. Furthermore, relevant factors with effects on the environmental and technological context changed. Specifically, FDI and energy prices decreased during the crisis (Garsous and Kozluk, 2017), as did GDP and trade (Ziaei, 2015).

We performed additional regressions to have *ENV_PERF* interact with different contextual proxies to contrast hypotheses H2–H4. First, Model (1) is extended by adding a dummy variable (*RENEWABLE*) that takes a value of 1 when the proportion of renewable energy over the total energy used in the country is higher than 20%, and 0 otherwise, and its interaction is with environmental performance (*ENV_PERF* × *RENEWABLE*). This new Model (2) allows us to analyze the effect of green policies set by the government on the relationship between the stock prices and environmental performance.

$$PRICE_{it} = a_0 + a_1 ENV\_PER_{it} * RENEWABLE_t + a_2 BVPS_{it} + a_3 PERF_{it} + a_4 DIV_{it} + a_5 SIZE_{it} + a_6 AGE_{it} + a_7 GROWTH_{it} + a_8 INF_t + a_9 GDP_t + \sum_{k=1}^{m} S_k + \sum_{t=2005}^{2017} Y_t + \varepsilon_{it} \quad (2)$$

Model (3) includes green patents (*PATENT*), measured as the logarithm of the number of technology patents related to climate change mitigation technologies, such as energy generation, transmission, and distribution, and its interaction with the environmental performance (*ENV_PERF* × *PATENT*). Green patents act as a proxy for the technological framework by country, in which firms undertake their strategies to improve the environmental performance.

$$PRICE_{it} = a_0 + a_1 ENV\_PER_{it} * PATENTS_t + a_2 BVPS_{it} + a_3 PERF_{it} + a_4 DIV_{it} + a_5 SIZE_{it} + a_6 AGE_{it} + a_7 GROWTH_{it} + a_8 INF_t + a_9 GDP_t + \sum_{k=1}^{m} S_k + \sum_{t=2005}^{2017} Y_t + \varepsilon_{it} \quad (3)$$

Finally, Models (4) and (5) analyze the effects of foreign trade policies on the relationship between the stock prices and environmental performance. *FDI*, measured as the logarithm of the value of private direct investment made by non-resident investors in the reporting economy, is the proxy added in Model (4) to interact with the environmental performance (*ENV_PERF*×*FDI*).

$$PRICE_{it} = a_0 + a_1 ENV\_PER_{it} * FDI_t + a_2 BVPS_{it} + a_3 PERF_{it} + a_4 DIV_{it} + a_5 SIZE_{it} + a_6 AGE_{it} + a_7 GROWTH_{it} + a_8 INF_t + a_9 GDP_t + \sum_{k=1}^{m} S_k + \sum_{t=2005}^{2017} Y_t + \varepsilon_{it} \quad (4)$$

Similarly, the logarithm of the amount of goods exported by country (*EXPORTS*) is included in Model (5) and interacts with the environmental performance (*ENV_PERF*×*EXPORTS*).

[6] All the continuous variables at the bottom and top 1% of their distributions are winsorized to avoid outlier effects.

Table 1
Average environmental performance, renewable energy, green patents, and foreign trade by country.

COUNTRY	ENV_PERF	RENEWABLE	PATENTS	FDI	EXPORTS
UNITED KINGDOM	−0.3866	1.0000	1.0253	25.0602	26.8171
FRANCE	−0.3008	0.7429	1.2608	24.2968	27.0211
SPAIN	−0.5892	0.9846	1.3402	24.2218	26.3575
GERMANY	−0.7931	0.9055	1.2456	24.8296	27.8968
ITALY	−0.4138	0.8871	1.1760	23.0455	26.8760
SWEEDEN	−0.2495	0.8104	0.8180	22.9372	25.8548
FINLAND	−0.4965	0.7840	1.5553	23.1583	25.0521
NETHERLANDS	−0.3557	0.8477	1.8070	26.1829	26.9363
POLAND	−0.5095	0.7917	1.6814	23.1335	25.8812
NORWAY	−0.3055	0.5933	1.3558	23.1808	25.6172
AUSTRIA	−0.8338	0.9186	1.3078	22.7234	25.7753
PORTUGAL	−0.3281	0.6993	1.5630	23.0008	24.7185
DENMARK	−0.2860	0.8000	1.6965	22.0879	25.4048
IRLAND	−0.5700	0.9008	0.4936	24.6347	25.6606
GREECE	−0.0988	0.6901	1.0569	21.5512	24.0138
BELGIUM	−0.3644	1.0000	2.4638	25.0905	26.3689
Total	−0.4306	0.8570	1.2729	24.0476	26.3254

