National Climate Policies and Corporate Internal Carbon Pricing

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While national governments pledged to reduce their greenhouse gas emissions under the Paris Agreement, delivering on these aims will require significant changes in the activities of major sources of emissions such as companies. To drive such changes, companies will need to consider carbon emissions as a cost of production and many companies have begun doing so through internal carbon pricing. By employing data from the Carbon Disclosure Project, we evaluate how national carbon pricing policies influence firm-level internal carbon pricing and corporate emission targets. We find that firm-level internal carbon prices are significantly higher in countries explicitly pricing carbon through tax and/or cap-and-trade programs. These findings shed light on how companies are factoring climate change in their decision-making and on the drivers that can contribute to the generalization of climate pricing in the economy.

Keywords: carbon pricing; carbon tax; cap-and-trade; corporate environmental performance.

1. INTRODUCTION

The adoption of carbon pricing instruments has increased significantly in recent years. The World Bank (2018) estimates that countries representing more than one-half of global greenhouse gas emissions plan to use or will consider carbon pricing as at least one approach to implement their nationally determined contributions under the 2015 Paris Agreement. To deliver on the long-term goals of the Paris Agreement, more countries and more ambitious domestic programs will be necessary (Aldy et al., 2016; du Pont, 2017; Chyong et al., 2020). Carbon pricing policies create strong, transparent incentives to firms to internalize the social costs of carbon emissions (Popp et al., 2010; Kolstad et al., 2014; Nordhaus, 2014; Weitzman, 2015). In addition, major investors, along with financial regulators, are increasingly calling on companies to disclose their risks under climate change and policies intended to mitigate greenhouse gas emissions (Guardian, 2019).

An increasing number of companies around the world has adopted internal carbon pricing (ICP), also referred to as "shadow carbon pricing" or "internal carbon tax pricing". ICP is a method for companies to internalize the implicit (actual or expected) cost of carbon. According to the large database collected by the Carbon Disclosure Project (CDP, 2017), over 600 companies in the world, with a market capitalization of US$15 trillion, already used ICP by 2017.

Companies adopt internal carbon prices in various settings and for multiple reasons: to manage the regulatory and financial risks attached to the implementation of climate policies; to guide strategic planning activities as carbon pricing informs the long-term business model; to factor carbon prices into the decisions about capital investments (I4CE, 2016; CDP, 2016; Aldy and Gianfrate 2019; Bento and Gianfrate, 2020). Hence companies use internal carbon prices as an input into scenario planning, forecasting, sensitivity analyses, and investment net present value evaluations (WBCSD, 2015). Internal carbon prices may also serve to signal to the government that additional regulatory action is unnecessary, as well as represent a form of "greenwashing", i.e. opportunistic communication to persuade stakeholders that firms are delivering environmental improvements when in practice they are not undertaking meaningful changes (Kim and Lyon, 2011).

The goal of this study is to investigate how firms respond to the implementation of a national carbon-pricing regime with respect to the carbon prices they set internally for their decision-making. We empirically investigate the adoption of internal carbon pricing by major companies reporting to the Carbon Disclosure

Project. A matching estimator enables an appraisement of the effect that climate change policies have in the decision of companies to set their internal carbon prices. We find a causal relationship between the national carbon policies in place and the level of internal carbon prices. The treatment effect of having a national carbon pricing policy in place is economically (27 USD per ton) and statistically significant.

The paper is structured as follows. Section 2 describes firm adoption of internal carbon prices and places this decision in the framework of government carbon pricing policies. Section 3 explains the research strategy to deal with the problem of endogeneity for the study of the firms' responses to a national carbon pricing with respect to setting their own carbon prices, as well as presents the variables, dataset and descriptive statistics. Section 4 analyzes the effect of the existence of a national carbon pricing and the impact of different carbon price levels. Finally, Section 5 concludes with the main findings and raises some questions for further research.

