Determinants of Internal Carbon Pricing

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Abstract

Action against climate change is urgent and requires the participation of firms. The progressive internalization of carbon costs by firms is essential in the transition to a low-carbon economy. Internal carbon pricing is an emerging set of practices voluntarily adopted by companies to embed climate footprint in operations and business models. We explore the factors that explain the adoption of internal carbon prices (ICP) among global companies reporting to the Carbon Disclosure Project between 2015 and 2017. We specifically test whether the macroeconomic, regulatory, industry, and firm-specific characteristics affect the disclosed level of the ICPs. Results show that the ICPs depend to a large extent on the national climate policy, country's development, industry, and corporate governance. Furthermore, context explain more the differences in ICP than industry and firm-specific characteristics. Thus uncertainties around countries' climate policy hampers carbon pricing in business. These findings shed light on the factors that contribute to the dissemination of carbon pricing in society.

Keywords: environmental economics; corporate environmentalism; internal carbon price; climate policy; climate change.

1. Introduction

Carbon pricing needs to expand in order to deliver on the goals of the Paris Agreement and limit the rise of the temperatures below 2ºC (Tvinnereim et al., 2018; Aldy et al., 2016). The World Bank (2016) estimates that carbon pricing mechanisms have been implemented by countries which collectively represent a quarter of the world's total greenhouse gas (GHG) emissions in 2016—although carbon pricing only covered a half of the emissions in those economies. To reach the climate goals, firms are also expected to progressively internalize the social costs of carbon emissions (Popp et al., 2010; Kolstad et al., 2014; Nordhaus, 2014; Pindyck, 2016; Olivier, 2018).

An increasing number of global companies has adopted internal carbon pricing (also referred to as "shadow carbon pricing" or "internal carbon tax pricing"). Internal carbon pricing is a voluntary method for companies to internalize the implicit (actual or expected) cost of carbon under various policies and regulations even when all or part of their operations are not currently subject to external carbon regulations (WBCSD, 2015). According to the large database collected by the Carbon Disclosure Project (CDP, 2016), over 1,200 companies in the world currently use internal carbon pricing or plan to implement one in the short term.

Companies adopt internal carbon prices in various settings and for multiple reasons (I4CE, 2016; CDP, 2016). First, the internal pricing of carbon is used for risk management purposes: as companies are increasingly exposed to regulatory and financial risks attached to the implementation of governmental carbon pricing regimes, they seek to measure, model, and manage such risks. Internal pricing of carbon allows investors to assess the extent to which companies' activities (especially from high polluting sectors) are vulnerable to increasing carbon costs (Bianchini and Gianfrate, 2018). Second, internally defined prices of carbon are featured in strategic planning activities as carbon price is an important input in the definition of the long term business model, including the identification of new strategic risks and opportunities. Third, internal carbon prices can be factored into the decisions about capital investments in relation to projects involving increases in GHG emissions, changes in the portfolio of energy sources, and reductions in emissions via energy efficiency schemes. Hence they enter as an input into scenario planning, forecasting, sensitivity analyses, and net present values estimations (WBCSD, 2015).

Previous studies have focus on the drivers and impacts of the disclosure of corporate carbon emissions (Lee et al., 2015; Amran et al., 2014; Mastumura et al, 2014; Kim and Lyon, 2011; Reid and Toffel, 2009; Tagesson et al., 2009; Stanny and Ely, 2008). This is part of an extensive literature that examines the voluntary disclosure of environmental information (see Chrun et al., 2016 for a review). The literature has documented the heterogeneity of countries, sectors and firm strategies concerning climate change issues (Backman et al., 2017; Pinkse and Kolk, 2010; Weinhofer and Hoffmann, 2010; Okereke, 2007). Most of the studies analyze data that is a decade old and it is important to understand the evolution of the corporate climate strategies in a crucial moment for climate mitigation (Jenkins, 2014; Koldstad et al., 2014). Despite the growing importance of internal carbon pricing, the determinants and motivations of such prices remain largely unexplored (Ioannou et al., 2015).

This study seeks to answer to the following research questions: What drives the decision of companies to price carbon? What are the determinants influencing the choice of internal carbon prices? What factors drive the choice of internal carbon prices to pursue environmental and corporate strategies? To answer the questions, we analyze the CDP datasets from 2015 to 2017 containing information on the climate strategies of over a thousand global companies, among which more than a hundred disclosed their internal carbon price. So far to our knowledge no study has investigated the factors underpinning the internal adoption of higher or lower carbon prices on the main large multinational companies, which could shed light on the way these influential firms manage the transition to a low-carbon economy.

The remainder of the article is structured as follows. Section 2 reviews the foundations of the main stakeholders' decisions in environmental-related issues. Section 3 presents the empirical setting and introduces the database, the variables and the models before exploring the determinants of carbon pricing in Section 4. Section 5 discusses the implications of the findings for the adoption of environmental instruments in business, as well as for policy makers aiming to generalize the implementation of carbon prices in society.

2. Determinants of internal carbon pricing

2.1 Different approaches to price carbon

There are at least two approaches to choose and implement a price on carbon emissions, depending on the focal actor: social planner and corporations (voluntarily).