Note. The variables' definitions are reported in the Appendix.

$$PRICE_{it} = a_0 + a_1 ENV\_PER_{it} * EXPORTS_t + a_2 BVPS_{it} + a_3 PERF_{it} + a_4 DIV_{it} + a_5 SIZE_{it} + a_6 AGE_{it} + a_7 GROWTH_{it} + a_8 INF_t + a_9 GDP_t + \sum_{k=1}^{m} S_k + \sum_{t=2005}^{2017} Y_t + \varepsilon_{it} \tag{5}$$

Table 2
Summary statistics.

	Mean	Std. Dev	Median	Min	Max
PRICE	26.7490	42.7783	14.9521	0.5095	414.2000
ENV_PERF	−0.4306	0.6500	0.0000	−2.0509	0.0000
BVPS	26.6815	50.8893	10.5882	0.0185	388.8780
PERF	0.0585	0.0635	0.0493	−0.1377	0.3153
DIV	1.1623	2.1111	0.3165	0.0000	11.5535
SIZE	8.9768	1.5579	8.9725	4.6315	12.9532
AGE	18.9428	6.3030	20.0000	2.0000	31.0000
GROWTH	0.0070	0.0280	0.0058	−0.3296	0.4258
INF	0.0183	0.0122	0.0186	−0.0171	0.0470
GDP	1.2860	2.7141	1.7376	−9.1325	25.1625
RENEWABLE	0.8570	0.3501	1.0000	0.0000	1.0000
PATENTS	1.2729	0.7073	1.2383	0.0000	4.6899
FDI	24.0476	1.4352	24.1761	17.3680	27.3215
EXPORTS	26.3254	0.9122	26.5994	23.7259	28.0165

Note. This table reports the descriptive statistics (mean, standard deviation, median, maximum, and minimum) of the variables used in the models. The variables' definitions are reported in the Appendix.

Table 3
Multicollinearity analysis and VIF factor.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
ENV_PERF	1.08	1.08	1.08	1.08	1.08
BVPS	1.58	1.58	1.58	1.58	1.58
PERF	1.20	1.20	1.20	1.21	1.20
DIV	1.68	1.69	1.68	1.72	1.73
SIZE	1.39	1.40	1.39	1.47	1.71
AGE	1.31	1.31	1.33	1.32	1.35
GROWTH	1.07	1.07	1.07	1.07	1.07
INF	1.05	1.05	1.06	1.06	1.06
GDP	1.05	1.05	1.05	1.12	1.06
RENEWABLE		1.02			
PATENTS			1.05		
FDI				1.22	
EXPORTS					1.45
Mean VIF	**1.27**	**1.24**	**1.25**	**1.28**	**1.33**

Note. The variables' definitions are reported in the Appendix.

4. Results and discussion

4.1. Descriptive statistics

Table 1 shows the average values, by country, of the environmental performance, the proportion of renewable energy, and the logarithms of green patents, FDI, and goods exports for the period studied.

In Table 2 we present the summary statistics of the financial and environmental variables. The average stock price of European listed firms is 26.75 with a standard deviation of 42.78, whereas the environmental performance is −0.43 with a standard deviation of 0.65. Concerning the contextual factors of interest by country and year, the average values obtained for the European countries during the studied period are 0.86, 1.27, 24.05, and 26.33 for the renewable proportion dummy, green patents, FDI, and goods exports, respectively. The proportion of renewable energy for European countries parsimoniously evolved from 12% to 20% during the period under analysis (untabulated), although most countries have remarkably smaller proportions, indicating an enormous margin for improvement.

