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RESEARCH ARTICLE

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Environmental self-regulation for sustainable development: Can internal carbon pricing enhance financial performance?

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Abstract

Internal carbon pricing is an innovative self-regulation mechanism where companies set their own carbon prices on business operations to mitigate climate risk and achieve sustainable development. While internal carbon pricing has gained popularity among multinational enterprises, its firm-level impact is underexplored. This research provides novel theoretical and empirical evidence on how the internal carbon price as a cost component can contribute to profitability growth. We construct a panel dataset of 132 multinational enterprises across Europe, North America, and Asia by tracking their use of internal carbon pricing from 2013 to 2017 based on their records at the Carbon Disclosure Project. To address endogeneity bias, we employ propensity score matching method on a fixed-effects model. Results indicate that using internal carbon pricing can increase return on assets by 1.1%. Firms with internal carbon prices are more likely to reduce cost of goods sold to improve return on assets. Our study suggests that internal carbon pricing as environmental self-regulation can generate profitability gains through cost reduction. The research also points out the potential of voluntary internal carbon pricing to complement command-and-control carbon pricing regulations.

KEYWORDS

climate change, environmental strategy, financial performance, internal carbon pricing, propensity score matching, self-regulation

1 | INTRODUCTION

Carbon pricing has been an indispensable instrument in reducing carbon emissions and mitigating climate change. It is a cost attached to the greenhouse gas emissions to hold emitters responsible and change their behavior. Carbon prices can be imposed by government agencies in the form of carbon tax and emissions trading system (ETS). Based on the economic theory of externalities, pricing carbon emissions would produce the maximum benefits for the society if the carbon price were equal to the marginal damage of carbon emissions. However, carbon pricing regulations can bring significant compliance cost for companies and fail to achieve their policy goals because of carbon leakage (Babiker, 2005). Carbon leakage occurs when the companies under stringent carbon regulations move their production entities to other countries with more relaxed measures, implying that carbon mitigation policies are ineffective and costly (van der Meijden et al., 2017).

LIST OF SYMBOLS AND ABBREVIATIONS: a, carbon emissions per capita without internal carbon price; A, productivity; ATT, average treatment effect on the treated; b, marginal effect of internal carbon price on carbon emissions per capita; C, cost; CDP, Carbon Disclosure Project; D_{it}, use of ICP for firm i in year t; ESG, environmental, social, and corporate governance; ETS, emissions trading system; ICP, internal carbon pricing; ISO, International Organization for Standardization; K, capital; L, labor; LSDV, least squares dummy variable; MNE, multinational enterprise; p, price; PSM, propensity score matching; q, output; R, revenue; R&D, research and development; ROA, return on assets; u_{it}, error term for firm i in year t; v, rental rate for capital input; w, wage of labor input; X_{it}, cost of goods sold for firm i in year t; Y_{it}, return on assets for firm i in year t; Z_{it}, vector of covariates for firm i in year t; α, output elasticity of capital; α_k, industry fixed effect; β, output elasticity of labor; μ, carbon emissions per capita; π, profit; ρ, internal carbon price; τ_t, year fixed effect.

Many multinational enterprises are using internal carbon pricing (ICP) as a business strategy for self-regulation, alongside the government-imposed carbon prices. In 2017, over 1400 firms reported using internal carbon prices or planning to implement within the next 2 years, and over 20% of the Fortune's Global 500 companies currently price carbon internally, according to the Carbon Disclosure Project (CDP, 2017). Fifteen percent of the companies set an evolutionary price on carbon, which reflects the price level of government carbon policies to prepare for compliance risks (CDP, 2017). The remaining companies see the carbon price as static for the purpose of accelerating decarbonization in their organizations.

Companies use the shadow price and the internal fee as two typical types of ICP approaches. The shadow price is calculated for business decision making but not charged in reality. The shadow price level among companies ranges from 2 to 893 dollars per metric ton of carbon emissions, with the majority beyond the government standards of 10 dollars (Center for Climate and Energy Solutions, 2020). For example, E.ON uses shadow prices of 20 euros as a base case and 40 euros as the worst case when evaluating investment decisions (CDP, 2015). Their prices are estimates of future cost of emission certificates under the EU ETS. The internal fee takes a step further by charging responsible business units for their emissions and reinvesting the collected fees in green technologies and low-carbon initiatives, where the price level varies between 5 and 20 dollars (Center for Climate and Energy Solutions, 2020). For instance, Microsoft currently collects an internal carbon fee of 15 dollars per metric ton from business units and uses the fee to fund sustainability projects (Smith, 2020).

Apart from reducing emissions, ICP has the potential to improve the profitability of MNEs through cost reduction and productivity increase. Emissions can deliver important message about weakness and inefficiencies in product design and production process for a company (Porter & van der Linde, 1995). Under the budget pressure from ICP, managers and employees have the incentive to revise business models or production methods to achieve energy efficiency and reduce cost of emissions. This self-regulation mechanism would motivate MNEs to become more productive, sustainable, and efficient in using their assets to generate profits. Meanwhile, promoting ICP among firms to complement carbon regulations can help policymakers prevent the risk of carbon leakage and attain the political goal of climate change mitigation.