Social planner: the role of GDP and national climate policy

Social planners internalize the externalities of the economic activity so that actors "have an economic incentive to minimize the external costs of pollution" (Popp et al., 2010: 877). Taxing carbon emissions is increasingly important in the environmental policy for climate mitigation (Schmalensee and Stavins, 2017). It has been estimated with reference to two main concepts: Social Cost of Carbon (SCC) and Marginal Abatement

Cost (MAC). SCC is the marginal damage in the present and in the future generated by an additional ton of carbon (CPLC, 2017). Estimating the SCC typically involves two main components: a damage function comprising climate change metrics and a valuation of impacts on the economy; a socio-economic module including discounting factors, risk aversion, inequality metrics, potential for catastrophic damages, and assumptions on climate change policies and their impacts on population, technology and GDP growth (Pizer et al., 2014).[1]

The Marginal Abatement (or avoidance) Cost (MAC) is another approach to estimate the value of carbon. MAC has been widely used to estimate the cost of externalities whenever it is difficult to get an objective estimate of the cost and benefits of the policies (like in climate change). It consists on assessing the efficient costs to achieving a given target for the reduction of carbon emissions given the current emissions and technologies available (Kolstad et al., 2014; DEFRA, 2007). The estimations take into account factors such as carbon emissions, technology performance and costs, regulation and technological progress (DEFRA, 2007). This approach has helped the implementation of several market mechanisms like the European Trading System (ETS) to influence the decisions of actors, starting with large polluting companies. Empirical studies found that the main drivers of the price of carbon allowances in the ETS, beyond energy prices and weather, have been institutional changes (i.e. active national carbon policies) and economic activity/development (Chevallier, 2013; Alberola et al., 2008).

[1] Integrated assessment models (IAM) commonly compute the SCC (Nordhaus, 2014). For instance, the United States Environmental Protection Agency estimated in this way the SCC between $11 and $56 per ton of CO2 in 2015, depending on the discount rate was respectively 5% or 2.5% (US EPA, 2016). However, several review studies point that many estimates of SCC are biased downward (CPLC, 2017) as a result of problems in the damage function (Kolstad et al., 2014) or with the costs of catastrophic damages (Pindyck, 2016, suggesting instead a method based on expert elicitation).

Corporates: the importance of the energy sector

In parallel, companies can decide to engage in environmentally friendly practices, such as applying a carbon price to internal activities. That decision typically takes into account market, political and technological conditions (see Aldy and Gianfrate, 2019; Backman et al., 2017; Lyon and Maxwell, 2008). Market conditions can change due to new demands from consumers which may request more action in climate mitigation from the companies (Aldy and Gianfrate, 2019). Political conditions can lead companies to adopt a climate strategy in order to anticipate a regulation change, to avoid stricter measures or to avert conflicts (Lyon and Maxwell, 2008). Finally, technological (and costs) conditions are important for the choice of the level of engagement in emissions reduction. In particular, the energy sector is the most important single sector that is source of carbon emissions and the one for which profitability is very sensitive to the price of carbon (Chevallier, 2013; Weinhofer and Hoffman, 2010).

Different reactions of companies to climate policy uncertainty

Policies can change the effective value of carbon in practice with a complex setting of price and non-price regulations. The OECD (2013a) finds large discrepancies between carbon prices that are *explicitly* defined by carbon taxes or emissions trading systems, and prices that are *implicitly* derived from the application of other regulations. *Effective* carbon prices, another category, encompass both "explicit" emission permit price and carbon tax as well as more "implicit" taxes on energy use. OECD (2016) estimated the average effective carbon prices for 41 countries (mostly from OECD) at 14.44 $/tCO2.

Table 1 presents data on explicit carbon prices, implicit carbon prices and effective carbon prices for several countries. It shows a high dispersion across countries and sectors. Explicit carbon prices can vary on the same fuels across different uses, within the same country (see also OECD, 2013b). Implicit carbon prices mainly in road transport, households and electricity generation, push up effective carbon prices. Overall, this complex carbon taxation impacts on the effective CO2 prices perceived by the companies.

	Average Explicit Carbon Prices	Estimated implicit carbon prices by sector					**Average Effective Carbon Prices**
	All sectors	Electricity generation	Road transport	Pulp & paper	Cement	Households	**All sectors**
Australia	20	51	58	2	1	104	**100**
Brazil	3	13	210			1	**9**
Chile	12	29	44	1	1	34	**73**
China	7	35		0	1		**40**
Denmark	26	39	180	8	6	127	**186**
Estonia	6	71	77			11	**152**
France	25	59	88	9	9	8	**170**
Germany	6	118	111	26	9		**209**
Japan	3	159	85	2	2		**177**
Korea	16	236	75	6			**145**
New Zealand	8	12	61	2	1		**84**
South Africa	21		185				**115**
Spain	6		103				**128**
United Kingdom	26	100	118	12	8		**265**
United States	2-15	34	79	5	0	39	**17**

Explicit carbon prices includes prices of cap-and-trade or taxes: EU ETS data from https://www.eex.com for averages in 2016; Denmark, Estonia, France, Germany, Japan, Korea, New Zealand, Spain and United Kingdom from World Bank (2016); Australia (assuming average 0.87 AUD per USD) and China from Aldy and Pizer (2016); Brazil, Chile and South Africa estimated from the OECD (2016) assuming 15% of road energy in carbon prices. *Estimated implicit carbon prices by sector* from the OECD (2013a) were adjusted for inflation to 2016 EUR with the GDP deflator from Eurostat and then converted to 2016 USD by using the simple average of the exchange rate in 2016 (0.90 EUR per USD), data from the European Central Bank. *Average effective carbon prices* includes emissions permit price, carbon tax and other specific taxes: data from the OECD (2016).