Table 3 displays the variance inflation factor (VIF), which is necessary to check the potential multicollinearity among the explanatory variables. Following Marquardt (1980), the multicollinearity issue is not present in the test, since all of the VIF indicators are less than 10.

4.2. Results on the value relevance of the environmental performance

The results obtained with the GMM estimation show that environmental performance contributes to explaining the stock prices in a positive and significant way (Table 4, column 1), thus supporting our first hypothesis. The bottom-line financial items BVPS and PERF act as positive drivers of firms' prices, which is in line with the vast empirical literature testing the Ohlson model and in line with the scarce number of works testing the role of environmental factors as "other information" in the Ohlson model (Hassel et al., 2005; Jaggi et al., 2018). DIV is negative, as it should be according to the model (Ohlson, 1995), which is unlike most previous evidence in which no other variables are added apart from those extracted from the financial statements. The positive effect emphasizes the importance of the environmental performance for

Table 4
The impact of the environmental performance on stock prices.

	(1)	(2)	(3)	(4)
	Full sample	Crisis period	No crisis period	Full sample
$PRICE_{t-1}$	0.9464***	0.5782***	0.9979***	0.9981***
	[0.0019]	[0.0893]	[0.0085]	[0.0125]
ENV_PERF	1.5964***	−0.1226	1.5997***	1.9889***
	[0.1372]	[4.6484]	[0.4192]	[0.7441]
ENV_PERF*Crisis				−1.0392**
				[0.4354]
BVPS	0.0427***	0.4953***	−0.0210***	−0.0116
	[0.0016]	[0.1023]	[0.0066]	[0.0109]
PERF	0.4471	−30.2204	−6.2256**	−20.0245***
	[0.8207]	[27.7183]	[3.0293]	[5.8886]
DIV	−0.0881***	−0.9818	0.8950***	0.8768***
	[0.0299]	[1.1484]	[0.1070]	[0.1626]
SIZE	1.3917***	−2.4284	1.6665***	1.2799***
	[0.0717]	[2.6477]	[0.2179]	[0.3897]
AGE	0.1409***	0.1031	0.0977***	0.0500
	[0.0118]	[0.4330]	[0.0313]	[0.0730]
GROWTH	37.5899***	63.0578*	61.8299***	46.0827***
	[1.5349]	[34.4189]	[7.1914]	[13.8797]
INF	64.5198***	−257.8178**	8.4006	153.9410***
	[4.9939]	[113.1238]	[17.5116]	[25.0770]
GDP	0.0209	0.2411	−0.7667***	0.1009
	[0.0207]	[0.4176]	[0.1057]	[0.1662]
Constant	−14.5433***	25.4571	−19.7538***	−14.4124***
	[0.7720]	[22.5089]	[2.0150]	[3.5581]
Observations	2867	832	2085	2867
Number of firms	304	281	304	304
Time Dummies	YES	YES	YES	YES
Industry Dummies	YES	YES	YES	YES
Hansen Test	279.6	30.92	170.7	113.8
Freedom degrees	273	24	157	113
Sig. Hansen	0.379	0.156	0.216	0.462
AR2	0.725	0.819	−0.235	0.707
Sig. AR2	0.469	0.413	0.814	0.480

Note. This table shows the results of the GMM estimation of the relationship between the stock price and environmental performance. The variables' definitions are reported in the Appendix. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

shareholders and investors, which are in line with the results found by Clarkson et al. (2015) for a similar sample of firms under the EU ETS, reporting carbon emissions as a mandatory obligation, and by several authors (Matsumura et al., 2014; Griffin et al., 2017) in the US context. The results of the Hansen test and the AR2 test indicate the absence of overidentification restrictions and of autocorrelation in the models.