2. THE ADOPTION OF INTERNAL CARBON PRICES

The cost of carbon effectively faced by companies is often complex, combining price and non-price regulations in different sectors (De Gouvello et al., 2020; Newbery et al., 2019; Stiglitz, 2019). Large discrepancies exist 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. Explicit carbon prices were found to vary on the same fuels across different uses, within the same country (OECD, 2013b). For example, the OECD (2016) estimated the average *effective* carbon prices—encompassing both "explicit" emission permit price and carbon tax as well as more "implicit" taxes on energy use—for 41 countries at 14 \$/tCO2. The effective carbon price differs significantly between transportation energy – with an average of \$74/tCO2 covering 98% of emissions in this sector – and non-transport energy – with an average of \$13/tCO2 covering 30% of these sectors.

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. Effective carbon prices are clearly higher than explicit carbon prices driven by implicit carbon prices in road transport, households and electricity generation. Aligning climate and energy price and non-price regulation (e.g. standards, innovation support) is important for a long-term strategy on climate mitigation that can pave the way to the emergence of a carbon pricing in society (De Gouvello et al., 2020; Finon, 2019; Stiglitz, 2019), and companies may anticipate a future stringent carbon policy.

Firms tend to react differently to carbon policy complexity (Chen et al., 2018). Studies show that there is heterogeneity in firm strategies concerning climate change issues (Backman et al., 2017; Pinkse and Kolk, 2010; Okereke, 2007). Electricity producers, for example, change their decisions depending on the institutional context, firm size and emissions (Weinhofer and Hoffmann, 2010). In addition, large firms respond differently to policy uncertainty involving carbon taxes (Backman et al., 2017). The greater uncertainty over carbon prices under cap-and-trade programs relative to carbon tax systems may also influence firm expectations and investment behavior (Aldy and Armitage 2020). However, low carbon prices have generally provided weak signals for firms to reduce their emissions.

Firms' incentives to take climate action also depend on other factors than the current level of carbon prices. Companies with long lasting assets can be more vulnerable to increases in the carbon price than other companies with short lifecycle assets. This is particularly the case of heavy industries (e.g. steel, cement) or energy companies (e.g. oil and gas, electricity utilities). These companies may be more willing to implement internal carbon prices that are higher than explicit carbon prices (carbon taxes or prices issued from trading systems), independent of currently low carbon taxes. Thus, internal carbon pricing allows investors to assess the extent to which companies (especially from high-polluting sectors) take measures in order to reduce their vulnerability to increasing carbon costs.

Table 1 Average effective carbon rates and estimated implicit carbon prices (by sector) in several countries, in 2016 U.S. dollars

	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**
United Kingdom	26	100	118	12	8		265
Germany	6	118	111	26	9		209
Denmark	26	39	180	8	6	127	186
Japan	3	159	85	2	2		177
France	25	59	88	9	9	8	170
Estonia	6	71	77			11	152
Korea	16	236	75	6			145
Spain	6		103				128
South Africa	21		185				115
Australia	20	51	58	2	1	104	100
New Zealand	8	12	61	2	1		84
Chile	12	29	44	1	1	34	73
China	7	35		0	1		40
United States	2-15	34	79	5	0	39	17
Brazil	3	13	210			1	9

Explicit carbon prices includes prices of cap-and-trade or taxes: EU ETS data from https://www.eex.com ; Denmark, Estonia, France, Germany, Japan, Korea, New Zealand, Spain and United Kingdom from World Bank (2016a); 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* include emission permit price, carbon tax and other specific taxes on energy use (e.g. value-added tax excluded), data from the OECD (2016).

Large corporations have publicly disclosed their internal carbon prices through the Carbon Disclosure Project (CDP), which is a global initiative that surveys the carbon strategies of large companies. The CDP initiative 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 firm 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 queries the world's largest companies about the perceived business threats and strategies related to climate change, organizes the responses into a large dataset and publishes an annual report that presents the results of the inquiry. The CDP represents 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 in 2016 from countries that have put in place a carbon policy, according to data from World Bank (2016a), by intervals of prices. This proportion tends to increase with the level of prices, suggesting a relationship between *domestic carbon policies* and carbon strategy of companies. A large fraction of the ICPs fall in the range between 0 and 40 USD. The companies in this lower interval implement prices that are similar to the contemporary carbon market value (e.g. Newbery et al., 2019), whereas the companies in the higher interval may expect an increase in the carbon price over time. The figure also shows the growth in the number of companies disclosing prices in 2017 in relation to the previous year, revealing a more marked increase in the interval of prices 40-80 $/tCO2.