Table 1. Average explicit, implicit (by sector) and effective carbon prices in several countries, in 2016 US dollars

Firms react differently to carbon policy complexity. Their strategies are heterogeneous concerning climate change issues (Backman et al., 2017; Pinkse and Kolk, 2010; Okereke, 2007). Electricity producers, for example, adapt the decisions depending on their size, emissions and institutional context (Weinhofer and Hoffmann, 2010).

Firms respond differently to uncertainty on the carbon policy which has evolved over time. For long time, carbon prices were absent or low providing weak signals for long-term investments. But recently uncertainty has increased on the evolution of national climate policies, affecting companies differently depending on their type of activity. Companies with long lifecycles assets may be more vulnerable to increases in the carbon price than others with short lifecycle assets. This is the case of energy companies (e.g. oil and gas, electricity utilities) which typically make decisions on infrastructures that last for several decades. These companies may be more willing to implement internal carbon prices which are higher than explicit carbon prices (carbon taxes or prices issued from trading systems) to prevent an increase of the price during the lifetime of the new assets.

2.2 Drivers of the corporate decision to price carbon

The motivations of companies to engage in environmentally friendly practices have been associated to the firm's characteristics in terms of cost effectiveness, as well as to more contextual variables such as market demands and political factors (Lyon and Maxwell, 2008). In the absence of studies for internal carbon pricing, we draw insights from the literature on the firms' decision to disclose carbon emissions.

Companies disclose environmental information as a result of several factors (see Chrun et al., 2016 for a review). The literature primarily relates the decision on disclosing to the firms' attributes. Firm size increases the possibility of information disclosure (e.g. Matsumura et al., 2014; Tagesson et al., 2009). Previous disclosures and foreign sales improve the propensity to disclose information about climate change (Stanny and Ely, 2008). Other factors that promote social and environmental disclosures include industry membership, country domiciliation, profitability, state ownership, and heavy-polluting sectors (Matsumura et al., 2014; Tagesson et al., 2009).

Governance variables in terms of board composition and independency can affect the propensity to disclose. Amran et al. (2014) shows evidence that a high proportion of outside (independent) members, along with separating the CEO and chair board roles, increase emissions disclosure. The literature on the relationship between recruitment of independent members for the board and firms' environmental disclosure is still in a developmental phase (Chrun et al., 2016). Even though there is uncertainty on the relationship between corporate social responsibility (including environmentalism) and financial performance (Margolis et al., 2009), evidence exists that indicates a positive relationship between corporate governance and environmental practices in the management and accounting literature (de Villiers et al., 2011).

The threat of state regulations and of shareholder resolutions increase the propensity of companies to disclose climate change strategies (Reid and Toffel, 2009). The number of countries putting a price on carbon emissions has significantly increased in recent years (World Bank, 2016). In presence of national carbon policy (e.g. carbon tax, quotas), companies tend to voluntarily disclose information in order to reduce the risk of further regulatory intervention (Matsumura et al., 2014; Reid and Toffel, 2009).

The market impacts of carbon disclosure can inform about the possible effects of internal carbon pricing. Lee et al. (2015) present evidence of negative market reaction against disclosure, which can be mitigated with frequent carbon communication. Mastumura et al. (2014) find that markets penalize companies for their carbon emissions and that a further penalty is recorded by firms that do not disclose emission information. Kim and Lyon (2011) demonstrates that CDP participation increases share prices with the probability of climate policy. However, as reported by Ioannou et al.

(2015), there is still little knowledge about the relationship between corporate target setting and environmental performance.

Therefore, while a structured stream of the literature has studied the determinants and the consequences of disclosing carbon emissions, there is still the need to understand how companies price carbon emissions and use them in operational activities.

3. Methods

3.1 Empirical setting: Internal carbon prices

The Carbon Disclosure Project (CDP) is a global initiative that surveys the carbon strategies of large companies. The CDP started in 2002 at the request of 35 institutional investors managing more than $4.5 trillion of assets because of the growing need to obtain information about the financial impacts of climate change in firms operations. By 2016, CDP endorsement has grown to 827 investors with more than $100 trillion of assets under management, collecting information from almost 6,000 companies (CDP, 2016). The CDP inquiries information about the business threats and strategies related to climate change including internal carbon prices of the world's largest companies, organizes the responses into a large dataset and publishes an annual report that presents the results of the inquiry. The CDP has been reported to be the largest effort to assemble standardized data on carbon emissions as well as information on companies' risks, opportunities and strategies to manage the effects of climate change (Chrun et al., 2016; Lee et al., 2015).

Figure 1 presents the proportion of companies disclosing the internal carbon price from countries that have put in place a carbon policy, according to data from World Bank (2016). This proportion tend to increase with the level of prices, suggesting a possible relationship between *local carbon policies* and the strategy of companies to price carbon internally.

