Network centrality and the environmental-financial performance nexus of EU ETS firms

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Abstract

Cap-and-trade schemes are particularly attractive among climate mitigation policies as they promote investments in low-carbon technologies while allowing companies to minimise their compliance costs. This may generate a less negative or even positive relationship between companies' environmental performance and financial performance. However, cap-and-trade schemes can be difficult to manage for firms with limited financial resources, leading to their under-participation in the allowance market. For this purpose, the present paper examines how participation in the EU ETS (measured by network centrality measures) may affect the relationship between environmental performance and financial performance. A panel quantile regression analysis is performed to account for possible heterogeneous behaviors at different quantiles of the financial performance distribution. Results suggest that lower emission intensity is associated with higher financial performance, the more (less) so the higher the firm's network centrality in selling (buying) allowances. Moreover, the positive relationship between environmental and financial performances is stronger and clearer at the bottom (rather than at the top) of the financial performance distribution, thus confirming the importance of accounting for heterogeneous behaviors at different quantiles of the distribution.

Keywords: EU-ETS, network analysis, panel quantile regression, financial performance, environmental performance

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1 Introduction

Climate change is greatly challenging the sustainability of human society and globally economic systems. International agreements like the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol pointed the way to limit global warming and mitigate the effects of climate change. Nevertheless, greenhouse gas (GHG) emissions are still critical, although they are receiving growing attention and efforts have been made to more accurately assess the amount of human-induced emissions. As a consequence, environmental issues are becoming more relevant drivers in the decision process of a wide perimeter of stakeholders (De Villiers and Van Staden 2010, Griffin and Sun 2013, Qiu et al. 2016, Dhanorkar et al. 2018, Li and Wu 2020), inducing firms to start aligning their businesses to the proposal of emissions reduction.

The attention to environmental problems has been reinforced by their widespread economic consequences. Several different economic activities from international trade (Mattoo et al. 2009, Brack 2013) to agriculture (Howden et al. 2007, Nelson et al. 2009, Iglesias et al. 2012) are exposed to climate change. Furthermore, the globalization is likely to intensify economic vulnerabilities (o'Brien et al. 2004, Tol 2009, Leichenko et al. 2010), while the rapid rate of variation of climate conditions is also responsible for the uncertainty on the dynamics and projections of environmental-related variables (Houghton et al. 1991, Alley et al. 2003, Meehl et al. 2007, Collins et al. 2013). Unsurprisingly, there exists therefore a heated debate on how to properly evaluate externalities and design appropriate policies to prevent severe risks for the economy and society at large (Nordhaus 1994, McKibbin and Wilcoxen 2002, Nordhaus 2007, Stern 2008, Carney 2015).

To comply with commitments on GHG reduction, several national and regional emission trading systems have been adopted worldwide. The European Union Emissions Trading System (EU ETS) was launched in 2005 as the world's largest carbon trading market to promote greenhouse gases reductions in a cost-effective and economically efficient manner (European Commission 2003). The EU ETS is considered to be the cornerstone of the EU climate policy covering about 45% of GHG emissions produced by approximately 11,000 installations and 1,400 aircraft operators in 31 European countries. It relies on the principle of "cap-and-trade". Installations participating in the EU ETS can emit a total amount of GHG emissions that is "capped" and decreasing over time to reduce the aggregate emissions produced by the system.

The effectiveness of such mechanism is related to the fact that energy-intensive industrial installations are mandated to participate in the EU ETS, although for some sectors only installations above a certain size are included. Practically, liable entities under the EU ETS regulations are required to surrender an amount of allowances (named European Union Allowances, henceforth EUAs) which covers their emissions during the compliance period. More precisely, the EU ETS relates one tonne equivalent of carbon dioxide to one EUA. Installations that manage to reduce their emissions can either hold the allowances in excess to comply with their future needs, or sell them to other participants that have a shortage of allowances. By allowing permits trading across installations, the EU ETS thus creates a carbon price mechanism that stimulates firms to reduce their own emissions. As a consequence, robust EUA market price signals provide a key economic rationale for the promotion of investments in clean and low-carbon intensive technologies.

EUAs are either auctioned or granted for free by the regulator on the primary market (Ellerman et al. 2016). While initially most EUAs were freely allocated to EU ETS participants, the share of auctioned allowances has been increasing remarkably over time up to 57% of total EUAs over the period 2013-20. Transition from free allocation to auctioning has proceeded at different speeds in different sectors. For instance, the power sector has already completed the transition to full auctioning since 2013, while the share of free allowances received by the manufacturing industry decreased progressively from 80% in 2013 to 30% in 2020. Nowadays, free allowances are restricted to sectors particularly energy-intensive and/or trade-exposed that are regarded at risk of carbon leakage and, therefore, exempted from the auctioning of allowances.

Participants in such trading schemes are under pressure from regulators and stakeholders to design appropriate actions to contain carbon emissions (Hoffman 2005, Kolk and Pinkse 2005, Laing et al. 2014, Cadez et al. 2019). Firms investing in low-carbon projects tend to benefit from financial incentives, the containment of long-term operational costs and the commitment with the existing regulation, while high-polluting firms appear those more exposed to future environmental liabilities (Reinhardt and Stavins 2010, Busch and Hoffmann 2011, Horbach et al. 2012, Cecere et al. 2018). Furthermore, climate change may influence firms' investment decisions by affecting their financial performances (van Vuuren et al. 2011, Lee 2012, Dahlmann et al. 2019).

Hence, firms' increasing environmental awareness along with the importance of achieving a balance between GHG reduction and economic growth stimulate the investigation of the

relationship between environmental performance (EP) and financial performance (FP) (see, e.g., Ambec and Lanoie 2008, Horváthová 2010, Wagner 2010, Endrikat et al. 2014). For firms participating in the EU ETS, these performances are linked through the capacity to generate revenues and absorb costs. Revenues essentially come from production activities, whose production level and technology determine GHG emissions. Costs are also influenced by GHG emissions since firms in order to comply with environmental regulations must detain an amount of EUAs equal to their verified emissions, thus requiring them to buy additional allowances if they emit more, or alternatively to adopt cleaner, possibly more expensive, technologies. The literature has scrutinized the EP-FP relationship trying to answer the main question "Does it pay to be green?" (see, e.g., Jaffe et al. 1995, Barnett and Salomon 2012, Dixon-Fowler et al. 2013, Busch and Lewandowski 2018, among others). Indeed, increasing efforts have been spent to relate the environmental performance with the performance and competitiveness of firms participating in the EU ETS (see, e.g., Anger and Oberndorfer 2008, Laing et al. 2014, Ellerman et al. 2016, Martin et al. 2016, Dechezleprêtre et al. 2018). However, the way these two performances impinge each other is still controversial and to be explored in further depth.

Interestingly, recent studies have tested a quantile approach to identify non linear effects shaping the EP-FP relationship. For instance, Segura et al. (2018) analyze a set of Spanish firms participating in the EU ETS in the period 2005-2015 employing a quantile analysis based on copulas to study both the impact of production levels on the ratio of verified emissions over assigned allowances and the effect of the latter on economic results. Tzouvanas et al. (2019) propose a quantile analysis to investigate the link from EP to FP for the European manufacturing sector and find a positive relationship which is heterogeneous across the conditional distribution of FP. In our work, we extend previous analysis by relying on a panel framework encompassing firms referring to all European sectors included in the EU ETS for which we map EP and FP along the interval 2013-2016. To the best of our knowledge, this is the first study which employs a quantile regression in a panel framework to investigate the EP-FP relationship in the EU ETS. Such investigation framework is motivated by our first research question which aims at disentangling different effects of EP on conditional quantities of FP, which underlies the U-shaped EP-FP relationship discovered in some empirical studies. In doing so, we are also interested in distinguishing between variability over time and firm-level variability, thus exploiting the panel dimension of the sample. Specifically, we refer to only the most recent and available observations of EU ETS Phase III since, as it will be clarified below, the system has

experienced profound transformations moving from the early stages to the current phase. Our results show that there is a positive relationship between EP and FP, but the magnitude of such effects are substantially higher for those firms placed at the bottom part of the FP distribution.