Our research provides novel empirical evidence on the positive effect of ICP on firm's profitability. ICP is a management innovation of heightening interest for multinationals and governments, but there has been no quantitative research on the impact of ICP, as we find in Section 2. In Section 3, we build a microeconomic model to illustrate how the internal carbon price as a cost component can increase return on assets (ROA) with a moderating effect from cost of goods sold. We establish a unique dataset that tracks MNEs' use of ICP for 5 years in Section 4. We then employ propensity score matching (PSM) to obtain a balanced sample and run a weighted regression with fixed effects to address endogeneity bias in the Section 5. Section 6 presents robust results that support our hypotheses. The last section discusses business implications, contributions, and limitations of our research.

2 | LITERATURE REVIEW

2.1 | Carbon pricing regulations and performance

The current literature in carbon pricing primarily focuses on the environmental regulations imposed by governments. It is controversial whether carbon pricing as a regulatory mechanism improves or diminishes the profitability of firms. Several empirical studies have observed a positive effect of carbon pricing on profits. Makridou et al. (2019) analyze 3952 firms under EU ETS policy in the manufacturing sector during the period between 2006 and 2014 and find that carbon pricing increases profits for energy-efficient firms. This could be because energy-efficient firms use more advanced technologies and production methods that help reduce energy costs. Similarly, Marin et al. (2018) use the sample of 792 ETS firms and 2500 non-ETS firms between 2002 and 2012 and find a 1.5% profit increase in phase I and 3% increase in phase II.

On the other hand, Dechezleprêtre et al. (2018) find that EU ETS does not have significant impact on profits across three phases based on the sample of 1787 ETS firms and 1280 non-ETS firms in manufacturing sector between 2008 and 2012. But the heterogeneity effect analysis suggests a significant positive impact among medium and large companies, because the larger companies are considered to possess more power to pass through that compliance cost to customers.

There is also evidence of negative policy impact on profitability, stemming from the belief that command-and-control carbon pricing regulations add to the cost burden of companies. Commins et al. (2011) use return on capital as a proxy for profitability and evaluate the sectoral impact of energy tax and ETS on 160,000 European companies between 1996 and 2007. They find that energy tax has a significant positive effect on profitability. However, negative effect is observed in some sectors. For example, airport transport sector sees increase in profits because it is exempt from energy tax, which lowers the demand and the price for fossil fuel. However, water transport, wood products, and quarrying and refining sectors were negatively affected perhaps due to their participation in energy taxation and weaker capacity to transfer the tax burden to clients as upstream suppliers of fossil fuel.

2.2 | Self-regulation and performance

ICP is a voluntary self-regulation mechanism adopted by companies to reduce carbon emissions and manage climate risk in response to carbon pricing regulations. The emergence and popularity of this self-regulation led by multinational enterprises signify corporate efforts in exerting their global power as private authorities to influence regulatory standards (Albareda, 2008). ICP as environmental self-regulation has the potential to complement carbon regulations to achieve emissions target of policymakers. Prakash and Potoski (2013) find that International Organization for Standardization (ISO) certification as a widespread certified self-regulation is more effective in countries with weaker environmental regulations than those with stringent law. Demirel et al. (2018) also find evidence that certified and noncertified self-regulation can address the inefficiency and gaps in environmental regulations.

Meanwhile, this type of environmental self-regulation methods could lower future cost of compliance by reducing emissions and thus provide a competitive advantage for companies adopting them by shaping industry norms and standards (Anton et al., 2004). There is abundant empirical evidence on the positive impact of environmental self-regulation on financial performance, although the channels and direction of relationship are controversial. Klassen and McLaughlin (1996) use environmental performance awards to measure environment management effort and find a positive effect on market valuation with financial event study method. López-Gamero et al. (2010) find that voluntary environmental self-regulation have a positive influence on financial performance both directly and indirectly through cost and differentiation competitive advantage. Tang, Lai, and Cheng (2012) find that environmental governance can improve financial performance through corporate reputation and customer satisfaction using a sample of largest US firms. Fujii et al. (2012) study Japanese manufacturing firms and find that the environmental performance improve ROA through returns on sales and capital turnover. The profitability effect of voluntary environmental practices also proves to be significant in both emerging markets and developed countries (Dögl & Behnam, 2014). Jiang et al. (2019) also find that voluntary environmental regulation can increase research and development (R&D) investment for technological innovation based on a sample of Chinese manufacturing firms. This innovation effect may translate into productivity gains and profitability growth for the companies.

On the other hand, there are contradictory findings on this causality. Some scholars hold that self-regulation diminishes financial returns because of associated costs and lack of investor interest (Gilley et al., 2000; Preston & O'Bannon, 1997). Fisher-Vanden and Thorburn (2011) find that corporate membership in voluntary environmental programs leads to stock prices decline, and the negative impact is more significant for companies with weaker governance standards. Several researchers also believe that the negative impact can turn positive in the long run (Freedman & Jaggi, 1992; Horváthová, 2012). Other studies reveal a nonlinear effect of self-regulation. Trumpp and Guenther (2017) find a U-shaped effect of environmental performance on profitability and stock market performance based on a cross-country sample. Also, Boakye et al. (2021) focus on the environmental practices of small and medium enterprises and confirm an inverted U-shaped relationship between environmental management and financial performance.