The firms' internal carbon prices are higher than explicit carbon prices (Table 1). This observation could reflect several situations: (1) firms price carbon at the level of effective carbon prices (command-and-control regulation, technology mandates and subsidies, etc.) which are greater than prices in cap-and-trade markets or carbon taxes, (2) firms expect carbon prices to increase over the economic lifetime of the investments; and (3) firms do not implement the disclosed carbon prices in their investment decisions (Jenkins, 2014).

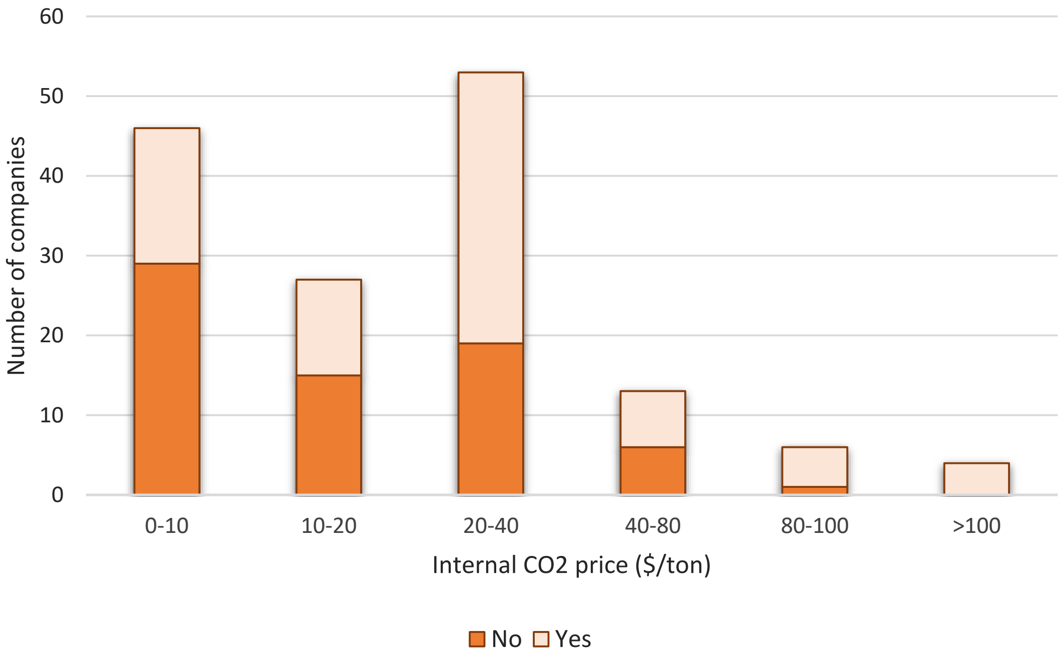

Figure 1. Number of companies disclosing the internal carbon price (US$ per ton), by interval of prices ("Yes" means there is a carbon price in the home country, "No" otherwise.) Source: CDP, 2016.

Figure 2 shows the distribution of internal carbon prices of companies in OECD and non-OECD countries. More than four-fifths of the internal carbon prices reported in the sample are from companies with headquarters in OECD countries. The companies in this area show a more fragmented distribution of prices with a concentration in low levels and also in high levels (right-hand graph) compared to companies from non-OECD countries, even if the low number of observations in the latter tends to concentrate the values.