In addition, the literature has recognized the emergence of different effects of EU ETS participation across different sectors. For instance, firms belonging to energy intensive sectors tend to react differently to EU ETS regulations (Neuhoff et al. 2006, Ellerman et al. 2010, Demailly and Quirion 2008, Chan et al. 2013). Moreover, the sectors regarded as more exposed to carbon leakage (i.e., the relocation of activities outside EU) tend to benefit from a more favourable allocation of allowances as compared to other sectors (Martin et al. 2014a, 2014b, Schmidt and Heitzig 2014). Finally, financial intermediaries which voluntarily operate in the EU ETS are more active in trading EUAs than regulated entities (Betz and Schmidt 2016, Borghesi and Flori 2018).

Against this background, we propose to study how the level of participation in the EU ETS contributes to FP, which constitutes our second research question. In fact, empirical studies have not yet explored in depth whether the role played by firms within the EU ETS in terms of how actively they trade EUAs could provide valuable signals for evaluating the EP-FP relationship. Firms can trade EUAs with several counterparts, which can be located in other countries and belong to different sectors, acting as either supplier or purchaser of EUAs; in addition, firms can transfer EUAs following different intensity of trading, being very active during the whole compliance period or, conversely, operating only in specific periods such as in proximity of the surrendering of allowances to compensate verified emissions. The set of these transactions thus defines a network of flows connecting firms within the EU ETS. Some firms are very central in the network, since they trade with many counterparts and transfer a large amount of EUAs, while others are more peripheral and perform only a few transactions. In this paper, we investigate how a firm's centrality level in such a network can be informative for its FP. Specifically, we follow existing literature exploring how the topological features of a given system are informative of its resilience and efficiency. Such framework relies on tools from network theory and complex system methodologies that have been successfully applied to describe the dynamics of several economic systems, from financial networks to trade interdependencies and social networks (see, e.g., Newman 2003, Jackson 2010, Borgatti and Halgin 2011, among others).

There are only a few papers that employ network properties to the study of the EU ETS structure. Borghesi and Flori (2018) apply a network perspective to assess the centrality of

national registries within the EU ETS over the period 2005-2012 and detect which are the most relevant types of account responsible for shaping the structure of the EU ETS, while in Borghesi and Flori (2019) a Brexit scenario is investigated through the application of complex systems tools that reallocate links of the transaction network according to the relevance of the counterparts forming the topological neighborhood of the United Kingdom. Instead, Karpf et al. (2018) exploit the network of transactions to evaluate how the topological configuration affects price formation and detect structural causes of the emergence of information asymmetries on the carbon market, while in Zhang et al. (2019) a directed limited penetrable visibility graph and a coarse graining method are applied to study the dynamic evolution characteristics of carbon prices. In our paper, we rely on a firm-level network representation where nodes are firms participating in the EU ETS that are connected by the amount of transferred EUAs. To highlight the role of firms as sellers or buyers of EUAs, we characterize firms' topological properties by means of centrality measures which are computed on the network of pure transactions. The way firms operate in the trade of allowances reveals a relevant interplay with their environmental performance, thus providing insights on how they effectively manage their EUAs in order to comply with regulatory constraints and sustain their efforts to mitigate carbon emissions. By accounting for the interaction effects between environmental performance and network centrality, we show that companies' financial performance is enhanced (diminished) when firms have a central role in the network as key and active players in selling (buying) allowances.

The rest of the paper is organized as follows. Section 2 reviews the literature background motivating our study, with a particular focus on the two main pillars: the EP-FP relationship and the functioning of EU ETS. Section 3 presents the data exploited in the study and describes the panel quantile approach employed in the investigation framework. Our empirical findings are shown and discussed in Section 4. Section 5 contains some concluding remarks.

2 Literature review

The present study relates to two vast and ever-growing strands of research: on the one hand, the literature on the firms' environmental-financial performance relationship, on the other hand, the literature on the EU ETS.

As to the first research line, the interplay between environmental and economic performances has been widely debated both in the theoretical and in the empirical literature. Two main

competing theoretical perspectives have emerged among scholars. According to the instrumental stakeholder theory, firms with higher EP tend to perform better financially since trust and cooperation contribute to enforce competitive advantages and attract investors. As an example, if stakeholders require more stringent actions to combat climate change, those firms able to satisfy such request are then able to improve their reputation and customers' loyalty. By contrast, the neoclassical theory states the opposite and points to the fact that firms involved in EP investments face additional costs and competitive disadvantages, which increase their marginal cost of production. Finally, other perspectives have been proposed so far in the literature, such as the natural resource-based view or the slack resource argument, which try to reconcile these two paradigms suggesting more complex patterns in the EP-FP relationship.

More in general, *win-win* (i.e. Porter hypothesis) and *win-lose* (i.e. trade-off EP-FP) paradigms have been adopted to explain the relationship between EP and FP (see, e.g., Porter and Van der Linde 1995, Pinkse and Kolk 2010, Hart and Dowell 2011, Boiral et al. 2012, Dixon-Fowler et al. 2013). The *win-win* perspective argues that the reduction of carbon emissions, through for instance a more efficient use of the resources and cleaner technologies, implies new opportunities of competitive advantages, thereby generating profits. On the other hand, the *win-lose* point of view emphasizes how the efforts to reduce emissions generate additional costs thus deteriorating economic performance. Such costs are related to environmental actions, such as the prevention, reduction and repair of environmental damages, and to environmental losses, such as financial penalties, as well as to changes in the environmental regulatory framework (Beckmann et al. 2014). If no environmental regulation is in place, firms will tend to voluntarily adopt actions to contain carbon emissions only if the generated benefits overcome the burden of the corresponding costs (Porter and Van der Linde 1995). It is not surprising, therefore, that the literature has found a positive (negative) impact of proactive (reactive) environmental actions on economic performance (Endrikat et al. 2014, Trumpp and Guenther 2017, Hang et al. 2018).

More generally, the empirical literature on the EP-FP relationship has found mixed results (Ambec and Lanoie 2008, Horváthová 2010, Albertini 2013, Endrikat et al. 2014). Some authors have found, for instance, a positive relationship between the two types of performances (see, e.g., Klassen and McLaughlin 1996, Judge and Douglas 1998, King and Lenox 2002, López-Gamero et al. 2009), while others have found evidence of a negative link (see, e.g., Sarkis and Cordeiro 2001, Filbeck and Gorman 2004, Wagner 2005), or even a neutral relationship (see,

e.g., McWilliams and Siegel 2001, Gilley et al. 2000, Elsayed and Paton 2005). As a consequence, more complex frameworks to reconcile these opposite relationships have been proposed. For instance, Trumpp and Guenther (2017) estimate a U-shaped relationship between environmental and financial performances in the manufacturing and service sectors, while Lewandowski (2017) finds that the non-linear relationship between annually reported carbon emissions and financial performance is positive for firms with superior EP but negative for those with inferior performance.

The second research strand we want to contribute is the one on the EU ETS. As the literature on the EP-FP relationship, also that on the EU ETS is very large. However, very few studies have looked at the EP-FP relationship in the EU ETS context up to now, so that the two literature show little intersections so far. This looks particularly surprising, given the importance of the EU ETS in the European climate policy and in the international context.

Indeed, the EU ETS is the world's first international emissions trading system representing the prototype of several ETS regimes deployed in other regions (Ellerman et al. 2010). It was originally divided into three different phases: (i) Phase I: 2005-2007, which was intended as a pilot learning phase; (ii) Phase II: 2008-2012 corresponding to the first commitment period of the Kyoto Protocol; (iii) Phase III: 2013-2020, in which a single EU-wide cap on emissions replaced the previous system based on national caps and the allocation method shifted progressively from free allocation to auctioning.[1] Due to the absence of reliable information on emissions, in Phase I the cap was based on emissions estimates, causing an excess of supply of allowances with respect to verified emissions. Since these allowances could not be banked for use in the following phase, the price of allowances practically declined to zero in 2007 (at the end of Phase I). At the beginning of Phase II, the outbreak of financial crisis led to a drastic fall in emissions reductions. This caused again a large surplus of allowances, which heavily influenced EUAs market price that remained very low throughout Phase II. In response to this, a new Directive was passed (European Commission 2018) aimed at reforming the EU ETS in several directions: by revising the legislative framework for Phase IV (2021-2030), by enforcing the so-called Market Stability Reserve (an automatic adjustment mechanism to address EUAs surplus), and by defining safeguard measures for the international competitiveness of industrial sectors at risk of carbon leakage.