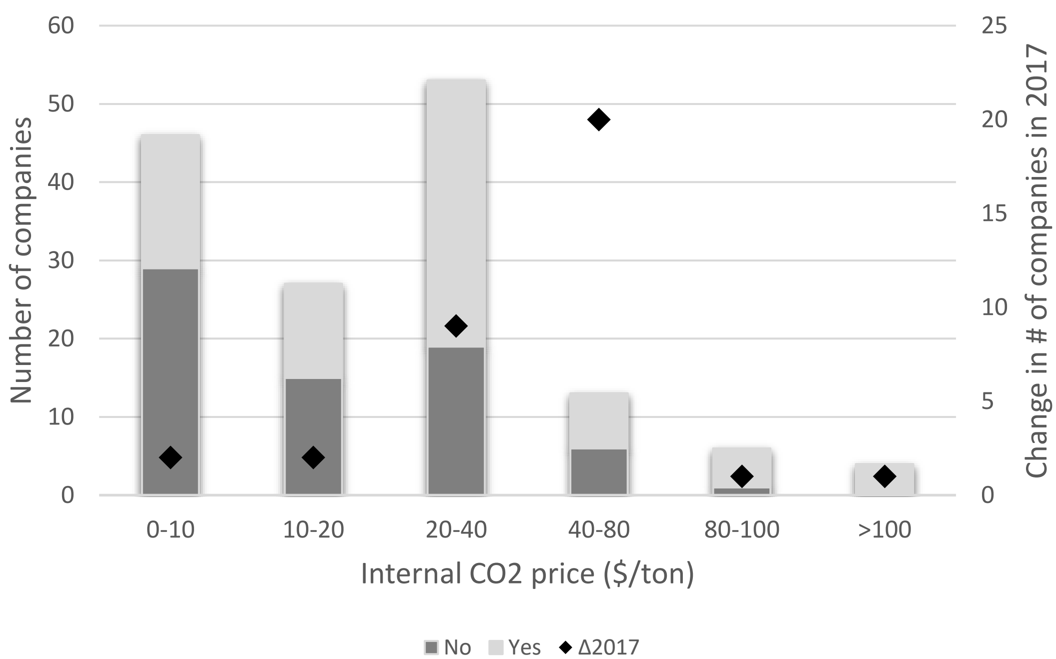

Figure 1. Number of companies disclosing the internal carbon price (2016US$ per ton), by interval of prices in 2016 ("Yes" means firm headquartered in country with explicit carbon pricing, "No" means firm headquartered in country without explicit carbon pricing.) Diamonds show the change in the number of companies disclosing ICPs by interval of prices in 2017 comparing to the previous year.

Figure 2 shows a breakdown of the internal carbon prices by sectors grouped according to the Global Industry Classification Standard.[1] The figure shows that there is a strong heterogeneity of ICPs adopted by companies from different sectors. Average prices change from $10 (information technology, staples) to $30 (energy). The energy industry, a traditionally high-emitting sector, has the second highest prices in companies after health care.