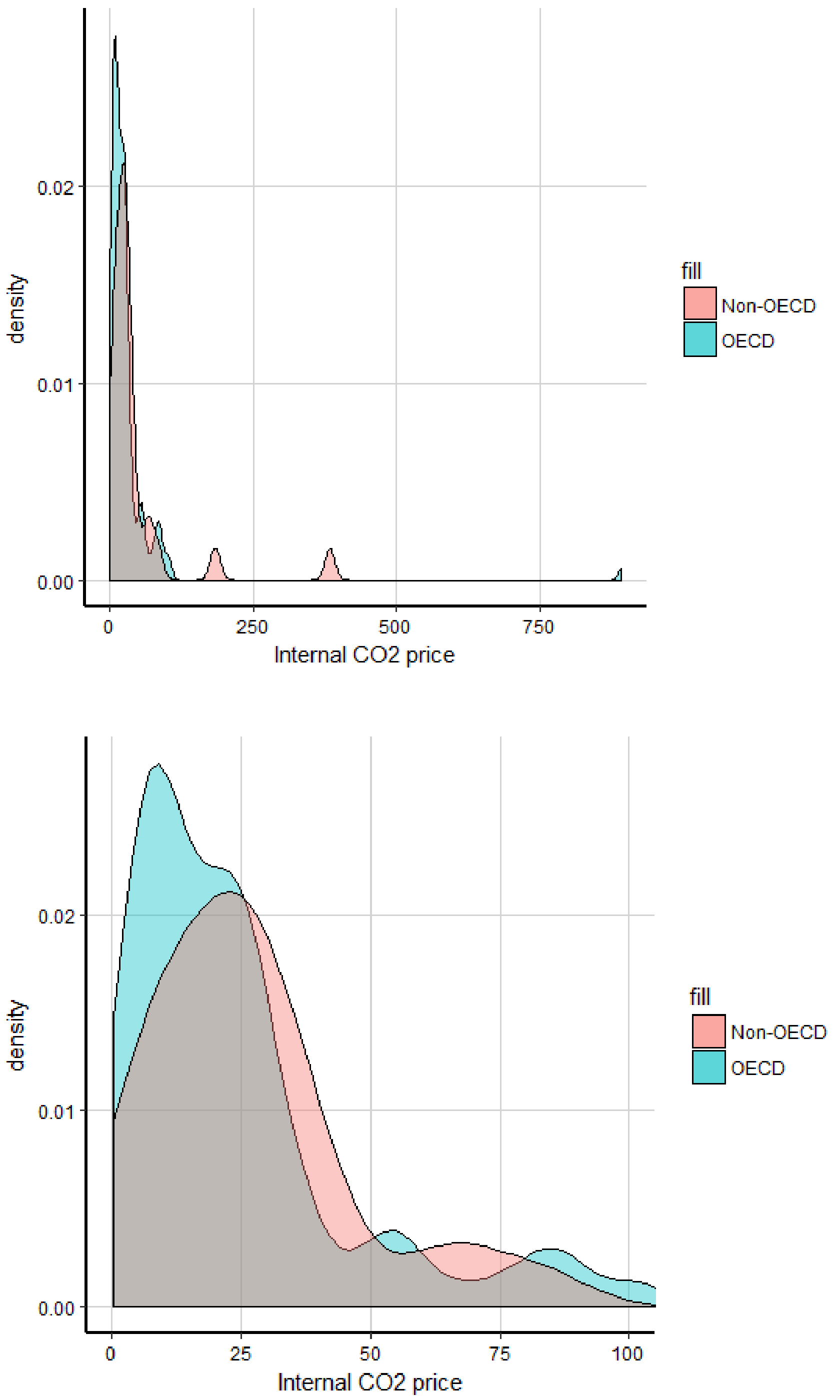

Figure 2. Density distribution of internal carbon prices (US$ per ton) of companies from OECD (n=121) and Non-OECD (n=28) countries. Complete distribution (top) and prices up to 100€ (bottom). Source: CDP, 2016.

Figure 3 shows a breakdown of internal carbon prices by sectors grouped according to the Global Industry Classification Standard - GICS (Utilities, Energy, Financials, Telecommunication Services, Materials Sectors, Health Care, Consumer Discretionary, Information Technology, Consumer Staples and Industrials). The shadow prices are more dispersed among the sectors in non-OECD countries (but a lower number of observations). Energy, a traditionally highly emitting sector, has the highest mean prices in companies reporting from OECD countries (the second highest in companies from non-OECD). In addition, Energy and Utilities have the highest proportion of companies planning to price carbon or that currently price it (52% and 63%, respectively) among the disclosing companies (not shown, cf. CDP, 2016).

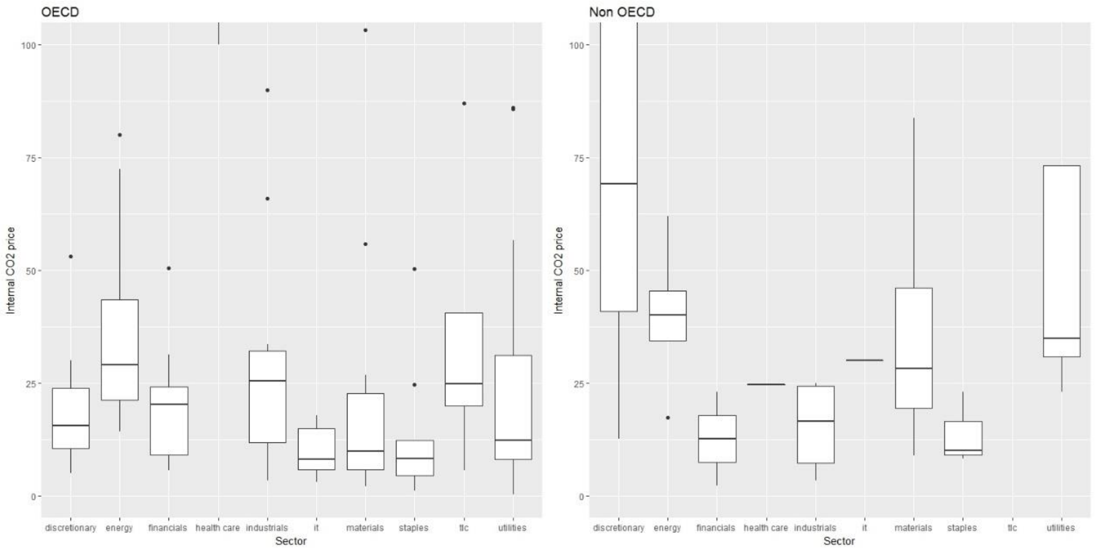

Figure 3. Boxplot of internal carbon prices by sector in OECD countries (n=121, left-hand) and non-OECD countries (n=28, right-hand). "it" stands for information technology and "tlc" for telecommunication services. Source: CDP, 2016.

Despite the growing importance of internal carbon pricing, the determinants and motivations of such practice remain generally unexplored.