[1] In the period under study in this paper (namely, 2013-2016), Member States have generated nearly $15.8 billion from the auctioning of EUAs. More than 80% of these revenues has been utilized for climate and energy purposes in line with Article 10(3) of the ETS Directive (Le Den et al. 2017).

Many studies have examined the consequences of the EU ETS on participating firms investigating its impact on three different but related aspects (Ellerman et al. 2016, Martin et al. 2016): (i) innovation (Hoffmann 2007, Rogge et al. 2011, Schmidt et al. 2012, Borghesi et al. 2015, Calel and Dechezlepretre 2016, Cainelli et al. 2020) (ii) emission abatement (Ellerman and Buchner 2008, Anderson and Di Maria 2011, Bel and Joseph 2015, Jaraite-Kažukauske and Di Maria 2016), (iii) economic performance and competitiveness (Fabra and Reguant 2014, Martin et al. 2014a, Branger et al. 2016, Joltreau and Sommerfeld 2019, Marin et al. 2018, Borghesi et al. 2020). Some studies, moreover, have focused on EUAs market price dynamics (see, e.g., Alberola et al. 2008, Chevallier 2011, Koch et al. 2014, Medina et al. 2014, Hintermann et al. 2016, Fan et al. 2017), while others have analyzed the policy design of the EU ETS (see, e.g., Sijm 2005, Hepburn et al. 2006, Convery 2009, De Perthuis and Trotignon 2014, Kollenberg and Taschini 2016, Koch et al. 2016, Perino and Willner 2016, Naegele and Zaklan 2019).

Despite this large number of studies on several different aspects of the EU ETS, hardly any attention has been paid to the market structure governing the EU ETS. Jaraitė et al. (2013a) and Jaraitė et al. (2013b) describe the ownership structure of firms participating in the EU ETS during Phase I by mapping individual EU ETS accounts to their Global Ultimate Owner. Liu et al. (2017) use transaction data of EUAs for the first two phases to study how emission levels affect the trading performance of emitting firms. Betz and Schmidt (2016) find that most installations regulated by the EU ETS in Phase I were not or hardly participating in the system, while only a small portion of accounts, often belonging to non-regulated companies, were very active. The fact that regulated firms showed limited participation to the EU ETS due to initial lack of knowledge about its functioning was also reported in early studies based on surveys (see, e.g., Pinkse and Kolk 2007, Engels et al. 2008, Trotignon and Delbosc 2008) and in a recent network-based analysis in which non-regulated entities have been shown to dominate the transaction of allowances, heavily influencing the configuration of the system (Borghesi and Flori 2018).

The present paper intends to contribute to this literature using network theory instruments to study how firms' participation in the EU ETS may affect their EP-FP relationship. This allows us to bridge the two streams of literature (on the EU ETS and the EP-FP relationship, respectively) combining them from an innovative, network-based perspective. For this purpose, in the following sections we will investigate how measures of network centrality and active participation in the EU ETS market may influence the environmental and financial performance

of the EU ETS firms.

3 Data and methodology

3.1 Data

The study employs a large database of EU firms participating in the EU ETS in the period 2013-2016, thus covering the first four years of Phase III. We collect EU ETS transaction data from the *European Transaction Log* (EUTL) database. Following existing literature, in order to represent the EU ETS system we focus on transactions -both within and across national registries- that consist of pure trade flows (EUTL codes: 3-0, 3-21, 10-0). Hence, we disregard those transactions, such as the issuance and surrendering of allowances, performed for regulatory and compliance purposes through governmental accounts. Beside the latter, the main types of accounts in the EUTL correspond to liable entities, which must comply to the EU ETS regulations, and trading accounts, specifically created for instance by brokerage firms and financial intermediaries to trade allowances. Under the EU ETS regulatory framework, liable entities are required to surrender each year by the end of April an amount of allowances equals to their emissions produced during the previous corresponding compliance year. In accordance with Annex XIV (4) of Regulation 389/2013, transaction data are made available with a lag of three years after the recording of the information.

In the EUTL, the information regarding compliance aspects, such as the amount of verified emissions, allocation and surrendering of allowances, is provided at installation level. Each installation corresponds to an account, but several accounts may be actually held by the same holding account. In our analysis, to match EUTL information with balance sheets data for each firm, we rely on the holding account level and we collect the corresponding compliance data needed to compute the environmental performance by aggregating the information from single installations at country level. The list of holding accounts from EUTL is then matched with the Orbis Bureau van Dijk database to get balance sheet information at firm level. This leads to a sample consisting of 7,181 firms.

3.2 Model

Our analysis is based on a quantile regression model estimated using the penalized fixed-effects estimation procedure proposed by Koenker (2004). This approach starts from the classical

linear model:

$$y_{i,t} = x_{i,t}^T \beta + \alpha_i + u_{i,t}, \tag{1}$$

where subscript i identifies the N firms, and t is the index for time. The extension to the quantile regression framework states that the conditional quantile functions of the response $y_{i,t}$ of firm i at time t can be modeled as follows:

$$Qy_{i,t}(\tau|x_{i,t}) = x_{i,t}^T \beta(\tau) + \alpha_i, \tag{2}$$

where τ refers to the selected quantile. Model (2) thus indicates that the effects of covariates $x_{i,t}$ depend upon the selected quantile τ, whereas α's do not. Hence α's imply a pure location shift effect on the conditional quantiles of y. Koenker (2004) proposes to simultaneously estimate model (2) for several quantiles using the following minimization problem:

$$min_{\alpha,\beta} \sum_{k=1}^{Q} \sum_{i=1}^{N} \sum_{t=1}^{T} w_k \rho_{\tau_k}(y_{i,t} - \alpha_i - x_{i,t}^T \beta(\tau_k)) \tag{3}$$

in which $\rho_\tau(u) = u(\tau - I(u < 0))$ stands for the piecewise linear quantile loss function of Koenker and Bassett (1978) and the weights w_k control for the influence of the Q quantiles on the estimation of α_i. Model (3) can be solved with interior point methods which proceed iteratively by solving a sequence of diagonally weighted least squares steps based on a Cholesky factorization.

Furthermore, the quantile loss function includes a l_1 penalty, $P(\alpha) = \sum_{i=1}^{N} |\alpha_i|$, instead of a typical Gaussian penalty. This determines that the linear programming problem preserves the sparsity of the design matrix, while providing computational advantages. As pointed by Koenker (2004), the penalized version of model (2) thus becomes:

$$min_{\alpha,\beta} \sum_{k=1}^{Q} \sum_{i=1}^{N} \sum_{t=1}^{T} w_k \rho_{\tau_k}(y_{i,t} - \alpha_i - x_{i,t}^T \beta(\tau_k)) + \lambda \sum_{i=1}^{N} |\alpha_i| \tag{4}$$

where the fixed effects vanish when $\lambda \to \infty$, while the fixed effects estimator restores to that of formulation (2-3) when $\lambda \to 0$.

More in general, the resulting fixed effects estimator is obtained through a minimization problem based on the weighted sum of Q ordinary quantile regression objective functions in which the slope coefficients of the covariates depend on the selected values of τ, whereas coeffi-

cients corresponding to the fixed effects do not, thus reducing the dimensionality added by the estimation of many fixed effects. Following such procedure proposed by Koenker (2004), the corresponding vector of the fixed effects coefficients are computed by imposing an l_1 penalty term shrinking these coefficients toward zero. In our study, we use identical weights for each τ, while λ is set to the default value of 1.

3.3 Variables selection

Our analysis intends to relate the environmental performance of the firm to its profitability (see, e.g., Horváthová 2010, Busch and Hoffmann 2011, Lewandowski 2017). To this end, We measure the firm's financial performance in terms of Returns on Equity (ROE).[2]

Environmental performance is measured as the ratio of reported emissions by the firm during a compliance period to its size, typically measured by total assets or sales (Aragón-Correa 1998, Wagner 2005, Aggarwal and Dow 2012, Misani and Pogutz 2015, Trumpp et al. 2015, Fernández-Cuesta et al. 2019). In this work, we rely on the logarithmic ratio of the verified emissions reported by each firm over its total assets (*log(CO2/TA)*).