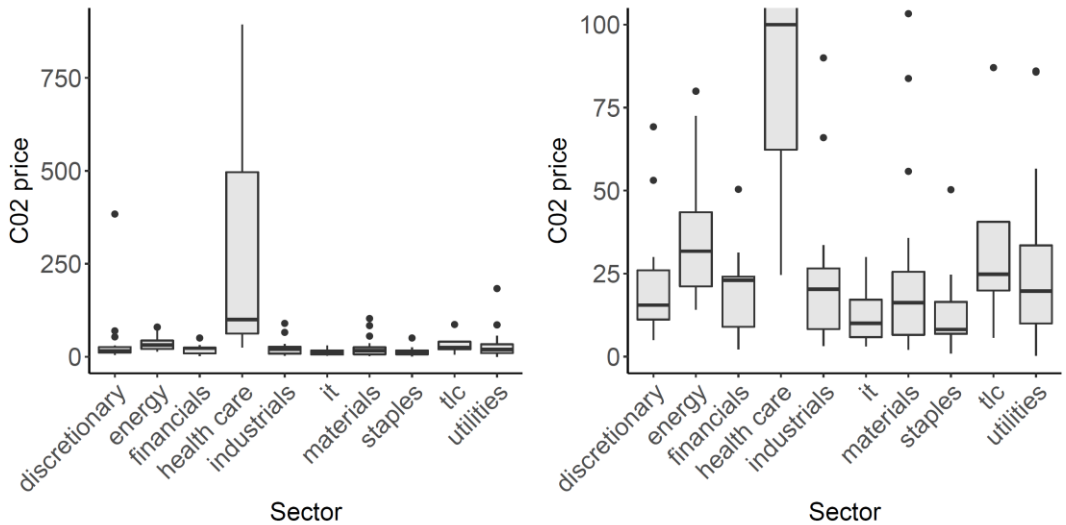

Figure 1. Internal carbon prices by sector (US$ per ton, left-hand graph). Right-hand graph zooms in to show prices up to $100. "it" stands for information technology and "tlc" for telecommunication services. Source: CDP, 2016.

3. METHODS AND DATA

To investigate firms' reaction to the implementation of national carbon policies, we employ a research design that takes into account endogeneity issues by using propensity score matching techniques for identification. Our dataset contains information on the internal carbon prices of companies who respond to the Carbon Disclosure Project, which we combine with information about national carbon pricing regimes from the World Bank. We examine how the existence of a national carbon pricing regime influences firms' internal carbon prices. We assign those firms headquartered in a country with a national carbon pricing system to our

[1] For more information regarding the Global Industry Classification System, refer to https://www.msci.com/gics.

treatment group, and we assign those companies not headquartered in a country with a national carbon pricing system in place to our control group.

The Carbon Disclosure Project (CDP) collected data on the practices of internal carbon pricing for 1,249 large global companies (CDP, 2016). In this sample, approximately 600 companies declared that they use carbon pricing internally and about 140 companies publicly disclose their internal carbon price. The data are available on-line from the dedicated reports on internal carbon prices.[2] We acknowledge that this is a highly-selected sample (i.e., firms that voluntarily select ICPs and voluntarily disclose them through CDP). However, the sample is still valuable to understand how prominent companies around the world are responding to government carbon policies. It can also serve as an indicator for how firms outside our sample may behave in the future.

We report the descriptive statistics and sources of our data in Table 2. The observable variables for the matching are at the firm-, industry-, and country-level. The identification of the treatment, namely whether the country where the firm is headquartered has a national carbon pricing system in place, is from the annual State and Trends in Carbon Pricing report series published by the World Bank (2016a; 2018). The level of firm-determined internal carbon prices is the outcome of interest as a function of the carbon pricing policies. If companies are not located in a country with a national carbon-pricing system in place they are assigned to the control group.

The outcome variable is the dollar level of internal carbon prices in the years 2015, 2016, and 2017. We also detect whether the treatment has an impact on the reported firms' decision of integrating internal carbon prices in their corporate decision. In this case, the outcome is a binary variable equal to 1 if a company declares it will factor internal carbon prices in its business targets, 0 otherwise. We expect treated companies to be more likely to adopt internal carbon prices as a binding internal cost that is taken into consideration in project decisions in the context of targets for emission reductions, rather than a shadow—though passive—indicator.

[2] The annual reports can be accessed via the CDP archive: https://www.cdp.net/en/reports/archive.

Table 2. Summary statistics and main sources

Variable	*Mean*	*Std. Dev.*	*Source*
Internal Carbon Prices (in $)	33	68	CDP
Revenues (in $ bn)	20.4	34.7	Datastream
Board Independence - Number of independent directors/Total number of directors	0.57	0.24	BoardEx
Board Size - Number of directors	11	4	BoardEx
National Carbon Price ($)	10.5	23.9	World Bank
GDP per capita (in $)	38.085	12.896	World Bank
Government Effectiveness	1.218	0.618	World Bank
Regulatory Quality	1.200	0.684	World Bank
Rule of Law	1.192	0.708	World Bank
Voice and Accountability	0.978	0.661	World Bank
World Value E&S Index	0.513	0.072	World Value Survey/ European Value Study

Estimating the Average Treatment Effect on the Treated (ATT) using propensity score methods traditionally involves a two-step procedure. As a first step, we predict the probability of being treated by the implementation of a national carbon pricing regime. As a second step, we match treated and control companies and estimate the treatment effect by computing the difference in the outcome variable between matched companies.