2.3 | ICP and performance

ICP as an emerging self-regulation strategy has been rarely explored in empirical research, despite the increasing popularity and the growing attention among MNEs and policymakers. No quantitative research has tried to examine the firm-level impact of adopting ICP. Light (2019) conducts a case study on Yale University's implementation of ICP as an example of private environmental governance. However, private universities differ from multinational enterprises because profit is not the primary motive for universities to operate. Aldy and Gianfrate (2019) provide case studies of how internal carbon prices alter investment decisions of multinationals such as ExxonMobil and ConocoPhillips. Yet they concentrate on the risk management function of ICP and discuss little about the cost-saving effect. These studies also lack external validity due to the strong focus on individual cases.

This research sheds a new light on the field of carbon pricing and self-regulation by bringing quantitative evidence that ICP can improve profitability of companies. The contribution of ICP to financial performance can be partly illustrated by the Porter's hypothesis arguing that environmental regulations could add to the competitiveness of firms through innovation offsets (Porter & van der Linde, 1995). However, ICP requires a different perspective from Porter's hypothesis, because it is inherently a self-regulation measure that enjoys more flexibility than government regulations and is driven by the ultimate goal of maximizing profits rather than social benefits. This paper hence creates an explanation for the profit-generation effect of ICP based on the fundamentals of profit maximization.

3 | THEORY AND HYPOTHESES

3.1 | Positive effect of ICP

We introduce a static model based on profit maximization theory to illustrate how ICP as a cost for firm can ultimately add to profits. We assume that a firm operates in a perfectly competitive market as a price taker. Using the Cobb–Douglas production function where K and L represent capital and labor, respectively, the output of this company can be expressed as

$$q = AK^{\alpha}L^{\beta}. \quad (1)$$

If p is the market price, the total revenue of this company will be

$$R(q) = pq. \quad (2)$$

If vK represents the cost of capital and wL represents the cost of labor, the total cost function will be

$$C(v,w,K,q) = vK + wL = vK + w\left(\frac{q}{A}\right)^{\frac{1}{\beta}}K^{\frac{-\alpha}{\beta}}. \quad (3)$$

Then, we set the carbon emissions per worker as μ. The reason for measuring emissions per capita is that carbon pricing incentivizes workers to keep emissions within carbon budgets. The internal carbon price is set as ρ, which means the price per ton of carbon emissions. The total cost of carbon emissions would be

$$C(\rho,\mu,L) = \rho\mu L. \tag{4}$$

Therefore, after imposing internal carbon price, the profit function would be:

$$\pi = R(q) - C(v,w,\rho,\mu,K,q) = pq - vK - (w+\rho\mu)\left(\frac{q}{A}\right)^{\frac{1}{\beta}} K^{\frac{-\alpha}{\beta}}. \tag{5}$$

When we take partial derivative of profits π to carbon price ρ, we find that the internal carbon price would have a negative impact on profits because of the negative sign of the Equation 6:

$$\frac{\partial \pi}{\partial \rho} = -\mu\left(\frac{q}{A}\right)^{\frac{1}{\beta}}\left(\frac{1}{K}\right)^{\frac{\alpha}{\beta}}. \tag{6}$$

However, this marginal effect can turn positive when we consider the effect of carbon pricing on carbon emissions. Carbon emissions per worker μ will decline if price of carbon ρ increases, vice versa. This reverse relationship can be written as a linear equation:

$$\mu(\rho) = a + b\rho \ (a>0, b<0). \tag{7}$$

Then, we plug this linear function 7 into the profit equation 5 and take partial derivative again as below:

$$\pi = pq - vK - [w + \rho(a+b\rho)]\left(\frac{q}{A}\right)^{\frac{1}{\beta}}\left(\frac{1}{K}\right)^{\frac{\alpha}{\beta}}, \tag{8}$$

$$\frac{\partial \pi}{\partial \rho} = -(a+2b\rho)\left(\frac{q}{A}\right)^{\frac{1}{\beta}}\left(\frac{1}{K}\right)^{\frac{\alpha}{\beta}}. \tag{9}$$

According to the partial derivative equation above, the sign of result depends on the coefficient $-(a+2b\rho)$. When $a+2b\rho<0$, or $\rho>(-a)/2b$, $\partial\pi/\partial\rho$ will be positive. In this case, the sign of profit effect is determined by the coefficients, or to say, the size of effect of carbon price on carbon emissions per worker. Hence, the positive effect on profits relies on the effectiveness of carbon price in reducing carbon emissions per worker. A properly designed carbon price that effectively reduces carbon emissions per worker could contribute to profits. Based on this derivation, we propose the following hypothesis:

Hypothesis 1. ICP has a positive effect on firm's profitability.