Environmental performance is only significantly value-relevant for the non-crisis period (vid. Cols. 2 and 3). This result is supported using an alternative specification, since the negative coefficient of the interaction of the environmental performance with the crisis dummy partially offsets the positive coefficient of the environmental performance (col. 4). Carbon emissions and energy consumption are closely related (Ziaei, 2015) since energy prices and consumption are negatively affected during crisis periods, as well as FDI (Garsous and Kozluk, 2017), GDP, and trade (Ziaei, 2015); hence, a more in-depth analysis is required, since energy technology and consumption are the main explanatory factors of most carbon emissions, while international trade works as a means of dissemination for clean technologies.

Table 5 presents the results of the effects of green policies and technologies on the relationship between the environmental performance and stock prices. Column 1 presents the interaction between the environmental performance and the renewable energy used by country. The negative coefficient obtained for RENEWABLE is in line with the heavy burden of this renewable energy policy on the firms' costs (implementation of regulation, investment in new technologies, etc.) (Owen, 2006), and the additional negative coefficient of the interaction supports H2, suggesting an additional cost (or loss) for good performers in a country setting of a growing renewable share (Van den Bergh et al., 2013). Column 2 tests the effect of the interaction between the environmental performance and the number of patents developed to mitigate climate change. In this case, the green technological level of the country seems to exert a negative effect on the firms' value, which is consistent with the costly adjustment periods of firms to eco-innovation and green technologies (Horbach et al., 2012) in an EU ETS setting of growing stringency. However, according to our expectations in H3, it is a positive factor for firms reducing emissions, which is in line with previous literature (Paramati et al., 2017; De Haas and Popov, 2019). Higher negative coefficients of the interaction with renewables (or not significant in the case of patents) during the period 2008–2010 indicate that the difficulty of passing these costs onto the final prices is aggravated with the crisis (untabulated[7]).

Finally, Table 6 analyzes the interactions between the environmental performance and two proxies for foreign trade development: the FDI (column 1) and goods exports (column 2). Both interactions are negative and significant, showing a mitigation of the positive effect of the environmental performance on stock prices and supporting hypothesis H4. The results are addressed by the effect during non-crisis periods, in which trade openness as a driver of higher emissions seems to be detrimental for good performers, suggesting a more expensive production process when penalized by investors through market prices. During the crisis period, foreign trade by country does not play a role in the effect of environmental performance on firms' prices (untabulated).

[7] Untabulated results are available upon request.

Table 5
Impact of the environmental performance on stock prices. Renewable policies and green patents effects.

	(1)	(2)
$PRICE_{t-1}$	0.8935***	0.9517***
	[0.0016]	[0.0022]
ENV_PERF	2.2781***	0.7939***
	[0.2033]	[0.1622]
RENEWABLE	0.6637***	
	[0.0884]	
ENV_PERF*RENEWABLE	−1.8848***	
	[0.1709]	
PATENTS		−0.3164***
		[0.0616]
ENV_PERF*PATENTS		0.8211***
		[0.1018]
BVPS	0.0790***	0.0400***
	[0.0013]	[0.0018]
PERF	28.3186***	−1.4811
	[0.8211]	[0.9597]
DIV	−0.3272***	−0.0317
	[0.0203]	[0.0318]
SIZE	0.9232***	1.3494***
	[0.0832]	[0.0647]
AGE	0.3039***	0.1233***
	[0.0162]	[0.0117]
GROWTH	19.4284***	38.3511***
	[1.7056]	[1.8023]
INF	42.5987***	71.4806***
	[3.1609]	[5.3347]
GDP	0.0787***	0.0545**
	[0.0204]	[0.0212]
Constant	−14.4025***	−13.3331***
	[0.7677]	[0.6781]
Observations	2867	2867
Number of firms	304	304
Time Dummies	YES	YES
Industry Dummies	YES	YES
Hansen Test	308.6	278
Freedom degrees	358	272
Sig. Hansen	0.972	0.388
AR2	0.695	0.730
Sig. AR2	0.487	0.465

Note. By using GMM estimation, this table reports the interactions between the environmental performance and renewable energy (column 1) or the number of green patents (column 2). The variables' definitions are reported in the Appendix. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.3. Robustness analysis