3.2 Data sources and variables

We study the determinants of the internal carbon prices adopted by companies by examining the information that has been collected by the Carbon Disclosure Project in several reports (CDP 2015, 2016, 2017a). We test whether firms' attributes, technological characteristics and institutional context play any role in the determination of the internal carbon prices. This enables us to investigate the factors that contribute to the dissemination of carbon prices in the economy.

We pooled data from the Carbon Disclosure Project's (CDP) reports published between 2015 and 2017 that collected data on the practices of internal carbon pricing for up to 1,389 large global companies (CDP, 2017a). The data reveals a wide heterogeneity of internal carbon prices with prices ranging from $0.01 to €908.85 per CO_2 metric ton. Median is $21.87 per ton and mean is $33.38 per ton.

The independent variables consist on the factors that were previously identified in the literature review and comprise typical financial indicators which characterize the firm's attributes such as: revenues as a proxy of the size; the profitability; the ratio of number of independent directors to total number of directors as the measure for board independence; and the ratio of number of female directors to total number of directors.

Additionally, other independent variables include: "National Carbon Price" to account for corporations with headquarters domiciled in a country with an active carbon pricing regime; "GDP per capita" accounting for the GDP per capita in the country where the company is domiciled; "Energy" for companies operating in the Energy sector. Table 2 presents all the variables, including units of measurement, expected results and data sources.

Variable	*Variable name*	*Expected sign* [b]	*Source*
GDP per capita – Natural log of GDP per capita of the country where company is headquartered	GDPP	+	World Bank
National Carbon Price (dummy variable =1 if the country where company is headquartered has a national carbon price in place, 0 otherwise)	NCP	+	Carbon Watch (World Bank)
Energy (dummy variable =1 if the company operates in the Energy sector, 0 otherwise)	ENE	+	CDP
Size – Natural log of revenues	SIZE	+	Datastream; Financial Reports for unlisted companies[a]
Profitability % - Return On Invested Capital	ROIC	+	Datastream
Board Independence (%) - Number of independent directors/Total number of directors	BIND	+	BoardEx
Female Directors (%) - Number of female directors/Total number of directors	BFEM	+	BoardEx

[a] For 6 unlisted companies the revenues have been collected manually from the annual reports available on their corporate websites.
[b] See Section 2 for more details on the justification of the expected signs.

Table 2. List of Variables

	N. Observations	Mean	Median	Minimum	Maximum	Std.Dev.	Skeweness	Kurtosis
1. Internal carbon price (Log)	442	2.925	3.085	-4.605	6.812	1.089	-.849	8.624
2. GDP per capita (Log)	1710	10.457	10.556	8.653	11.549	.487	-1.847	6.257
3. National Carbon Price (Dummy)	1710 (618 Positive)	.361	0	0	1	.481	.577	1.333
4. Energy (Dummy)	1710 (153 Positive)	.089	0	0	1	.286	2.877	9.275
5. Revenues (Log)	1332	15.696	15.907	6.649	19.290	8.225	-.868	5.404
6. % Independent Directors	1488	.573	.565	0	1	.241	-.152	2.054
7. % Female Directors	1506	.219	.220	0	.630	.139	.095	2.260
8. Profitability	1344	6.539	6.05	-57.383	56.153	8.225	-.408	16.414

Table 3. Summary statistics for variables

	1.	2.	3.	4.	5.	6.	7.	8.
1. Internal carbon price(Log)	1							
2. GDP per capita (Log)	.425***	1						
3. National Carbon Price (Dummy)	.274***	.194***	1					
4. Energy (Dummy)	.184***	.067***	-.082***	1				
5. Revenues (Log)	.247***	.196***	.127***	.083***	1			
6. % Independent Directors	.152***	.236***	-.291***	.167***	.055*	1		
7. % Female Directors	.176***	.169***	.023	.061**	.060**	.402***	1	
8. Profitability	.045	-.031	.020	-.230***	-.019	-.041	-.040	1

Note: the table displays the Pearson correlations between the variables. *, ** and *** are significance at 10%, 5%, and 1%, respectively.

Table 4. Correlation between variables

Table 3 provides descriptive statistics of the variables used in the main Model (Equation 1). Following Wooldridge (2012, p.168), we keep the confidence in the estimations, despite the high kurtosis of some variables including internal carbon prices, as normality of the variables becomes less relevant for large sizes of the sample. In fact, we have over 300 observations and thus greater than 30 deemed necessary for the central limit theorem to hold. Moreover, we estimate a model of the conditional expectation function that is the best linear approximation according to the explanatory variables (cf. Angrist and Pischke, 2008).

Table 4 presents the correlation matrix. This shows that internal carbon prices are correlated (with strong statistical significance) with the GDP per capita, presence of a national carbon price mechanism, energy sector, level of revenues, percentage of independent directors on the board, and percentage of female directors on the board.