3.2 | Interaction effect of cost of goods sold and ICP

According to Porter's hypothesis, environmental regulations could spur companies to examine and solve the inefficiencies in business operations through innovation and improvement in order to reduce cost of compliance (Porter & van der Linde, 1995). The efficiency gains from environmental regulations through innovation effects would offset the cost of compliance. Similarly, both carbon pricing regulations and ICP have made it more expensive for firms to use fossil fuel as production input, leading firms to pursue eco-innovations or environmental innovations that can reduce that cost and improve efficiency. This positive effect of environmental regulations on eco-innovations has been observed by several empirical studies. Wagner (2007) and Horbach (2008) both use survey and patent data of German manufacturing firms and discover that environmental regulation and self-regulation can foster eco-innovations. Demirel and Kesidou (2019) conduct a survey on UK firms and find that companies using voluntary self-regulation are more likely to engage in eco-innovations.

As a result, the environmental regulations imposing cost pressure may push firms to identify cost-saving opportunities from eco-innovations. Rave et al. (2011) find relevant evidence that firms engaging in eco-innovations are more sensitive to cost reduction, especially energy and resource costs, based on survey data of German firms. These eco-innovations driven by cost reduction purposes may further enhance profitability of firms. Rexhäuser and Rammer (2014) observe from German firms that both regulation-driven and voluntary eco-innovations that effectively reduce cost of resources have a positive effect on profitability. On the other hand, Marin (2014) use a sample of Italian firms and find that regulation-driven eco-innovations may have a negative effect on productivity by crowding out other profitable innovations. However, this crowding-out effect is not observed when Leeuwen and Mohnen (2017) use a sample of Dutch companies and innovation occurrence instead of patent counts as the dependent variable. Moreover, environmental self-regulation coupled with environmental technologies can generate greater efficiency gains (Ozusaglam et al., 2018).

An internal carbon price as self-regulation would place greater cost pressure on business units to reduce carbon emissions. Driven by the motive of cost reduction, managers and employees would be incentivized to engage in eco-innovations to improve energy efficiency. For example, Microsoft managed to save energy cost of 10 million dollars per year by collecting an internal carbon fee from business units and reinvesting it in green innovations (CDP, 2020). Based on the literature, we propose the second hypothesis on the interaction effect of ICP and cost of goods sold. Cost of goods sold is defined as the direct costs of materials, labor, and manufacturing overhead for production of goods.

Hypothesis 2. Firms with ICP are more likely to reduce cost of goods sold to improve ROA.

4 | DATA AND MEASURES

4.1 | Data

The sample of this study consists of 132 multinational enterprises across Europe, Asia, and North America with disclosure records between 2013 and 2017 in the database of CDP. CDP is a non-for-profit global environmental disclosure system where companies voluntarily report data of carbon emissions performance and carbon pricing practices through the annual climate change questionnaire. CDP has listed companies currently using or planning to use ICP in the next 2 years in their reports published between 2014 and 2017. This classification naturally forms treatment and control groups for this research. Companies currently using ICP would fall into treatment group, and the companies planning to use internal carbon in the future would become control group.

To obtain the panel data, we track the use of ICP among companies listed in the most recent CDP report published in 2017 by comparing with reports in previous years to find out the year when the companies started treatment (CDP, 2014, 2015, 2016, 2017). We find that the firm data in these publications are lagged by 1 year, meaning that the data actually spans from 2013 to 2016, so we manually collect data in year 2017 from the CDP online database and gain a full dataset from 2013 to 2017.

In the beginning, we find panel data of 197 companies in CDP reports from six sectors, including energy, materials, utility, industrials, consumer discretionary, and healthcare. These sectors are examined because they constitute the majority of companies who have disclosed their carbon pricing practices. The energy-intensive nature of these sectors also allows the sample firms to be more comparable with each other. We then use Compustat database for firm-level financial data from 2013 to 2017, including assets, employees, R&D investment, cost of goods sold, net income or loss, and long-term debt.

After removing sample firms with missing values, we obtain a sample of 660 observations, with 5-year data of 132 MNEs. These MNEs are headquartered in 20 countries, including Austria (2), Belgium (1), Canada (1), Switzerland (4), Germany (12), Denmark (1), Spain (7), Finland (6), France (16), the United Kingdom (17), India (3), Ireland (2), Italy (3), Japan (31), Luxemburg (1), Netherlands (8), Norway (4), Portugal (1), Sweden (4), and the United States (8).

Figure 1 shows that the number of companies using ICP is growing year by year. Materials and industrials sectors saw the most significant growth across 5 years. They surpassed the energy sector in 2014 and became the top two largest groups of firms that use ICP up to 2017.

Among the companies currently using ICP, only 43 companies have disclosed specific carbon price levels. The rest of sample companies have not disclosed price information due to competition concerns. Figure 2 shows the scattering pattern of these 43 companies in terms of their ROA and carbon price level in 2017. Since this subsample is very small, it is hard to observe a correlation between ROA and carbon price amount from the scatter plot. But Figure 2 provides an interesting message that most companies set their internal carbon price between 20 and 50 dollars. This range of prices is defined by CDP and We Mean Business Coalition (2015) as the operational level that drives change of energy use from coal to gas. Ten companies set their price beyond 50 dollars, which is considered as transformational level that can direct capital flows to renewable energy and low-carbon technologies (CDP & We Mean Business Coalition, 2015).