This section reports additional tests to verify the robustness of our results. Tables 7–9 display the empirical results when the logarithm of the verified emissions is considered instead of environmental performance as the main explanatory variable of interest to test the hypotheses (Wang et al., 2014). The negative effects of the verified direct emissions on stock prices found in all the regressions support the results shown in Table 4. The positive (negative) signs obtained for the interaction between emissions and renewable energy, FDI, and exports (green patents) are consistent with the results shown in Tables 5 and 6 (Table 5), thus confirming hypotheses H2, H3, and H4.[8]

Finally, we use alternative methodologies to verify if our results depend on the estimation method. First, we re-estimate the models by using Ordinary Least Squares (OLS), clustering the standard errors at the year level. In addition, we estimate an instrumental variables (IV) regression model with a maximum likelihood to solve possible reverse causality problems, considering the GMM estimator and relying on the use of endogenous and instrumental variables. In this case, environmental performance is included as a continuous endogenous regressor, and the chosen instruments are the price of the emissions allowances, the tangibility of the firm, and the shortfall allowances.[9] The first instrumental variable is the closing market price of the European Union Allowances (EUA) under the EU-ETS (Van den Bergh et al., 2013); tangibility (Tascón et al., 2021) is measured as net property, plant, and equipment to total assets; and shortfall allowances (Clarkson et al., 2015) are calculated as the difference between the firm's allowance allocation and the total direct emissions, multiplied by the price of each allowance in the EU market and divided by the total assets. Using both methodologies (untabulated), we still find a positive relationship between the environmental performance and stock price in most cases. The coefficients of the interaction terms support our results in all cases, confirming the validity of the models and hypotheses.

[8] The Hansen test in the column 2 of Table 9 shows that the instruments are partially weak.

Table 6
Impact of the environmental performance on stock prices. Foreign trade.

	(1)	(2)
$PRICE_{t-1}$	0.9096***	0.9041***
	[0.0015]	[0.0016]
ENV_PERF	43.4021***	24.6578***
	[3.4330]	[1.1462]
FDI		0.2498***
		[0.0269]
ENV_PERF*FDI		−0.9510***
		[0.0476]
EXPORTS	0.8652***	
	[0.1233]	
ENV_PERF*EXPORTS	−1.6474***	
	[0.1304]	
BVPS	0.0772***	0.0576***
	[0.0013]	[0.0012]
PERF	21.1036***	23.4301***
	[0.7978]	[0.7512]
DIV	−0.3745***	0.0755***
	[0.0205]	[0.0251]
SIZE	−1.0965***	−0.0988
	[0.0779]	[0.0621]
AGE	0.2746***	0.3046***
	[0.0230]	[0.0177]
GROWTH	21.3107***	23.7123***
	[1.2461]	[1.0067]
INF	−21.8585***	32.5699***
	[3.3496]	[2.9820]
GDP	−0.0318***	−0.2487***
	[0.0115]	[0.0227]
Constant	−14.6883***	−7.4983***
	[3.0285]	[0.8774]
Observations	2867	2867
Number of firms	304	304
Time Dummies	YES	YES
Industry Dummies	YES	YES
Hansen Test	287.2	280.3
Freedom degrees	505	442
Sig. Hansen	1.000	1.000
AR2	0.705	0.743
Sig. AR2	0.481	0.457

Note. By using the GMM estimation, this table reports the interactions between environmental performance and the FDI (column 1) or goods exports (column 2). The variables' definitions are reported in the Appendix. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

5. Conclusions

This study analyzed the effect of environmental performance on stock prices considering a green technological context. Taking all of the listed firms in the main stock index in 16 European countries during the

[9] Time and industry dummies are considered as exogenous variables.

Table 7
The impact of carbon emissions on the stock prices.