The list of covariates includes balance sheet information at firm level. Following for instance Tzouvanas et al. (2019), we add the share of intangible assets over total fixed assets (*Intangibles share*) as an indicator of firm's capacity to generate value in the future through, e.g., research and development investments. To account for capital deepening, we include the ratio between total fixed assets (tangible and intangible) and the number of employees in log (*log(K/L)*). In line with recent works on EU ETS (see, e.g., Segura et al. 2018, Fernández-Cuesta et al. 2019, Makridou et al. 2019, Tzouvanas et al. 2019), we control for firm's risk and liquidity dimensions by measuring the risk of the firm in terms of the Altman Z-score computed for non-listed firms (*Z-score*), while liquidity conditions are included by using the ratio of Current Assets minus Stocks over Current Liabilities (*Liquidity*) and firm's ability to generate cash-flows as measured by the annual growth rate of sales (*Sales growth*). Finally, we control for firm's size using the number of employees in log (*log(L)*) (see, e.g., Clarkson et al. 2011, Broadstock et al. 2018, Tzouvanas et al. 2019). To limit endogeneity issues and reduce simultaneity bias, in line with previous studies all balance sheet variables are lagged by one year (see, e.g., Wagner 2010, Busch and Hoffmann 2011, Clarkson et al. 2011, Misani and Pogutz 2015, Lewandowski 2017, Pekovic

[2]It should be noted that ROE also accounts for the cost of purchasing EUAs and for the revenues from the sale of EUAs.

et al. 2018, Makridou et al. 2019, to name a few).

Table 1 reports summary descriptive statistics for each variable in the period 2012-2016.[3] As shown in the table, *ROE* exhibits increasing dynamics at the end of the reference period, while the proxy for environmental performance (namely, *log(CO2/TA)*) appears on average more stable. In addition, centrality indicators show a declining trend and a tendency towards a narrower dispersion over time. Balance sheet features, such as *Liquidity*, *log(K/L)*, *Intangibles share*, are pretty stable, while others like *Z-score* and *Sales growth* have a more erratic behavior. The size of the firms (*log(L)*) is also very stable over the reference period.

[3]The period under study is 2013-16 but descriptive statistics start from 2012 since balance sheet information is included in the models with one year lag.

Table 1: Summary descriptive statistics.

	2012				2013				2014				2015				2016			
	Q1	Mean	Q3	SD	Q1	Mean	Q3	SD	Q1	Mean	Q3	SD	Q1	Mean	Q3	SD	Q1	Mean	Q3	SD
ROE	-1.46	2.46	13.65	65.10	-1.62	-0.48	12.70	71.40	-0.64	2.24	13.73	71.90	0.00	3.30	15.02	64.90	0.58	7.00	16.49	61.56
log(CO2/TA)	-2.60	-1.25	0.22	2.49	-2.50	-1.30	0.06	2.39	-2.49	-1.30	0.09	2.45	-2.44	-1.25	0.18	2.39	-2.36	-1.18	0.24	2.40
In-degree	1.00	1.49	2.00	3.48	1.00	1.51	2.00	2.15	1.00	1.37	1.00	1.68	1.00	1.28	1.00	1.42	1.00	1.19	1.00	1.10
Out-degree	1.00	1.45	1.00	3.62	0.00	1.19	1.00	3.04	0.00	1.06	1.00	2.31	0.00	0.94	1.00	1.84	0.00	0.69	1.00	1.47
Z-score	0.85	4.98	2.48	139.72	0.84	2.71	2.50	48.75	0.84	2.69	2.51	35.48	0.88	1.92	2.53	15.33	0.89	2.38	2.52	30.94
Liquidity	0.85	2.37	2.17	5.16	0.85	2.64	2.18	6.78	0.85	2.51	2.22	5.83	0.88	2.54	2.26	5.97	0.89	2.60	2.27	6.17
Sales growth	-0.06	8.42	0.14	507.09	-0.05	8.52	0.11	409.34	-0.21	0.14	-0.06	8.68	-0.17	0.79	-0.03	38.92	-0.11	1.57	0.02	62.99
Intangibles share	0.00	0.07	0.05	0.17	0.00	0.06	0.04	0.24	0.00	0.06	0.04	0.17	0.00	0.06	0.04	0.17	0.00	0.06	0.03	0.17
log(K/L)	4.45	5.40	6.22	1.72	4.52	5.42	6.29	1.73	4.41	5.33	6.18	1.72	4.32	5.24	6.09	1.72	4.30	5.18	6.03	1.70
log(L)	3.69	7.35	6.30	9.44	3.76	7.35	6.35	9.43	3.78	7.32	6.33	9.43	3.83	7.32	6.33	9.47	3.83	7.30	6.33	9.48

The table reports for the years from 2012 to 2016, the first (Q1) and third quartile (Q3) of the distribution, the mean value and the standard deviation (SD) of the variables described in subsection 3.3.

3.3.1 Network indicators

To measure how firms operate in the EU ETS, we employ two network centrality indicators representing the amount of both incoming (*In-degree*) and outgoing (*Out-degree*) links of a given node/firm. A stream of literature particularly promising for dealing with the analysis of economic systems with instruments of network analysis is, in fact, the one that is developing at the intersection of applied economics and complex systems theory (see, e.g., Stanley et al. 1999, Newman 2003, Schweitzer et al. 2009, Jackson 2010, Borgatti and Halgin 2011), which has been already explored in several different economic domains (see, e.g., Foster 2005, Fagiolo et al. 2008, Acemoglu et al. 2012, Elliott et al. 2014, Glasserman and Young 2015, Carvalho and Thabaz-Salehi 2018, among others). A similar perspective has been already applied in the study of EU ETS in a few recent works (Borghesi and Flori 2018, Karpf et al. 2018, Borghesi and Flori 2019, Zhang et al. 2019).

More specifically, since the direction of the flows from transferring counterparts to acquiring ones indicates two opposite business needs, we thus specify the orientation of the links connecting pairs of nodes in order to highlight the role of a node in the network in terms of purchaser or seller of allowances. Practically, we represent the network of EU ETS transactions by means of an adjacency matrix A whose element a_{ij} stands for the flow of EUAs from a source node i to a target node j. We denote with $\textit{In-degree}_i = \sum_j^N a_{ji}$ the number of links entering into node i, while we refer to $\textit{Out-degree}_i = \sum_j^N a_{ij}$ as the number of departing links from node i. We compute these network indicators for each year separately including firms with at least one incoming or departing link during the year. Hence, a node with high values of *In-degree* correspond to a firm acquiring allowances from many other participants in the system, while high values of *Out-degree* correspond to a firm selling allowances to many different counterparts. The topological properties of a node thus signal whether a firm is central in selling or acquiring allowances. The way a firm manages its portfolio of allowances is thus translated in these centrality scores, with an excess of allowances probably favouring their transfer to other counterparts thus increasing the value of *Out-degree*. By contrast, a deficit of allowances may be compensated by acquiring allowances from the marketplace, thus increasing the value of *In-degree*. As a result, there might exist an interplay between the environmental performance of a firm and the way it operates in the market of allowances, which we propose to capture with these simple topological indicators.

3.3.2 Controls

We also include a rich list of controls for economic, environmental and country conditions. To map the market dynamic of EU ETS allowances, we include their average annual price (EUA). EUAs prices have experienced very volatile market patterns, especially during the financial crisis of 2007-08 and the switch from Phase I to Phase II of the EU ETS program (Engels 2009, Ellerman et al. 2016, Hintermann et al. 2016). One tCO_2 was priced at about €0.02 at the end of Phase I, rising to about €30 at the beginning of Phase II before dropping at the end of 2008 to about €15, then remaining at about €10-15 until 2011 when it started to sharply decrease to about €4-5 in 2013, reaching a more stable market pattern in the first years of Phase III when it ranged around €4-8. It is worth mentioning that firms with Phase II allowances were allowed to bank them and carry-over use in Phase III, when the cap requirements would be lowered at a faster pace that would likely result in market pressure on prices. Such market dynamics are important to assess the commitment of firms to control emissions, as very low carbon price deter firms from investing in cleaner technologies to reduce carbon emissions.