4.2 | Variables

This research measures firms' profitability by ROA, calculated as the ratio of net income to total assets. ROA has been frequently used by previous ESG studies as a proxy for profitability (Choi & Wang, 2009;

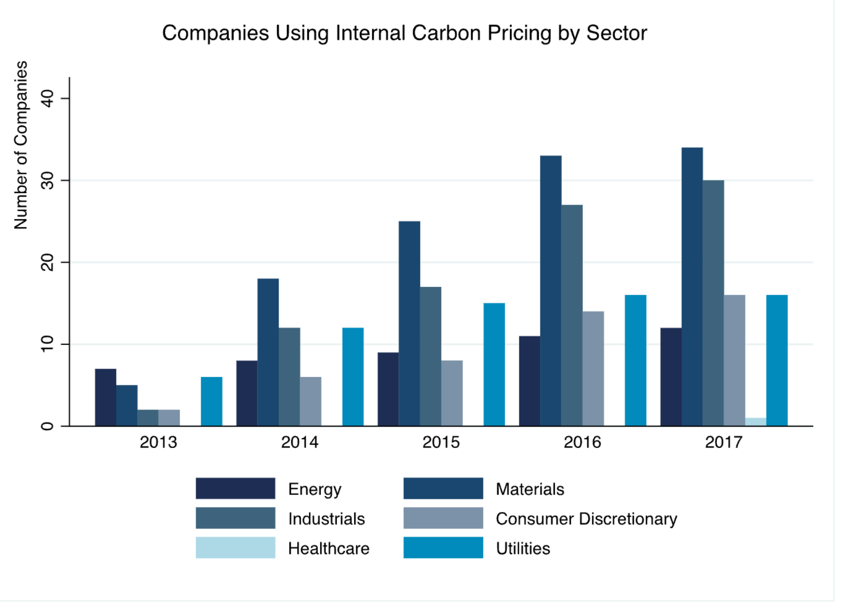

FIGURE 1 Companies using internal carbon pricing by sector from 2013 to 2017. Data are compiled from CDP publications [Colour figure can be viewed at wileyonlinelibrary.com]

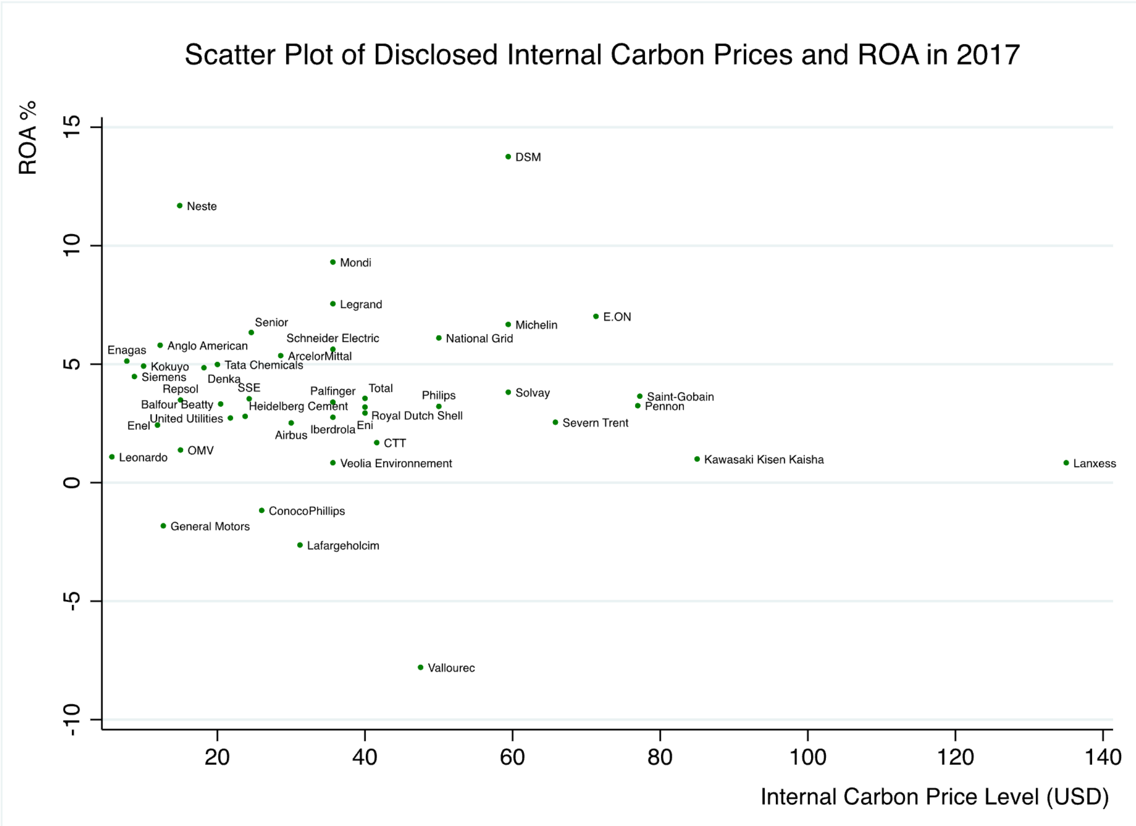

FIGURE 2 Scatter plot of disclosed internal carbon prices and return on assets (ROA) of corresponding firms in 2017. Data are compiled from CDP publications [Colour figure can be viewed at wileyonlinelibrary.com]

Duque-Grisales & Aguilera-Caracuel, 2019; Tang, Chiara, & Taylor, 2012). ROA reflects the efficiency of firms utilizing assets to generalize profits, which can be a good indicator for the financial performance under ICP.