To estimate the ATT, we first use a binary choice model to obtain the propensity scores. We report the corresponding results in Table 3. The estimations control for firm-specific characteristics – namely, the size, the quality of corporate governance (proxied by the percentage of independent directors on the total and the size of the board) – along with industry and several aspects of economic development, institutional quality, and environmental-related values.

Table 3. First stage regression (probit) for the probability of treatment

	Dependent variable: Treatment
Revenues (log)	0.170**
	(0.066)
Energy sector	-0.743***
	(0.275)
Materials sector	0.028
	(0.230)
Utilities sector	-0.404***
	(0.256)
GDP per capita (log)	-1.445***
	(0.449)
Government Effectiveness	1.451***
	(0.510)
Regulatory Quality	-.506
	(0.468)
Rule of Law	2.562***
	(0.785)
Voice and Accountability	0.359
	(0.607)
World Value E&S Index	-9.152***
	(2.551)
Board Independence (%)	-2.652***
	(0.443)
Board Size	-0.037
	(0.027)
Year 2016	0.040
	(0.229)
Year 2017	0.166
	(0.218)
Constant	13.768***
	(4.177)
Observations	380
Pseudo R^2	0.422
Chi^2	210.09***

4. RESULTS

4.1 The impact of national climate policies on internal carbon prices

We study to what extent internal carbon pricing depends on the national carbon policies, by implementing a matching strategy. Table 4 (Panel A) presents the estimate of the treatment effect without matching (just comparing the treated against the untreated) and the estimate of the "Average Treatment on the Treated" (ATT) matching on the nearest neighbor.[3] A naïve comparison of treated versus untreated units before matching, provides an estimate of the treatment effect of about $25 per ton of carbon (at 1% statistical

[3] Alternative matching techniques (Kernel and Radius) deliver consistent results.

significance). With matching, the presence of a national carbon pricing *regime* has a significant (at 1% level) impact – about $27 per ton of carbon - on the level of internal carbon prices adopted by companies. The magnitude of this estimate is particularly relevant considering that it implies more than doubling the ICP for moving from a no-carbon pricing policy country to a country with carbon pricing policy. Second, the ICPs are larger than the domestic carbon prices we see in practice for most countries (excluding Sweden-headquartered firms). This illustrates that the high ICPs may reflect some combination of expectations of higher carbon prices in the future and more stringent implicit carbon prices through non-pricing policies for firms headquartered in countries with carbon pricing.

Table 4. National carbon pricing regimes treatment effects on the ICPs (in US$)

Panel A: Full sample (380 Obs.)					
	Treated	Controls	Difference	Std. Errors	*T-stat*
Unmatched	48.34	23.56	24.77	7.24	*3.42****
ATT	48.34	21.74	26.59	11.15	*2.38****

Panel B: Companies with mostly domestic revenues (171 Obs.)					
	Treated	Controls	Difference	Std. Errors	T-stat
Unmatched	35.59	18.34	17.25	4.00	4.31***
ATT	35.59	19.80	15.59	8.80	1.79*

The table presents the treatment effect of companies being headquartered in a country with a national carbon pricing system in place. Treatment is therefore the presence of national carbon pricing (according to World Bank) for the country where the company is headquartered. The outcome of interest is the dollar level of ICP reported by each company to CDP. In Panel A, all the observation are included (380). First a naïve comparison (Unmatched) of Treated and Control units is shown. Then, on the basis of the propensity scores estimated in Table 3, the Average Treatment effect on the Treated (ATT) with nearest neighbour matching is shown. Panel B shows the same estimates for the sub-sample of companies for which at least 75% of the revenues are generated in the domestic market (from Thomson ONE). Notation of the significance levels: *p<0.1; **p<0.05; ***p<0.01.