3.3 Models

To test the relationship between the magnitude of internal carbon prices (as reported to CDP in years 2015, 2016, 2017) and firms, industry, and national characteristics we run the following panel regression:

$$ICP_{it} = \alpha + \beta_1 SIZE_{it} + \beta_2 ROIC_{it} + \beta_3 BOARQ_{it} + \beta_4 GDPP_{it} + \beta_5 NCP_{it} + \beta_6 ENE_{it} + \varepsilon_{it} \qquad (1)$$

where ICP_{it} is the natural logarithm of the carbon price of firm *i* in year *t*, $SIZE_{it}$ is the natural logarithm of revenues for firm i, $ROIC_{it}$ is the Return on Invested Capital, $BOARDQ_{it}$ is a measure of the corporate governance quality (alternatively captured by the ratio of independent board directors to total directors, and the ratio of female board directors to total directors), $GDPP_{it}$ is the logarithmic value of the GDP per capita of home country of firm *i*, NCP_{it} is a dummy variable with value 1 if the home country of firm *i* has a climate policy (climate tax or equivalent) and value 0 otherwise, and ENE_{it} is a dummy variable with value 1 if firm *i* is from the energy sector and 0 otherwise.

We investigate the determinants of ICP using a panel regression model. In order to choose between fixed effects model or a random effects model, we performed the Hausman specification test. With a $\chi^2(2)$ = -0.39 we are unable to reject the null hypothesis, therefore a random effect (RE) model is appropriate.

4. Results

Table 5 presents five model specifications. In order to isolate the effect of the different type of variables, we estimate the full model (cf. Equation (1)) along with partial models for contextual variables (country characteristics) and more idiosyncratic variables (industry and firm characteristics). For all the models the dependent variable is the internal carbon price (logarithmic). Model (1) focuses on the role of country characteristics, notably the level of economic development captured by GDP per capita and the presence of a national carbon price mechanism. Both macro-level determinants are positively associated with the internal carbon prices and are highly statically significant (at 1%). Overall, the R^2 of the model is above 21%.

The model shows that prices are significantly higher for companies domiciled in countries with higher GDP per capita (at 1% significance level). Similarly, prices are significantly higher for companies whose headquarter is located in countries which have a national carbon pricing system in place (carbon-tax or cap-and-trade) with a 1% significance level.

Model (2) and (3) focus on the industry and firm-specific determinants including the quality of corporate governance. Because of a moderate correlation (r=.403) between board independence and ratio of female directors, we test their impact distinctly in the two models. The results indicate that companies operating in the industry most exposed to carbon and climate regulation risks – namely, the Energy sector – report significantly higher internal carbon prices (at 1% significance level). In particular, companies in the energy sector have, on average, higher ICPs than the other companies. The models show a positive relationship between the size of the company (in terms of revenues) and internal carbon prices. While no significant relationship is detected for profitability, the alternative measures of corporate governance quality (at 10% and 1% level for independence ratio and female board members' ratio respectively) show a positive and statistically significant relationship with prices.

Model (4) and (5) account comprehensively for national, industry, and firm-specific characteristics. For both models, the level of GDP per capita, the existence of a national carbon price, and the affiliation to the energy sector have a positive and significant effect in the level of internal carbon prices. The coefficients are all highly statistically significant. Again the models feature alternatively two proxies of the quality of firm corporate governance, namely the percentage of independent board directors and the percentage of female board directors. We specifically look at the role of corporate governance by accounting for the level of board independence (measured as the number of independent directors to total number of directors) and for the ratio of female directors to total number of board members. We find that a higher weight of both independent directors and female directors in the board is on average positively associated with internal carbon prices, with moderate statistical significance (10%). Such findings are consistent with the association between corporate governance quality and environmental practices highlighted in the management literature (Haque, 2017; de Villiers et al., 2011). Overall, the two comprehensive models have an Adjusted R2 above 28%. The coefficients are stable across the models for the macro-and industry-level variables, along with the respective significance, what reinforces the confidence on the results.

Finally, the Breusch and Pagan Lagrange Multiplier test confirms the appropriateness of random effect for all the model specifications.

	Dependent variable: Internal Carbon Price (Log)				
	(1)	(2)	(3)	(4)	(5)
Country Characteristics					
GDP per capita (Log)	.766***			.664***	.702***
	(.171)			(.218)	(.216)
National Carbon Price (1:Yes; 0:No)	.514***			.603***	.583***
	(.123)			(.138)	(.145)
Industry					
Energy (1:Yes; 0:No)		.509***	.549***	.525***	.555***
		(.167)	(.156)	(.148)	(.146)
Firm Characteristics					
Size (Revenues)		.115**	.095*	.053	.055
		(.050)	(.049)	(.041)	(.041)
Profitability		.009	.008	.012**	.011**
		(.006)	(006)	(.005)	(.005)
% Independent Directors		.715*		.648*	
		(.404)		(.335)	
% Female Directors			2.10***		.984*
			(.575)		(.517)
Constant	-5.232***	.533	.804	-5.621**	-5.845**
	(1.804)	(.830)	(.786)	(2.375)	(2.355)
Observations	442	353	354	353	354
R^2	.213	.108	.136	.283	.288
Wald-χ^2 (2)	36.25***	21.56***	29.16***	51.74***	51.24***
Post-estimation: Breusch-Pagan LM $\bar{\chi}^2$	122.93***	100.78***	102.29***	87.14***	84.70***

The independent variable "GDP per capita (log)" is the natural logarithm of the GDP per capita from World Bank. "National Carbon Price" is dummy variable equal to 1 if the headquarter of the company is based in a country which has a carbon pricing mechanism in place as of 2015 (World Bank, 2016a), and 0 otherwise. "Energy" is a dummy variable equal to 1 if the company operates in the Energy sector, and 0 otherwise. "Size (Log of Revenues)" is the natural logarithm of Sales from Datastream. "Profitability" refers to the average returns on invesments (ROI) of the firm (from Datastream) in the 2015-2017 period. "% Independent Directors" is the ratio of board directors reported as independent and the total number of directors from BoardEx. "% Female Directors" is the ratio of board directors reported as female and the total number of directors from BoardEx. Clustered standard errors in parentheses. Notation of the significance levels: *p<0.1; **p<0.05; ***p<0.01.