We use ICP as a binary variable that is equal to 1 when a firm uses ICP currently. ICP equals 0 when a firm discloses planning to use in the next 2 years in the CDP publication, which also means it does not use for the current year. The main reason for using binary variable instead of numerical values of carbon prices is the limitation of data. Only a small number of firms have disclosed price levels as mentioned in Section 4.1.

Since we are interested in the interaction effect, we include ln(Cost) (logarithm of cost of goods sold) as an independent variable. Control variables include firm-specific characteristics that also affect profitability. We control for firm size by using ln(Assets) (logarithm of total assets) and ln(Employees) (logarithm of number of employees). We control for firm's unsystematic risk by using Debt Ratio, calculated as the ratio of long-term debt to total assets (Fischer & Sawczyn, 2013). ROA can also be affected by R&D activities, so we include ln(R&D) (logarithm of R&D investment) as a covariate (Lee & Jung, 2016).

Tables 1 and 2 list descriptive statistics and correlation matrix for the variables. The average ROA in this sample is 3.3%. From Table 2, we can find that ICP has a significant positive correlation with ROA at the significance level of 10%. R&D investment also has a positive association with ROA. Assets, employees, cost, and debt ratio are negatively correlated with ROA.

5 | METHODOLOGY

The primary objective of this research is to estimate the treatment effect of using ICP on profitability. If firms randomly adopted ICP, we

TABLE 1 Descriptive statistics

Variable	Obs	Mean	SD	Min	Max
ROA	660	0.033	0.042	−0.158	0.17
ICP	660	0.548	0.498	0	1
ln(Assets)	660	11.018	2.511	5.027	17.734
Debt Ratio	660	0.187	0.115	0	0.568
ln(Cost)	660	10.212	2.719	3.587	16.914
ln(Employee)	660	3.298	1.38	−1.47	6.465
ln(R&D)	660	5.94	3.397	−3.381	13.878

Abbreviation: ICP, internal carbon pricing.

TABLE 2 Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) ROA	1.000						
(2) ICP	.066*	1.000					
(3) ln(Assets)	−.118*	−.011	1.000				
(4) Debt Ratio	−.183*	.078*	−.093*	1.000			
(5) ln(Cost)	−.124*	−.072*	.947*	−.264*	1.000		
(6) ln(Employee)	−.137*	.036	.513*	−.080*	.540*	1.000	
(7) ln(R&D)	.069*	−.131*	.823*	−.259*	.841*	.530*	1.000

Abbreviation: ICP, internal carbon pricing.
*$p < .10$.

could compare the average ROA between firms with and without the treatment based on the rationale of the randomized controlled trial. However, in reality, the use of ICP does not follow a random pattern. The probability of using ICP can be different across firms depending on their expected outcomes and firm-level characteristics, which induces self-selection bias. Meanwhile, there may be reverse causality, as firms with higher ROA tend to have more capacity and resources to use ICP.

Self-selection and reverse causality can cause endogeneity that will bias the regression estimation. PSM as a quasi-experimental method can mitigate this issue by generating a matched sample where treated firms and controlled firms are almost identical in the combination of all covariate characteristics (Dehejia & Wahba, 1999; Heckman & Todd, 2009; Rosenbaum & Rubin, 1983). The PSM method has been used by several studies on sustainable business strategy and environmental governance to reduce endogeneity (Kanashiro, 2020; Tashman & Rivera, 2010; Xu et al., 2019).

To implement the PSM method, we firstly run a Probit model that includes all covariates and year and industry dummies to estimate the probability of using ICP for firms. The Probit model assigns a corresponding propensity score between 0 and 1 for each observation to represent its probability of accepting treatment. Second, we use the nearest-neighbor matching with replacement with a caliper of .01 to match a treated observation with up to four controlled observations (Kanashiro, 2020; Tashman & Rivera, 2010). The caliper restriction enables the distance of propensity scores between the treated and matched controls to be no more than .01. Matching with replacement allows a control unit to be used for multiple times to minimize the distance of propensity scores, so it can help reduce bias

TABLE 3 Regression results of fixed-effects models without PSM

	Model 1		Model 2	
Independent variables	**ROA**	***p* value**	**ROA**	***p* value**
ln(Assets)	.003	.233	.002	.444
Debt Ratio	−.085***	.000	−.086***	.000
ln(Employees)	−.005***	.000	−.005***	.000
ln(R&D)	.007***	.000	.007***	.000
ln(Cost)	−.012***	.000	−.010***	.000
ICP	.010***	.005	.038***	.002
ICP * ln(Cost)			−.003**	.013
Constant	.092***	.000	.081***	.000
Year fixed effects	Yes		Yes	
Industry fixed effects	Yes		Yes	
Observations	660		660	
R^2	.219		.226	
F test	10.488		10.254	

Abbreviation: ICP, internal carbon pricing.
*$p < .1$. **$p < .05$. ***$p < .01$.