Table 4 (Panel B) shows the ATT for companies for which at least 75% of the revenues come from the domestic market (according to Thomson ONE). This subsample of companies allows us to examine how national carbon pricing policies influence the ICPs of companies with primarily domestic activity. This can permit an assessment of whether multinational operations raise standards (e.g., a firm uses an ICP consistent with compliance in the most stringent market in which it operates) or lower standards (e.g., a least common denominator approach to compliance) in contrast to domestic-only (or domestic-primarily) oriented firms. The presence of a national carbon pricing *regime* has again a statistically significant effect: without matching, the treated units against the control units provide an estimated treatment effect of about $17 per ton of carbon.

When performing the propensity score matching as discussed before, the estimated effect is about $16 per ton of carbon (at 10% statistical significance). The focus on companies whose revenues are mostly domestic more than halves the initial sample and penalizes the representation of some industries that tend to be more export-oriented. However, the magnitude of the treatment effect on ICPs remains economically and statistically significant, albeit modestly lower than the full sample of companies.

4.2 A focus on ICPs in similar institutional contexts

We specifically focus on the European companies in our sample in order to provide further evidence that the stringency, or "dosage", of national carbon prices affects the level of ICPs adopted by companies. European countries are rather consistent from economic, institutional, and cultural perspectives and most of them share a common cap-and-trade system for pricing carbon but have implemented a variety of country-specific carbon taxes as well. In this setting we estimate the causal effects of receiving different ''dosages'' of national carbon prices on ICPs. Given the relative homogeneity of European countries, the unconfoundness assumption for our estimate is even more plausible.

Estimating a ''dose-response function'' (DRF) provides more information regarding the effectiveness of the program by uncovering heterogeneities in the effects of exposure to various levels of national prices. The key identifying assumption in estimating the DRF is that selection into levels of the treatment is random, conditional on the set of observable covariates shown in Table 3.

We use a generalized propensity score method (Hirano and Imbens, 2004) to estimate ATT of different national carbon prices, thereby constructing a two-step semiparametric estimator of the DRF. The first step involves a parametric estimation of the propensity scores based on generalized linear models and the second involves estimating the DRF using the estimated generalized propensity scores by employing a nonparametric partial mean estimator (Bia and Mattei, 2008). In comparison with the use of the classical propensity score in the binary treatment case, we use the estimated generalized propensity score to identify companies for whom it is difficult to construct counterfactual outcomes by imposing an overlap condition and to control for observed covariates in a more flexible way relative to ordinary least squares (Flores et al., 2012).

The key identifying assumption we use is that the selection into different treatment levels is unconfounded given the covariates, which include the rich set of pretreatment firm-specific, industry–specific, and country-specific variables discussed above.

In Figure 3, we present the plot of the DRF of national carbon prices level (logarithmic) on the ICP level (logarithmic) as the outcome. The plotted DRF (left panel) shows the relationship between the dose (x-axis) as the logarithmic value of the national carbon price and the response (y-axis) as the logarithmic value of the internal carbon prices. The plotted Treatment Effect Function (right panel) shows the derivative of the DRF.