We then add indicators for the energy and electricity markets to control for the well-documented impacts of policies and sector conditions on firms' environmental performances (see, e.g., del Río González 2007, Böhringer and Rosendahl 2010, Jaraitė and Kažukauskas 2013, Doumpos et al. 2017). We consider: i) the energy and supply components of the electricity price for both households and non-household consumers, and ii) the energy productivity measured as the ratio of GDP over gross energy use for a given calendar year. In addition, we include the energy efficiency policies score from the output-based scoreboard on energy efficiency targets computed by MURE (Measures d'Utilisation Rationnelle de l'Energie; values are expressed in a scale ranging from 0 to 100, where 100 is the best score; see, e.g., Makridou et al. 2019). All these indicators are computed at a country-year basis. More in general, these indicators stand for the domestic energy and electricity market conditions and the effectiveness of the policy framework. These conditions may influence firms' adoption of energy-saving and cleaner technologies aimed to prompt firms' environmental performance.

Finally, to capture different macro-economic conditions among firms operating in different countries and to control for country level environmental conditions, for each year and country we include the GDP per Capita growth rate and the logarithmic amount of GHG Emissions by all NACE activities.

4 Results

4.1 Baseline results

Table 2 shows the baseline estimation of the EP-FP relationship for different quantiles ranging from $\tau = 0.1$ to $\tau = 0.9$, with FP proxied by ROE. Panel A reports results for a simpler specification without any macro-level controls, while the specification for the full set of macro-level controls is shown in Panel B. The measure of environmental performance, log(CO2/TA), presents an almost monotonic pattern, with significant and negative coefficients for lower quantiles of FP, while for upper quantiles still points to a negative relationship but not statistically significant. Hence, we find that for firms in the lower tail of the ROE distribution, a better environmental performance could favor better financial performance, in line with the view of Porter and Van der Linde (1995). On the contrary, we observe that those firms that are more able to obtain a good financial performance are not statistically impacted by variations of log(CO2/TA). Overall, these results suggest that for a consistent portion of the ROE distribution, there is a statistically significant negative relationship with log(CO2/TA), meaning that solutions improving firms' environmental performance are likely to improve financial results. By applying a quantile analysis on a restricted sample of manufacturing firms, Tzouvanas et al. (2019) observe that the EP-FP relationship is U-shaped. Here, we notice that for a subset of firms performing very well financially, there is no statistically significant relationship with EP. As a result, a simple linear functional form for the whole sample is likely to misrepresent the EP-FP relationship.

We also observe that balance sheet features play an important role in shaping firms' financial performance. Z-score presents estimated coefficients that are statistically significant and positive in all quantiles. Reducing the financial distress thus helps firms to get better financial results, especially for those firms related to lower values of τ. Marginal effect of Z-score for those firms placed in the bottom of the FP distribution is about twice than the one of the best financially performing firms, thus supporting again the use of a quantile representation to uncover differences across firms with different financial performances. As regards liquidity conditions, we note a negative and significant impact, except in the extremes of the FP distribution where the sign is still negative but the effect is not statistically significant. Overall, higher mismatches between current levels of assets and liabilities seem to reduce firms' ROE. Instead, the annual growth rate of sales does not appear to play any significant role, with coefficients

Table 2: Baseline results

Dep. var.: ROE	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
Panel A - Results without macro-level control variables									
log(CO2/TA)	-0.777***	-0.370***	-0.291***	-0.249***	-0.186***	-0.148***	-0.086	-0.040	-0.195
	(0.176)	(0.077)	(0.059)	(0.053)	(0.055)	(0.055)	(0.066)	(0.092)	(0.148)
Z-score	1.561***	1.157***	1.005***	0.979***	0.978***	1.000***	0.932***	0.851***	0.726***
	(0.329)	(0.212)	(0.193)	(0.184)	(0.178)	(0.171)	(0.171)	(0.169)	(0.198)
Liquidity	-0.048	-0.066	-0.089*	-0.103**	-0.111**	-0.120***	-0.121***	-0.105*	-0.084
	(0.086)	(0.056)	(0.046)	(0.045)	(0.045)	(0.045)	(0.046)	(0.056)	(0.067)
Sales growth	-0.016	-0.023	0.022	0.021	0.090	0.087	0.174	0.168	0.155
	(0.048)	(0.063)	(0.071)	(0.078)	(0.132)	(0.133)	(0.130)	(0.126)	(0.117)
Intangibles share	-4.003	0.724	0.726	1.016	1.285*	1.429*	1.369	0.942	0.909
	(3.522)	(0.974)	(0.841)	(0.741)	(0.737)	(0.754)	(0.890)	(1.163)	(2.326)
log(K/L)	0.015	0.188	0.210*	0.115	0.086	0.020	-0.098	-0.298**	-0.641***
	(0.308)	(0.128)	(0.108)	(0.098)	(0.093)	(0.097)	(0.106)	(0.140)	(0.207)
log(L)	0.461*	0.301***	0.346***	0.364***	0.375***	0.363***	0.312***	0.256**	-0.088
	(0.241)	(0.091)	(0.065)	(0.061)	(0.065)	(0.068)	(0.070)	(0.103)	(0.177)
Panel B - Results with macro-level control variables									
log(CO2/TA)	-0.713***	-0.296***	-0.223***	-0.213***	-0.159***	-0.097	-0.064	0.012	0.124
	(0.181)	(0.075)	(0.058)	(0.056)	(0.056)	(0.059)	(0.066)	(0.086)	(0.166)
Z-score	1.491***	1.099***	0.996***	0.977***	0.984***	0.980***	0.906***	0.826***	0.703***
	(0.280)	(0.216)	(0.203)	(0.204)	(0.196)	(0.193)	(0.195)	(0.197)	(0.239)
Liquidity	-0.048	-0.086	-0.116**	-0.120**	-0.123**	-0.140***	-0.113**	-0.101*	-0.088
	(0.081)	(0.057)	(0.052)	(0.051)	(0.050)	(0.050)	(0.052)	(0.057)	(0.069)
Sales growth	-0.019	0.008	0.022	0.021	0.082	0.079	0.174	0.168	0.156
	(0.087)	(0.102)	(0.129)	(0.146)	(0.166)	(0.165)	(0.160)	(0.151)	(0.141)
Intangibles share	-5.374	1.138	1.438*	1.316*	1.707**	2.137***	2.043**	1.427	1.856
	(3.650)	(1.218)	(0.831)	(0.765)	(0.732)	(0.747)	(0.909)	(1.234)	(2.458)
log(K/L)	0.148	0.087	0.121	0.047	0.047	-0.010	-0.161	-0.370***	-0.652***
	(0.272)	(0.126)	(0.094)	(0.089)	(0.087)	(0.092)	(0.106)	(0.141)	(0.222)
log(L)	0.431*	0.220**	0.247***	0.318***	0.317***	0.357***	0.316***	0.284***	0.074
	(0.234)	(0.096)	(0.075)	(0.069)	(0.063)	(0.064)	(0.076)	(0.096)	(0.208)
Macro-level Controls:	YES	YES	YES	YES	YES	YES	YES	YES	YES

The table reports the quantile regression model, estimated using the penalized fixed-effects estimation procedure proposed by Koenker (2004) with intercept, for values of τ ranging from $\tau = 0.1$ to $\tau = 0.9$. Standard errors are reported in parenthesis. The number of firm-year observations are 10,596 in Panel A and 10,585 in Panel B. * p< 0.1, ** p< 0.05, *** p<0.01. Results for macro-level controls in Panel B are not shown and remain available upon request.

of Sales growth that are indistinguishable from zero. Similarly, the share of intangible assets has a (weakly) statistically significant and positive effect only in the middle of the distribution of ROE, suggesting weak links between short-term profitability measures (ROE) and longer term effects of innovation activities on performance. However, we find that capital deepening, log(K/L), has negative and significant coefficients in the upper tail of the distribution of ROE, meaning that for firms performing very well financially, a higher capital intensity is likely to negatively affect the respective financial performance. This could be related to the fact that for these very profitable firms the short-term returns of marginal increases in the capital intensity are lower than the (already very high) returns to capital. Finally, the coefficients of firm size, log(L), are practically always significant and positive, with a larger effect in the lowest part of the ROE distribution: expanding firms turns out to be more profitable in the short run. All these results are robust to the inclusion of macro-level control variables, as evident from Panel B.