TABLE 4 Probit model of firm's probability of using internal carbon pricing

Independent variables	ICP	*p* value
ln(Assets)	0.240**	.015
Debt Ratio	−1.235**	.047
ln(Cost)	−0.162*	.076
ln(Employees)	0.228***	.000
ln(R&D)	−0.132***	.000
Year dummies		
2014	0.938***	.000
2015	1.353***	.000
2016	1.973***	.000
2017	2.217***	.000
Industry dummies		
Utilities	1.024***	.001
Materials	0.505**	.015
Energy	0.573**	.027
Industrials	−0.205	.294
Healthcare	−1.147	.129
_cons	−2.123***	.000
Observations	660	
Log-likelihood	−321.57	
Likelihood ratio	265.60	
Pseudo-R^2	.2923	

Abbreviation: ICP, internal carbon pricing.
*$p < .1$. **$p < .05$. ***$p < .01$.

(Dehejia & Wahba, 2002). We use the *psmatch2* command in Stata15.1 for this matching process. The average treatment effect on the treated (ATT) is reported after matching, where we can find the effect of using ICP by differencing means of ROA between the treated and matched controls.

Third, we check the similarity between the treated and the matched control group based on *t* test on the mean difference of covariates. We obtain a balanced match when there is no significant difference in means of covariates between the treated and controlled firms. Finally, we run a weighted regression with industry and year fixed effects on the matched sample to measure the main effect and the interaction effect of cost of goods sold and ICP. The function form can be expressed as below:

$$Y_{it} = \beta_0 + \beta_1 D_{it} + \beta_2 X_{it} + \beta_3 (D_{it} X_{it}) + Z_{it} + \alpha_k + \tau_t + u_{it},$$

where Y_{it} = ROA for firm *i* in year *t*; D_{it} = the use of ICP for firm *i* in year *t*; X_{it} = cost of goods sold for firm *i* in year *t*; Z_{it} = the vector of covariates for firm *i* in year *t*, including logarithm of assets, logarithm of employees, debt ratio, and logarithm of R&D investment; α_k = industry fixed effect; τ_t = year fixed effect; and u_{it} = error term for firm *i* in year *t*.

TABLE 5 Treatment effect after PSM

Variable	Treatment effect	Treated	Controls	Difference	SE	*t*
ROA	Unmatched	0.036	0.030	0.006	0.003	1.70
	ATT	0.037	0.025	0.013	0.006	2.22

TABLE 6 Balance diagnostics of control variables for treatment and control groups after PSM

Variable	Sample	Mean: Treated	Mean: controls	*t*	*p* value
ln(Assets)	Unmatched	10.994	11.048	−0.280	.781
	Matched	10.987	10.999	−0.060	.953
Debt Ratio	Unmatched	0.195	0.177	2.000**	.046
	Matched	0.192	0.181	1.200	.229
ln(Cost)	Unmatched	10.034	10.428	−1.850*	.064
	Matched	10.082	10.227	−0.680	.500
ln(Employees)	Unmatched	3.344	3.243	0.930	.351
	Matched	3.294	3.222	0.670	.503
ln(R&D)	Unmatched	5.537	6.429	−3.380***	.001
	Matched	5.706	5.512	0.690	.488
2014	Unmatched	0.155	0.255	−3.230***	.001
	Matched	0.173	0.161	0.410	.680
2015	Unmatched	0.204	0.195	0.310	.755
	Matched	0.219	0.207	0.370	.714
2016	Unmatched	0.279	0.104	5.720***	.000
	Matched	0.262	0.280	−0.490	.622
2017	Unmatched	0.301	0.077	7.440***	.000
	Matched	0.278	0.290	−0.340	.733
Utilities	Unmatched	0.180	0.050	5.160***	.000
	Matched	0.142	0.065	3.230***	.001
Materials	Unmatched	0.318	0.252	1.870*	.063
	Matched	0.330	0.354	−0.640	.522
Energy	Unmatched	0.130	0.077	2.190**	.029
	Matched	0.120	0.176	−1.980**	.048
Industrials	Unmatched	0.243	0.426	−5.080***	.000
	Matched	0.265	0.274	−0.260	.797
Healthcare	Unmatched	0.003	0.013	−1.570	.116
	Matched	0.003	0.002	0.190	.850

*$p < .1$. **$p < .05$. ***$p < .01$.

We use the least squares dummy variable (LSDV) approach to estimate the model with industry and year fixed effects and robust standard errors. Fixed effects are necessary, since we run the *testparm* command on the industry dummies (the two-digit GIC sector code) and the year dummies and find a significant *p* value of .0006. Firm fixed effect is not used here because it eliminates the potential heterogeneity across different sectors. ICP may have stronger influence in certain industries. In the weighted regression, controlled observations are weighted by the number of times that they are matched to a treated observation to improve precision (Dehejia & Wahba, 2002).