Table 5. Results of the panel regression: internal carbon price reported by companies to CDP (2015-2017).

5. Discussion

The paper explores the determinants of internal carbon pricing by global companies. These practices are important for the dissemination of carbon prices across the society starting with the larger firms. To investigate the climate strategies of a worldwide sample of large companies which have a strong impact on emissions, we analyze their responses to the Carbon Disclosure Project (CDP). Standard OLS multivariate regressions examine the determinants of the level of internal carbon prices. The analysis sheds light on the factors that make companies adopt climate practices such as carbon prices to reduce the carbon emissions of their operations (as well as the vulnerability to stricter climate regulation).

The results show that the institutional context influences the choice of internal carbon prices. Companies with headquarters in a country with high GDP per capita are more likely to adopt stringent carbon prices. This confirms the results of previous empirical studies on corporate strategies and climate change (Backman et al., 2017; Weinhofer and Hoffman, 2010; Okereke, 2008). In addition, internal carbon prices are significantly higher whenever companies come from countries with a climate policy in force (carbon-tax or cap-and-trade scheme). This supports the findings from environmental economics studies on the role of institutions and regulation in the adoption of environmental practices (Popp et al., 2010; Jaffe et al, 2005).

The analysis shows a positive and significant relationship between internal carbon price and either board independence and energy sector. Board independence, in terms of higher shares of independent directors, is positively associated with higher carbon prices, *ceteris paribus*. The effect is even stronger with the share of female directors. This result corroborates the positive relationship between corporate governance and environmental practices highlighted in the management and accounting literature

(Haque, 2017; de Villiers et al., 2011). The energy sector discloses relatively higher internal carbon prices what is consistent with the expectation under which more sensible sectors adopt new environmental practices to avoid external pressures (Cho and Patten, 2007; Deegan, 2002). But the companies in this sector can also adopt shadow prices to avoid more stringent carbon regulation (Reid and Toffel, 2009, Darrell and Schwartz, 1997; Patten, 1991).

Contextual variables on the economy and regulation were found to explain more of the carbon pricing behavior of companies than industry and firm's characteristics put together. Therefore, an important implication for the policy is that lax national climate policies are negatively related to the dissemination of new climate practices among domestic companies.

This exploratory study presents limitations and opens new questions that can lay the basis for future research. The focus on large global companies limits the analysis of the effect of firm size in corporate strategies, and the extent to which the findings can be generalizable to small and medium firms. However, these companies represent a high share in carbon emissions (Heede, 2014; CDP, 2017b) and their behavior can have a strong impact (both positive and negative) on emissions as well as on the legitimation of the new environmental practices in the economy. In addition, the analysis to the disclosed carbon prices relies on secondary data and provides limited information about the extent to which internal carbon pricing practices really affect corporate strategies. Companies may disclose shadow prices as a communication strategy (Olivier, 2018) to improve reputation and/or to avoid more stringent climate policy, but, at the same time, they may not apply such prices in their actual decision-making ("greenwashing").

In terms of future research, a refinement of the factors that have been identified here will improve the understanding about the climate strategies of companies. Additionally, future reports on ICPs adopted globally will enable a better longitudinal analysis on companies' motivations to disclose their climate change strategies, including the possibility of strategic communication and "greenwashing". Future avenues of research may tackle how the carbon footprint of companies have evolved over time, the drivers of these performances—namely the size of the companies—and their relationship with the financial performances (further validating or refuting early studies, e.g. Kolk et al., 2008). This research could improve our understanding of policies to foster social acceptance and the dissemination of new environmental practices.

6. Conclusion and Policy Implications

This study aims to understand the determinants of internal carbon pricing. Action against climate change is urgent and requires the active involvement of companies that need to adopt new practices to measure and manage their carbon footprint. The findings support the view that both the institutional context and corporate characteristics affect the environmental accounting practices of global firms. National carbon pricing mechanisms incentivize companies to take into account the impact on emissions in their strategic decisions. Therefore, uncertainty on countries' carbon policies should be avoided if governments want to incentivize the adoption of new climate mitigation practices in businesses. This should particularly include the implementation of more transparent carbon taxation schemes which close the gap between explicit and effective carbon prices. Such schemes should also be more consistently applied for the same fuel across different uses (transport, industry, etc.), in order to facilitate the companies' operational and investment decisions.

More research is needed to understand how the practice of internal carbon pricing is implemented. The success of the Paris agreements will greatly depend on the way that carbon has a price and agents internalize this in the framework of their activities, namely by adopting effective internal carbon prices. This work reveals factors that can contribute to foster the adoption of carbon prices consistent with the Paris targets for climate. To the best of our knowledge, this is the first time such an effort is undergone at the global level that may open an important new line of research for the coming years based on the corporate carbon pricing and emissions reduction.

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