4.2 Results accounting for network measures

This section enriches the investigation framework discussed in section 4.1 by including network indicators. In particular, we describe the behaviour of each firm within the EU ETS by means of topological measures of centrality indicating how active is a firm in trading allowances either

as acquiring or selling account. In so doing, we attempt to disentangle the role played by the position of firms within the EU ETS network as a driver of FP, possibly highlighting peculiar effects across τ values of the FP distribution (see Table 3).[4]

A high value of In-degree means that the corresponding firm is an acquirer of EUAs from many different counterparts, while a high value of Out-degree stands for a firm selling EUAs to many other EU ETS participants. We use these two simple network indicators to differentiate the active role of a firm as a buyer and/or seller of EUAs. We investigate how the active role of a firm relates to its financial performance first by estimating the relationship between FP and both In-degree and Out-degree for different values of τ. Although not statistically significant in general, we observe in Table 3 that network centrality indicators seem to point to opposite effects for firms belonging to either the bottom or top deciles of the distribution of ROE. Specifically, In-degree has a positive effect for low performing firms, declining and becoming negative for higher values of τ. Conversely, a negative impact of Out-degree emerges for lower values of τ, while again an opposite effect results for those firms in the upper part of the distribution of ROE. The lack of any direct relationship between network centrality and financial performance is not surprising, however, as a strong link between network centrality and FP would imply that profits and losses, arising directly from allowance trading, contribute substantially to the overall level of profits. While this could be relevant for a subset of firms in emission-intensive sectors (e.g., power sector), it is less likely to be the case for sectors where the overall value of traded allowances (allocated, purchased and sold) is small compared to the economic size of the company.

In addition, Table 4 reports the estimates when alternative topological features are considered. Specifically, we include the Betweenness, the Eigenvector and the Closeness centralities. These indicators exploit the whole configuration of the network, providing a comprehensive view on the topological positioning of a firm in the network. The Betweenness is an asymmetric measure of centrality and indicates the likelihood of a node to play as an intermediary in the trade between other nodes, representing how frequently it lies in the geodesic pathways connecting other nodes. The Eigenvector centrality of a certain node considers the structure of the network and, in particular, it includes the importance of the neighborhood of the node in

[4]The inclusion of In-degree and Out-degree in the panel quantile regression largely confirms the findings reported in Table 2, thus supporting previous discussion on the presence of heterogeneous effects across deciles of the response variable and highlighting the importance of including firm's level information as long as macro and sectoral dimensions to shape firms' financial performances.

the computation of its centrality. Closeness centrality stands for the topological distance of a certain node with the rest of the system and it can be interpreted as an indicator of how long it takes to spread information from the node to the rest of the system sequentially. More practically, a node with a high value of Betweenness indicates that such node plays a role similar to an intermediary in the transfer of allowances between many other nodes in the network, a node with a high value of Closeness means that it is likely to trade with several other nodes directly, while the Eigenvector centrality of a node takes into account not only the amount of incoming links but, more importantly, the topological features of the corresponding connected neighbors. Our findings confirm that topological properties alone are unlikely to effectively impact on FP. An exception is the Eigenvector centrality, which appears to positively impact on FP for firms in the upper tail of the distribution, possibly signaling a better capacity of higher financially performing firms to benefit from trades with well-connected and central counterparts. Note how the estimates for the other regressors reported in Table 4, and in particular for EP, are largely in line with those shown in Table 3.

Table 3: Specification with network centrality measures

Dep. var.: ROE	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
In-degree	0.643	0.155	0.187	0.090	0.189*	0.191*	0.131	0.022	-0.141
	(0.540)	(0.205)	(0.134)	(0.106)	(0.109)	(0.114)	(0.142)	(0.162)	(0.354)
Out-degree	-0.767	-0.112	-0.126	-0.012	-0.082	-0.065	-0.024	0.163	0.264
	(0.626)	(0.207)	(0.128)	(0.098)	(0.103)	(0.126)	(0.150)	(0.171)	(0.268)
log(CO2/TA)	-0.779***	-0.294***	-0.192***	-0.213***	-0.276***	-0.239***	-0.212***	-0.007	0.013
	(0.177)	(0.091)	(0.067)	(0.061)	(0.064)	(0.071)	(0.077)	(0.095)	(0.190)
Z-score	2.096***	1.574***	1.503***	1.477***	1.562***	1.662***	1.740***	1.708***	1.599***
	(0.314)	(0.243)	(0.232)	(0.229)	(0.226)	(0.236)	(0.247)	(0.269)	(0.298)
Liquidity	0.006	-0.119*	-0.166***	-0.151***	-0.167***	-0.144**	-0.094	-0.064	0.052
	(0.073)	(0.062)	(0.059)	(0.057)	(0.056)	(0.056)	(0.057)	(0.07)	(0.099)
Sales growth	0.027	-0.028	-0.040	0.083	0.068	0.055	0.552	0.516	0.774
	(0.107)	(0.157)	(0.209)	(0.254)	(0.350)	(0.404)	(0.429)	(0.495)	(0.820)
Intangibles share	0.814	1.043	1.727*	2.028***	2.335***	2.205***	2.772***	2.161	3.969
	(3.265)	(1.252)	(0.891)	(0.766)	(0.777)	(0.849)	(1.065)	(1.359)	(2.456)
log(K/L)	0.167	0.078	0.183	0.097	0.051	0.006	-0.213*	-0.380***	-0.885***
	(0.290)	(0.137)	(0.121)	(0.109)	(0.105)	(0.110)	(0.125)	(0.145)	(0.276)
log(L)	0.488*	0.173	0.267***	0.277***	0.232***	0.230***	0.095	0.014	-0.554**
	(0.271)	(0.110)	(0.086)	(0.078)	(0.084)	(0.086)	(0.100)	(0.116)	(0.247)
Macro-level Controls:	YES	YES	YES	YES	YES	YES	YES	YES	YES

The table reports the quantile regression model, estimated using the penalized fixed-effects estimation procedure proposed by Koenker (2004) with intercept, for values of τ ranging from $\tau = 0.1$ to $\tau = 0.9$. Standard errors are reported in parenthesis. The number of firm-year observations are 6,455. * p< 0.1, ** p< 0.05, *** p<0.01. Results for macro-level controls are not shown and remain available upon request.

Firms within the EU ETS can experience the emergence of a surplus or deficit of EUAs for compliance purposes. This depends on their level of production, and thus of emissions, but also on their investments in carbon abatement technologies and activities. It may be the case, therefore, that within a given compliance period, a firm with improved environmental performance could exhibit an excess of allowances that may seek to sell in the EU ETS marketplace, while on the contrary firms with more emission-intensive production processes and lower capabilities to improve the environmental performance may rely more on acquiring EUAs from other operators. Hence, there exists a relationship between a firm's environmental performance