	(1)	(2)	(3)	(4)
	Full sample	Crisis period	No crisis period	Full sample
$PRICE_{t-1}$	0.8903***	0.5547***	0.9859***	0.9957***
	[0.0016]	[0.0882]	[0.0121]	[0.0126]
EMISSIONS	−0.1751***	0.0614	−0.4103***	−0.3291***
	[0.0145]	[0.5852]	[0.1112]	[0.0873]
EMISSIONS*Crisis				0.1217**
				[0.0488]
BVPS	0.0638***	0.5250***	0.0210**	−0.0102
	[0.0013]	[0.1080]	[0.0106]	[0.0111]
PERF	25.3383***	−35.0604	3.0096	−22.9681***
	[0.6618]	[29.1847]	[5.3291]	[5.9569]
DIV	−0.1965***	−0.9029	−0.4907***	0.8318***
	[0.0239]	[1.1950]	[0.1722]	[0.1623]
SIZE	0.6543***	−3.3588	0.4612	1.3123***
	[0.0792]	[2.4613]	[0.4654]	[0.3857]
AGE	0.2499***	0.1868	0.1719	0.0546
	[0.0210]	[0.4168]	[0.1145]	[0.0733]
GROWTH	19.8286***	62.2637*	33.6933***	56.7340***
	[0.8536]	[32.3298]	[12.4261]	[14.0644]
INF	25.2594***	−265.0791**	94.8966***	135.2523***
	[3.0234]	[115.4547]	[24.3804]	[24.6956]
GDP	0.0093	0.1968	0.2633	0.0777
	[0.0231]	[0.4216]	[0.1874]	[0.1712]
Constant	−8.0993***	35.8302*	−7.5512*	−12.9015***
	[0.6065]	[19.7714]	[4.2347]	[3.4201]
Observations	2867	832	2213	2867
Number of firms	304	281	306	304
Time Dummies	YES	YES	YES	YES
Industry Dummies	YES	YES	YES	YES
Hansen Test	288.2	31.38	118.3	114.4
Freedom degrees	443	24	102	113
Sig. Hansen	1.000	0.143	0.129	0.445
AR2	0.708	0.764	−0.551	0.717
Sig. AR2	0.479	0.445	0.581	0.473

Note. This table shows the results of the GMM estimation of the relationship between stock prices and carbon emissions. The variables' definitions are reported in the Appendix. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Table 8
Impact of carbon emissions on the stock prices. Renewable policies and green patents effects.

	(1)	(2)
$PRICE_{t-1}$	0.8920***	0.8870***
	[0.0019]	[0.0021]
EMISSIONS	−0.5479***	−0.1410***
	[0.0276]	[0.0202]
RENEWABLE	−0.1201	
	[0.0988]	
EMISSIONS*RENEWABLE	0.4564***	
	[0.0232]	
PATENTS		−0.4762***
		[0.0606]
EMISSIONS*PATENTS		−0.0239**
		[0.0120]
BVPS	0.0803***	0.0923***
	[0.0014]	[0.0014]
PERF	27.1619***	34.3757***
	[0.6763]	[0.7463]
DIV	−0.3299***	−0.4627***
	[0.0238]	[0.0282]
SIZE	1.0055***	0.9238***
	[0.0814]	[0.0695]
AGE	0.2921***	0.3034***
	[0.0171]	[0.0181]
GROWTH	19.9194***	13.3135***
	[1.5858]	[1.4388]
INF	44.7653***	43.0362***
	[3.9159]	[5.0530]
GDP	0.0610***	0.0255
	[0.0220]	[0.0210]
Constant	−13.5225***	−11.7209***
	[0.7140]	[0.6505]
Observations	2867	2867
Number of firms	304	304
Time Dummies	YES	YES
Industry Dummies	YES	YES
Hansen Test	281	342.9
Freedom degrees	358	299
Sig. Hansen	0.999	0.481
m2	0.698	0.696
Sig. m2	0.485	0.486

Note. By using the GMM estimation, this table reports the interactions between carbon emissions and renewable energy (column 1) or the number of green patents (column 2). The variables' definitions are reported in the Appendix. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

period of 2005–2017 as a sample, we computed the by-firm environmental performance based on the mandatory information on carbon emissions reported by these firms as participants in the EU ETS. This variable is added to a GMM model built on the valuation theory developed by Ohlson. Thus, market value is explained regarding the bottom-line of the firms' fundamentals (equity, net income, and dividends) plus "other information" not included in financial statements but with potential value relevance, such as environmental performance, identified in the literature as a proxy for future risks and opportunities of firms. Then we included three factors as explanatory components of the environmental technological framework, in which the firms are undertaking environmental efforts: renewable energy policy, the development of eco-innovation, and trade openness (the latter representing access to international advances in green technology).