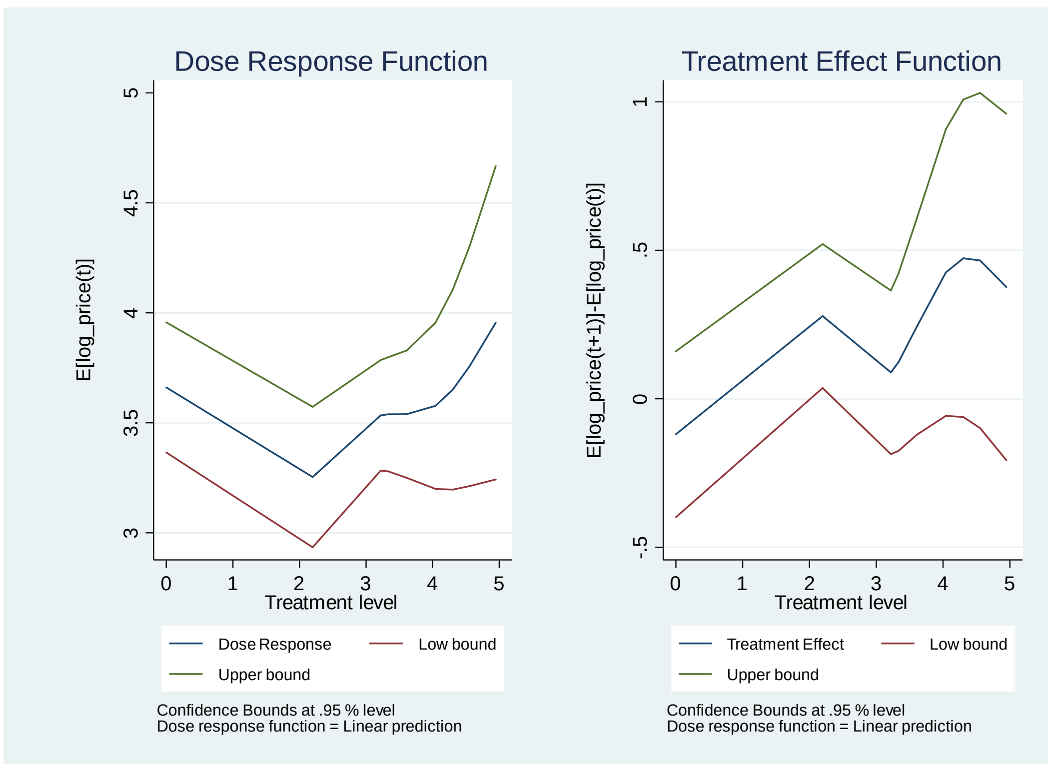

Figure 3. DRF and Treatment Effect of national carbon prices (log) on ICPs (log) in Europe

For European companies we observe a positive relationship, increasing with the treatment between national carbon prices and the adopted ICPs, although some of the 95% confidence intervals fall below zero. Considering that there are EU-wide carbon regulations in practice such as the cap-and-trade system, this result suggests that supranational carbon prices can have an impact on the decision of companies to price carbon internally. However, more research is needed on the interplay of national and international carbon pricing in the future.

5. CONCLUSION

Action against climate change is urgent and requires the participation of firms. Our findings support the view that national carbon pricing mechanisms lead companies to the adoption of higher internal carbon prices. Such prices appear to be consistent, up to a certain degree, with the effective carbon prices estimated by OECD. Our preliminary findings are at the crossroad of energy/climate policies and managerial studies, and we believe more interdisciplinary research is needed to understand how the practice of internal carbon pricing is implemented, as well as what type of regulatory frameworks can promote business adoption of internal carbon prices that are consistent with climate targets.

This work reveals factors that can contribute to the adoption of firm-specific internal carbon prices. It represents initial steps of a broader research program that is needed on the transformation of business models in a way that is consistent with Paris Agreement goals and the deep decarbonization of the economy.

In our view, future research should address at least three main questions. First, what are the drivers for the adoption of measures to reduce carbon emissions by companies, especially in the energy sector which is the most important single source of greenhouse gases? More empirical research is needed to understand the factors and motivations that propel companies to take action. We took a first step here with the analysis of institutional factors in terms of the national climate policies. Opportunistic behaviors such as avoiding regulation and “greenwashing” merit additional study as well.

Second, what type of strategies can companies deploy to lower their impact on the environment? Possible actions include technological and organizational changes in the way companies produce or consume energy (Costa-Campi and Garcia Quevedo, 2019). Future studies could develop a classification of instruments and practices available to managers to reduce corporate exposure to climate risks that could adversely affect the operations and the financial performance of companies.

Third, it is important to understand how company use of ICPs in investment and strategy decisions subsequently reduces their carbon footprints. For instance, is the adoption of ICPs related to lower emissions associated with the adoption of new technologies and the transformation of business models? A further research question would assess whether companies are undertaking behaviors aiming to externalize their carbon footprint to other businesses upstream and downstream or to become environmentally more sustainable.

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