Table 4: Specification with alternative topological indicators

Dep. var.: ROE	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
Betweenness	61.843	19.589	10.439	10.776	6.489	19.814*	15.619	10.102	50.351
	(212.814)	(47.415)	(27.720)	(18.199)	(12.697)	(11.529)	(16.634)	(34.032)	(57.174)
Eigenvector	12.657	9.131	6.957	3.020	4.987	6.503	8.881*	9.711	43.958***
	(15.222)	(7.465)	(4.947)	(4.439)	(4.331)	(4.663)	(5.068)	(7.246)	(15.966)
Closeness	-1113.692	-314.437	-189.666	-55.192	-287.663	-251.456	-267.173	-454.942	-1109.417
	(1116.808)	(481.553)	(333.547)	(249.634)	(252.301)	(288.121)	(347.235)	(455.498)	(826.407)
log(CO2/TA)	-0.732***	-0.301***	-0.185***	-0.229***	-0.279***	-0.231***	-0.201**	0.002	-0.141
	(0.191)	(0.084)	(0.071)	(0.066)	(0.069)	(0.070)	(0.078)	(0.105)	(0.182)
Z-score	2.141***	1.589***	1.520***	1.489***	1.557***	1.655***	1.753***	1.714***	1.676***
	(0.313)	(0.234)	(0.218)	(0.213)	(0.219)	(0.216)	(0.221)	(0.232)	(0.296)
Liquidity	0.007	-0.111	-0.168**	-0.152**	-0.168***	-0.145**	-0.09	-0.08	-0.005
	(0.072)	(0.074)	(0.07)	(0.066)	(0.065)	(0.064)	(0.061)	(0.069)	(0.104)
Sales growth	0.033	-0.029	-0.040	0.081	0.064	0.051	0.547	0.543	0.702
	(0.090)	(0.084)	(0.137)	(0.243)	(0.387)	(0.465)	(0.52)	(0.619)	(0.968)
Intangible share	1.034	1.053	1.736**	1.826**	2.294***	2.420***	2.687***	2.283*	3.783
	(3.268)	(1.234)	(0.860)	(0.789)	(0.756)	(0.852)	(0.992)	(1.23)	(2.361)
log(K/L)	0.171	0.095	0.198*	0.128	0.057	0.025	-0.168	-0.315**	-0.981***
	(0.305)	(0.138)	(0.114)	(0.109)	(0.112)	(0.104)	(0.124)	(0.150)	(0.273)
log(L)	0.502**	0.153	0.270***	0.279***	0.240***	0.234***	0.108	0.041	-0.609***
	(0.227)	(0.095)	(0.084)	(0.076)	(0.082)	(0.082)	(0.091)	(0.113)	(0.223)
Macro-level Controls:	YES	YES	YES	YES	YES	YES	YES	YES	YES

The table reports the quantile regression model, estimated using the penalized fixed-effects estimation procedure proposed by Koenker (2004) with intercept, for values of τ ranging from $\tau = 0.1$ to $\tau = 0.9$. Standard errors are reported in parenthesis. The number of firm-year observations are 6,455. * p< 0.1, ** p< 0.05, *** p<0.01. Results for macro-level controls are not shown and remain available upon request.

and how it actively manages its portfolio of EUAs. For this reason, in Table 5 we evaluate the impact of the interaction effects between log(CO2/TA) and the network indicators In-degree and Out-degree. To ease the interpretation of interaction terms, we took out from log(CO2/TA) its median value. This allows us to interpret the coefficients for In-degree and Out-degree as the effects for firms with median emission intensity.

Table 5: Interaction between network centrality measures and EP

Dep. var.: ROE	$\tau = 0.1$	$\tau = 0.2$	$\tau = 0.3$	$\tau = 0.4$	$\tau = 0.5$	$\tau = 0.6$	$\tau = 0.7$	$\tau = 0.8$	$\tau = 0.9$
In-degree	0.843	0.253	0.230	0.174	0.211*	0.269*	0.290*	0.137	0.456
	(0.583)	(0.235)	(0.153)	(0.113)	(0.122)	(0.151)	(0.173)	(0.222)	(0.359)
Out-degree	-1.053	-0.325	-0.241	-0.144	-0.129	-0.145	-0.091	-0.053	-0.240
	(0.673)	(0.213)	(0.151)	(0.111)	(0.100)	(0.124)	(0.140)	(0.179)	(0.310)
log(CO2/TA)	-0.784***	-0.263**	-0.195**	-0.259***	-0.321***	-0.301***	-0.255***	0.025	-0.131
	(0.272)	(0.111)	(0.088)	(0.073)	(0.070)	(0.081)	(0.091)	(0.131)	(0.243)
log(CO2/TA) × In-degree	0.252*	0.151**	0.118**	0.094*	0.116**	0.131**	0.115*	0.093	0.147
	(0.145)	(0.075)	(0.057)	(0.051)	(0.049)	(0.057)	(0.060)	(0.080)	(0.133)
log(CO2/TA) × Out-degree	-0.376**	-0.213***	-0.151**	-0.107*	-0.114**	-0.117**	-0.085	-0.141**	-0.129
	(0.185)	(0.075)	(0.063)	(0.057)	(0.055)	(0.059)	(0.058)	(0.071)	(0.144)
Firm-level Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES
Macro-level Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES

The table reports the quantile regression model, estimated using the penalized fixed-effects estimation procedure proposed by Koenker (2004) with intercept, for values of τ ranging from $\tau = 0.1$ to $\tau = 0.9$. Standard errors are reported in parenthesis. The number of firm-year observations are 6,455. * p< 0.1, ** p< 0.05, *** p<0.01. Results for other firm-level controls, Z-score, Liquidity, Sales growth, Intangibles share, log(K/L), log(L), and macro-level controls are not shown and remain available upon request.

As expected, the effects in Table 5 of In- and Out-degree on ROE for the median firm reflect the results from Table 3, that is a generally not significant effect, positive for In-degree and negative for Out-degree. However, we observe a generally positive interaction term for In-degree (except for the two top quantiles) and a generally negative and significant interaction term for Out-degree, again except the top quantiles.

However, by considering the interaction effects between network centrality measures and EP, we can quantify the effect of EP on FP for different levels of involvement in allowance trading. While we found, on average (see, e.g., Table 3), a positive relationship between EP (i.e., low emission intensity) and FP, this positive relationship is significantly attenuated for firms with high In-degree (except for the two top quantiles) and reinforced for firms with high Out-degree

(except the seventh and ninth quantile). We uncover, therefore, that the main effect of EP on FP is affected by how firms participate in the EU ETS as acquirer or seller of allowances.

To disclose how this interplay between ETS participation and EP influences FP, we report in Figure 1 the combinations of values for In-degree and Out-degree such that the relationship between EP and FP is positive (i.e., Porter-like effect, green area), null (EP and FP are independent, blue line) and negative (i.e., trade off between EP and FP, red area) for the different quantiles of FP.[5] Moreover, the orange dot in each panel identifies the average firm (in terms of In- and Out-degree) within each quantile. Note how, in general, the 'average' firm falls within the Porter-like area for all quantiles except $\tau = 0.8$, for which the average firm lies in the 'trade-off' area but close to the 'no-relationship' line.[6]

The main implication of these results is that to take advantage of EP-FP complementarities, firms will need to consider also their behaviour on the permits market. For instance, increasing the Out-degree (i.e., by enlarging the number of counterparts to which a firm sells allowances) and decreasing the In-degree (i.e., by reducing the number of counterparts from which allowances are bought) would signal a possible excess of allowances and thus a better EP contributing to foster FP. However, such combination of strategies appears to be unlikely in our sample, as for all τ we do observe a strong positive linear correlation between In-degree and Out-degree (see the yellow dashed line in Figure 1 which represents the linear fit between In-degree and Out-degree for each τ).[7] Interestingly, for lower quantiles of FP the yellow line lies completely in the green area (at least for In-degree and Out-degree lower than 4 which represents a typical range of connectivity in the system), while for $\tau = 0.8$ (and, to a lesser extent, $\tau = 0.9$) the yellow line lies in the 'EP-FP trade-off' area for low values of In-degree and Out-degree.

Hence, on average among firms in the bottom quantiles of financial performance, the positive impact of a better environmental performance on financial performance is reinforced by the EU ETS participation as a seller of (excess) allowances, i.e. high Out-degree. On the other hand, firms which are very active in purchasing allowances (i.e., high In-degree) are less likely to exploit synergies between environmental and financial performance, probably because they choose to comply with EU ETS regulation by purchasing allowances rather than by abating emissions.[8]