6 | RESULTS

Table 3 presents the regression results before conducting PSM. Model 1 estimates the main effect of using ICP, where ICP significantly increases firm's ROA by 1.0%, holding all else equal. Model 2 assesses the interaction effect of ICP and cost of goods sold. The significant negative coefficient of the interaction term suggests that firms using ICP are more likely to reduce cost of goods sold to increase ROA. The regression results support Hypotheses 1 and 2. However, the linear regression models suffer from endogeneity bias due to potentials of self-selection and reverse causality.

We then use PSM to address the endogeneity concern. Table 4 shows the results of Probit model with industry and year fixed effects for generating propensity scores for firm-year observations. There is significant evidence that firms with more assets, lower debt ratio, lower cost of goods sold, more employees, and less R&D investment have a greater likelihood of using ICP. Meanwhile, firms from the utility, materials, and energy sectors are more likely to use ICP. A high likelihood ratio of 265.60 indicates that the model is a good fit.

Table 5 indicates the treatment effect of ICP after PSM. The initial sample without matching contains 362 treated firm-year observations and 298 untreated firm-year observations. After matching, 324 treated observations and 212 untreated observations are left in the matched sample. Table 5 shows a significant ATT of 0.013, meaning that using ICP increases the average ROA of firms by 0.013, compared to the average ROA had they not used ICP. This result provides support for Hypothesis 1.

Table 6 shows the balanced distribution of covariates of treatment and control groups after PSM. In the matched sample, the mean differences between treated and controls are not significant across the covariates including assets, debt ratio, cost of goods sold, employees, and R&D investment, according to the *t* statistics and *p* values. The unmatched sample is unbalanced because there are significant differences in the average debt ratio, the average cost of goods sold, and the average R&D investment between the treated and untreated firms. The mean differences of covariates become insignificant after PSM, indicating that the treatment and control groups in the matched sample are highly similar.

Table 7 lists weighted regression results based on the number of times controlled observations are used for matching. According to results of Model 1, ICP causes a significant increase in firm's ROA by 1.1%, holding all else unchanged. In Model 2, the coefficient of the interaction term ICP * ln(Cost) is −.003 and statistically significant, suggesting that firms with ICP are more likely to reduce the cost of goods sold to improve ROA. Hence, the weighted regression results with fixed effects agree with Hypotheses 1 and 2.

TABLE 7 Weighted regression results after PSM

	Model 1		Model 2	
Independent variables	**ROA**	***p* value**	**ROA**	***p* value**
ln(Assets)	.003	.254	.002	.541
Debt Ratio	−.098***	.000	−.096***	.000
ln(Employees)	−.007***	.004	−.007***	.004
ln(R&D)	.007***	.000	.007***	.000
ln(Cost)	−.011***	.000	−.008***	.007
ICP	.011***	.007	.041***	.004
ICP * ln(Cost)			−.003**	.020
Constant	.096***	.000	.086***	.000
Year fixed effects	Yes		Yes	
Industry fixed effects	Yes		Yes	
Observations	536		536	
R^2	.280		.288	
F test	9.202		8.968	

Abbreviation: ICP, internal carbon pricing.
$^*p < .1$. $^{**}p < .05$. $^{***}p < .01$.

7 | CONCLUSION

Although MNEs are increasingly active in embedding ICP into business operations, there has been no quantitative research on the impact of this innovative corporate strategy on financial performance. This paper proposes insightful implications for business leaders and policymakers. ICP can not only serve as a risk management tool to monitor regulatory environment but also lead to cost-saving and business growth. Properly designed internal carbon prices could enhance competitiveness of firms. From the perspective of public policy, ICP could become an ideal complement for carbon tax and ETS, since this self-regulation mechanism can overcome the inefficiencies in government regulations based on command and control (Sinclair, 1997; Stoeckl, 2004).

This research provides empirical evidence for the positive effect of ICP on profitability. We build an interesting microeconomic model that factors cost of carbon emissions into profit function to illustrate how ICP as a cost can add to profitability. To overcome endogeneity bias arising from self-selection and reverse causality, we use PSM to construct a control group that is almost identical to the treatment group for regression. The final results after a weighted regression support our hypotheses. ICP can improve ROA of firms by 1.1%. Meanwhile, we observe an interaction effect where companies using ICP are more likely to reduce cost of goods sold for higher ROA. This research supports Porter's hypothesis on the positive relationship between environment and competitiveness by taking a self-regulation perspective. We contribute to the current literature arguing that environmental self-regulation can generate efficiency gains through cost reduction for companies.

Despite its contributions to business strategy research, this paper still has several limitations worthy of future studies. First, ICP is set as binary variable instead of numerical values due to data availability issue, which might not reflect the sophisticated effect on ROA. If more companies disclosed carbon price levels in the future, we could further obtain a more precise estimate on how different levels of carbon price per ton of emissions would influence profitability. Second, future research is necessary to study the effect of ICP on carbon emissions, as we assume that cost of emissions is a major source of cost reduction in our microeconomic model. It is also worthwhile to study the effect of ICP on ESG performance, investor attitudes and environmental innovation. Finally, given more data disclosure in the future, researchers can evaluate if there is any difference in the impact of shadow pricing and internal carbon fee on financial and environmental performance.

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