The results indicated that investors positively assess firms' environmental performance. However, the green technological framework in the period under analysis works as an offsetting factor for investors, except when good carbon performers operate in a scenario with higher levels of eco-innovation. During a crisis period, the positive effect of environmental performance is lower or not significant. This result is explained by a stronger offsetting effect of green technological contextual factors (renewable energy policy), whereas foreign trade becomes a non-significant factor. Overall, our results showed the interconnection of the firms' environmental performance, the technological framework in which the firms operate, the role of the market in assessing the entire process, and how the connections changed during the financial crisis.

Our findings are consistent with the costly and slow transition to greener technological frameworks (in line with the EKC), even in the EU context, where green policies are ambitious and Member States are determined to fight climate change. The direct negative effects of renewable policies and green technology development on prices could be explained by the costly development of green technology (and costly access when it is already developed) and delays in generalized applications (Owen, 2006). Furthermore, the negative effect of renewable policies on how the market evaluates firms' environmental performance suggests the existence of some inefficiencies. Specifically, this effect could be explained by the current ETS allowance trading system, which would penalize the best environmental performers (Van den Bergh et al., 2013). Our results support the positive effect of environmental performance on firms' market value in a more developed technological framework, in which green patents have already been developed. Regarding trade openness as a dissemination mechanism for green technology, in the case of technologically advanced firms under stringent green standards, it does not show a net positive effect coming from technology gain, but a negative effect coming from the less clean and less costly production processes of competitors. The lack of a significant effect during the crisis is consistent with the strong reduction of foreign trade, as well as the relegation of environmental objectives during crisis periods.

This paper has relevant implications for essential participants in the transition to environmentally conscious economic activity. Investors

Table 9
Impact of carbon emissions on the stock prices. Foreign trade.

	(1)	(2)
$PRICE_{t-1}$	0.9050***	0.8693***
	[0.0017]	[0.0022]
EMISSIONS	−3.2908***	−5.3563***
	[0.1312]	[0.3857]
FDI	0.1492***	
	[0.0313]	
EMISSIONS*FDI	0.1282***	
	[0.0055]	
EXPORTS		0.1612***
		[0.0278]
EMISSIONS*EXPORTS		0.1956***
		[0.0145]
BVPS	0.0568***	0.0852***
	[0.0015]	[0.0017]
PERF	23.5702***	29.9328***
	[0.6651]	[0.8039]
DIV	0.0710***	−0.0822***
	[0.0249]	[0.0254]
SIZE	0.0703	−0.8057***
	[0.0939]	[0.0762]
AGE	0.2793***	0.4762***
	[0.0213]	[0.0200]
GROWTH	23.5772***	21.2141***
	[0.9531]	[0.9305]
INF	34.4254***	22.2929***
	[3.6275]	[4.8648]
GDP	−0.2559***	−0.1939***
	[0.0205]	[0.0251]
Constant	−6.2100***	0.0000
	[1.1524]	[0.0000]
Observations	2867	2867
Number of firms	304	304
Time Dummies	YES	YES
Industry Dummies	YES	YES
Hansen Test	281.5	373.8
Freedom degrees	442	247
Sig. Hansen	1.000	0.0329
m2	0.747	0.694
Sig. m2	0.455	0.487

Note. By using GMM estimation, this table reports the interactions between carbon performance and FDI (column 1) or goods exports (column 2). The variables' definitions are reported in the Appendix. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

must be able to assess the potential environmental (regulatory, compliance, abatement, etc.) costs, as well as the reputational benefits of good carbon performers, the trade-off between technological adaptation of the productive systems, the materials and energy savings derived, and finally the restrictions on the ability of firms to pass on costs to customers, since all of these factors are relevant for the valuation impact of carbon emissions. The role of policymakers in providing information on the long-term effects of climate change is essential for stranded asset risks to be adequately valued by financial stakeholders and take part in the firms' price.