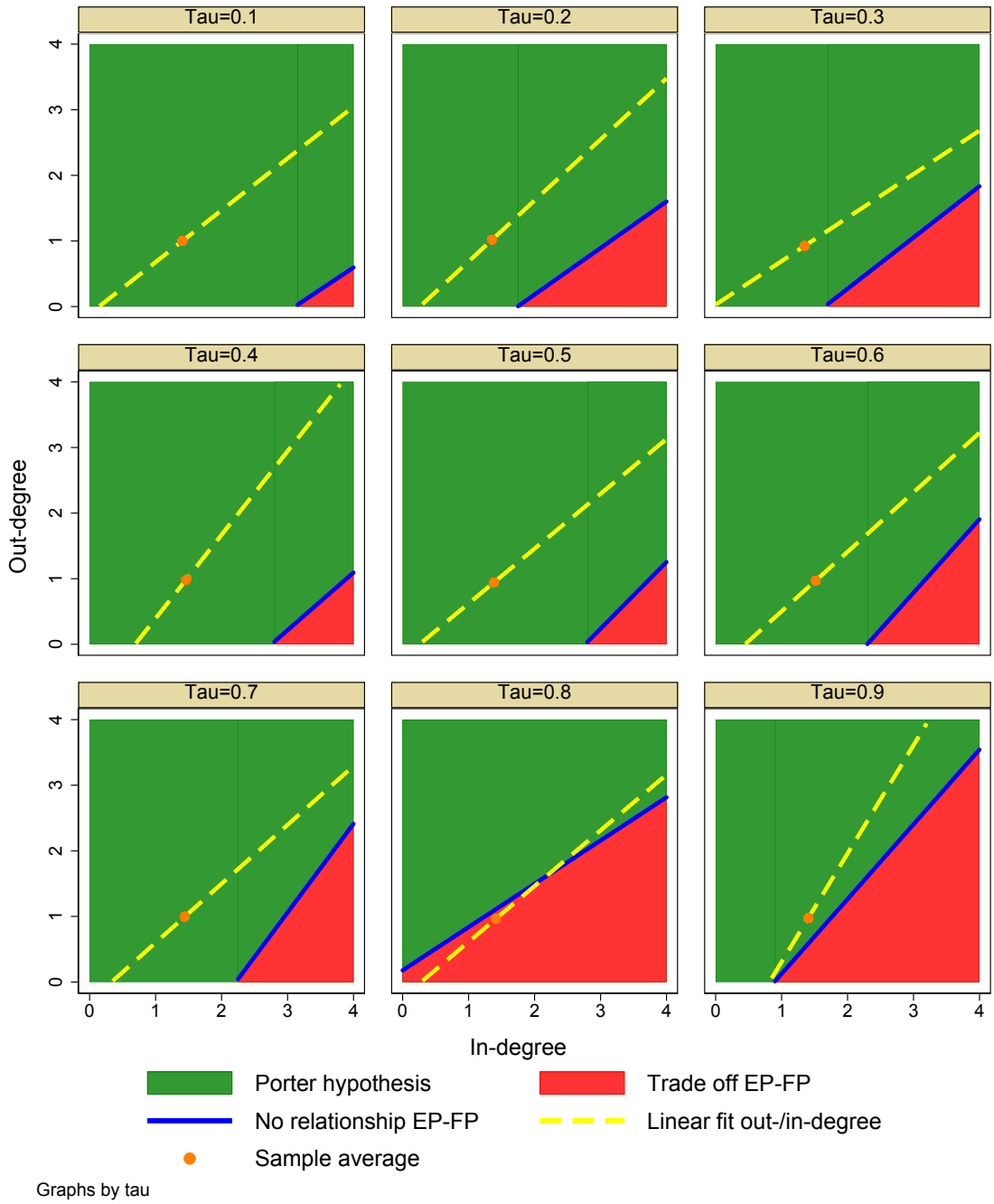
[5] This is done by taking the first derivative of FP with respect to EP and setting it equal to zero.

[6] Also for $\tau = 0.9$ we estimate that the average firm lies close to the 'no-relationship' line, but on the 'Porter-like' side.

[7] The smallest correlation coefficient is about 0.53 for $\tau = 0.1$ and $\tau = 0.3$, while the greatest correlation coefficient is about 0.87 for $\tau = 0.4$ and $\tau = 0.9$. If anything, there is a weak evidence of a relative stronger correlation between In-degree and Out-degree for higher quantiles than for lower quantiles.

[8] In principle, an intense activity of purchasing allowances might occur even when the firm performs abatement

Figure 1: Estimated relationship between EP and FP by FP quantile and In-/Out-degree



Combining high Out-degree with low In-degree, therefore, turns out to be the best way to take advantage (in terms of increased FP) of improvements in the environmental performance. Such 'optimal' combination, however, appears to be quite unlikely given the strong positive

activities but these are insufficient to offset the increase in the firm's production. However, in our regressions we control for changes in output by accounting for sales growth rate and total assets. Therefore, a high allowance demand is very likely to reflect little or no abatement activities.

correlation (in all τ_s) between In-degree and Out-degree in our sample of firms.

To avoid being "trapped" in the red area in Figure 1 and enjoy the EP-FP synergies characterizing the green area, firms should move north-west in the diagram by increasing their Out-degree and/or reducing their In-degree. A radical change in the way the firm complies with the EU ETS is needed to attain this outcome, shifting the firms' strategy from purchasing emission allowances to abating emissions. Such a shift in strategy can be pursued by developing and adopting low-carbon technologies (see, e.g., Calel and Dechezlepretre, 2016). Indeed, this reduces the need to purchase emission allowances (leading to a lower In-degree) and could result into a surplus in emission allowances, to be sold on the market (leading to a higher Out-degree). Our analysis also reveals that this strategy appears to be particularly hard to be implemented for firms at the top of the FP distribution, where switching into the green area would require particularly large values of Out-degree and, at the same time, very small values of In-degree.

5 Conclusions

A vast literature has addressed the issue of whether it pays to be green. To that end, increasing attention has been devoted over the years to the relationship between the firms' environmental performance (EP) and financial performance (FP). Moreover, following the well-known Porter hypothesis, many studies have examined whether and how environmental regulation affects firms' competitiveness and profits. Among the numerous different kinds of environmental regulations, the EU ETS is certainly one of the most interesting being the cornerstone of the EU climate policy and the prototype of all other ETSs that are rapidly spreading at the world level.

This paper intends to contribute to the long-standing literature on the EP-FP relationship with a fresh look from an innovative perspective, namely, focusing on the role of the EU ETS in affecting that relationship and adopting network theory instruments that have received little or no attention in this literature so far.

In particular, the present study differs from previous contributions in several respects. First, it focuses on the EP-FP relationship for the EU ETS firms exploiting only the most recently available observations (those referred to Phase III which differed remarkably from the first two phases and just finished at the end of 2020). Second, it investigates how active participation in the EU ETS (captured by centrality measures in the EU ETS network) affects the EP-FP relationship, thus combining three research strands (on Porter hypothesis, on the EU ETS and

on network theory) that have never been related so far. Finally, it uses quantile regression analysis to capture possible non linearities in the EP-FP relationship and heterogeneous behaviors among the EU ETS firms.

Three main results emerge from the empirical analysis. First, we find that lower emissions intensity is associated with higher financial performance, which suggests a statistically significant positive relation between environmental and financial performances, in line with the well-known Porter hypothesis.

Second, the EP-FP relationship varies across the level of financial performance of the firms. In fact, a better EP has a larger positive effect on FP for firms at the bottom of the FP distribution, while it has basically no effect (on average) for highly profitable firms. The use of a quantile regression, therefore, allows us to shed light on the existence of heterogeneous effects among the EU ETS firms. Those firms that are already performing well in financial terms are unlikely to be affected by their environmental performance. On the contrary, the environmental performance can make a remarkable difference for those firms that still have much possibility for improvement in financial terms.

Third, the nature of the EP-FP relationship is better specified when the EU ETS network features are taken into account. More precisely, the EP-FP relationship depends on the centrality of the firm in the EU ETS network and on the direction of its exchanges with other partners in the network. Indeed, the estimated positive impact of a better environmental performance (i.e., lower emissions intensity) on the firm's financial performance increases with its Out-degree level while it decreases with the firm's In-degree level. In other words, the firm's financial performance tends to improve with its environmental performance, the more (less) so the higher the centrality of the firm in selling (buying) allowances. This result suggests that the EU ETS can become a driver of additional financial returns for those virtuous firms that, by abating their emissions are able to sell more allowances. On the contrary, the financial benefits of investing in lowering emissions are reduced if the firm still needs to purchase many allowances on the EU ETS market. Increasing the Out-degree and/or decreasing the In-degree is, therefore, crucial for the firms that lie in the red area illustrated in the paper to cross the line and move to the green area where they can fully exploit the EP-FP complementarities. However, the strong positive correlation between the two measures in the sample suggests that such a strategy of increasing the Out-degree and decreasing the In-degree may be hard to implement in practice. Adopting low-carbon technologies can achieve this goal as it reduces the need to

purchase additional allowances while increasing the likelihood of having excess allowances to sell on the market.

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