Both regulators and governmental authorities should take advantage of the market's role in supporting/promoting green energy policies, as well as in bringing to light inefficiencies and potential future losses. Hence, providing real, quantitative information on current and future green policies is a powerful tool to be added to such incentives as subsidies and tax credits on renewable energy innovation, production, and consumption.

Regarding energy policy implications, regulators should be aware of the potential economic damage for best performers, since it works against interest alignment toward clean production (in the line of the Market Stability Reserve, designed to tackle surplus in allowances in the EU).

For the results on the value relevance of the three elements of the green and innovative context considered, four different implications can be derived. They are concerned about the proactive role that must be played by policymakers in designing energy and research policies that should facilitate the development of, access to, and effective application of clean technologies. (1) The use of renewables is unanimously supported by the empirical literature as a cause of carbon performance, but this process has not reached the turning point to a positive contribution to the firm's value. Desirable, but slow and costly, the change to renewables is not expected to take place unless enforcement mechanisms are established as part of the environmental policies (through regulation and control). (2) Green innovation is found to be part of an advanced environmental context in terms of the value relevance for firms. However, achieving registered green patents is the result of a highly resource-demanding research and development process that should also be promoted as a key objective of environmental policies, with special attention to upstream energy innovations to reach the turning point of financial value creation. (3) The negative effect of international trade on the value relevance of environmental performance suggests the necessity of screening and controlling both import-export and FDI inflow that is in line with the regulation recently developed by the EC (2019). (4) Regulators and policymakers should pay particular attention to the economic life cycle stages, since during crisis periods the green and innovative context does not contribute to reaching environmental aims; therefore, the aims imposed should be more ambitious during non-crisis periods.

Author contribution

Paula Castro: Conceptualization and writing, creation of models, data curation, formal and validation analyses, review, and supervision.

Cristina Gutiérrez: Conceptualization and writing, investigation, creation of models, review, and editing.

María T. Tascón: Conceptualization and writing, creation of models, review and editing, project administration, and funding acquisition.

Francisco J. Castaño: Conceptualization, data curation, creation of models, and review.

Compliance with ethical standards

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CRediT authorship contribution statement

Paula Castro: Conceptualization, and writing, creation of models, Data curation, Validation, Formal analysis, Supervision, formal and validation analyses, review, and Supervision. **Cristina Gutiérrez-López:** Conceptualization, Writing – original draft, Investigation, Writing – review & editing, creation of models, review, and editing. **María T. Tascón:** Conceptualization, Writing – review & editing, Writing – original draft, creation of models, review and editing, Project administration, Funding acquisition, Funding acquisition. **Francisco J. Castaño:** Conceptualization, Data curation, creation of models, and review.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2021.128868.

Appendix

Variables' definitions.

Variable	Definition
PRICE	Closing price of firm i at the fiscal period end t
ENV_PERF	Negative total verified direct carbon emissions (Scope 1) by the firm divided by sales
EMISSIONS	The logarithm of the total verified emissions
BVPS	Total equity divided by the average shares outstanding
PERF	Net income divided by the total assets
DIV	Total dividends divided by the shares outstanding
SIZE	Logarithm of the total assets
AGE	Number of years since the firm appeared in the Compustat database
GROWTH	Variation in the sales of the firm from the previous year
INF	Annual inflation rate by country
GDP	Annual GDP growth rate by country
RENEWABLE	Dummy equal to one if the proportion of renewable energy over total energy used by the country is higher than 20%, zero otherwise.
PATENT	Logarithm of the number of technology patents related to climate change mitigation technologies such as energy generation, transmission or distribution
FDI	Logarithm of the value of private direct investment made by non-resident investors by country
EXPORTS	Logarithm of goods exports by country

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