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The Impact of Firms' Carbon Emissions on Financial Performance and the Role of Innovation: Evidence from Türkiye

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Abstract

Carbon emissions, one of the main causes of climate change and environmental degradation, have recently become extremely important. In parallel, firms' disclosure of their environmental performance and activities to reduce carbon emissions are viewed positively by stakeholders and society. The question arises whether firms' activities to reduce carbon emissions create additional costs for firms or reduce their costs. In this study, we investigate the relationship between carbon emissions and firms' financial performance. We also examine the moderating effect of innovation on the relationship between carbon emissions and financial performance. The lack of a study on developing countries reveals the importance of this study. Within the scope of the analysis, 14 firms in the BIST Sustainability Index with carbon emissions and innovation data between 2017-2021 were included. Using the random effects model, we find that carbon emissions have a negative effect on firms' return on assets and return on equity, and this negative effect turns positive with innovation. On the other hand, no statistically significant effect was found between Tobin's q value and carbon emissions and innovation. The study shows that firms should adopt proactive environmental strategies and organize their resources and investments to manage their financial performance well.

Keywords: Carbon Emissions, R&D, Environmental Performance, Financial Performance, Ratio Analysis.

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1. INTRODUCTION

Today, global environmental problems have become a growing concern. Problems such as climate change, biodiversity decline, and depletion of natural resources have serious impacts not only on the environment but also on economic and social levels. Carbon emissions (CE), at the center of these problems, are one of the principal sources of climate change. CE are an essential environmental factor resulting from releasing greenhouse gases into the atmosphere from human activities such as the use of fossil fuels, production processes, and transportation. These emissions cause climate change by disrupting the temperature balance of our planet due to the greenhouse effect (Mikhaylov et al., 2020, p. 2897). CE have a profound impact not only on the environment but also on the challenges that firm faces in terms of sustainability and long-term success (Matsumura et al., 2014; Lee et al., 2015). Therefore, CE have become a critical issue for measuring and managing the environmental impact of industry and firm.

According to the agency theory perspective, firms' efforts to reduce their environmental impact, especially when high costs are taken into account, can reduce the profitability and shareholder wealth of the firm when competitors can avoid these costs while at the same time providing a competitive advantage for competitors (Friedman, 1970; Wedari et al., 2023, pp. 654-655). However, with the increase in environmental concerns in recent years, stakeholders have been pressuring firms to adopt green practices (Singh et al., 2021). Firms that emit more carbon dioxide contribute to climate change and may also be at a disadvantageous position in the market. This is because consumers increasingly demand products and services from firms which are committed to sustainability. In addition, governments also have taken some steps to combat climate change. Türkiye can be a party to these practices directly or indirectly. Some of the conventions and protocols to which Türkiye is a party can be listed as the “Vienna Convention and Montreal Protocol”, the “UN Framework Convention on Climate Change”, the “Kyoto Protocol”, and the “Paris Agreement”. The Paris Agreement, one of these conventions and protocols, envisages the provision of financing, technology transfer, and capacity-building opportunities to developing countries in need (Türkiye Cumhuriyeti Dışişleri Bakanlığı, n.d.). Another regulation that will indirectly affect Türkiye is the Border Carbon Adjustment Mechanism (CBAM), which is planned to be implemented gradually between October 1, 2023 and December 31, 2025. With this regulation, it is envisaged to levy a "carbon emission tax" on certain products imported by the European Union (EU) at certain rates at the border according to their carbon content (Bahadır, 2023).

Low- and middle-income countries, including Türkiye, were responsible for 53% of CE in 2000, which increased to 69% in 2021 (United Nations Environment Programme (UNEP), 2023, p. 6). According to 2021 data, Türkiye ranks 15th in CE worldwide with 598.351.400 tons (Ritchie and Roser, 2023). Per capita CE in Türkiye generally showed an upward trend between 1990 and 2020, except for the years of financial stagnation (The World Bank, 2023a). In terms of emissions by sectors, energy-

related emissions accounted for the largest share with 71.3%, followed by industrial processes and product use at 13.3%, agriculture at 12.8%, and waste at 2.6% (Türkiye İstatistik Kurumu [TÜİK], 2023). In this context, due to the EU's high share in Türkiye's exports and being one of the major suppliers of the EU, especially in sectors such as steel, cement, and aluminum, Türkiye is considered to be among the countries that will be most affected by regulations such as CBAM (Türkiye Cumhuriyeti Ticaret Bakanlığı, 2022). Reducing CE is essential for Turkish firms as goods produced within the scope of trade with the EU are required to comply with stricter carbon standards through CBAM implementation. Within the framework of this importance and the planning of CE reduction activities, the World Bank has provided $450 million in financing support within the scope of the "Türkiye Green Industry Project" for industrial firms in Türkiye to effectively keep pace with the green transformation. With this support, it is planned to help firms reduce their CE, improve their environmental performance and support green innovation activities (The World Bank, 2023b).

Increasing pressure from various stakeholder groups on firms to reduce their environmental impact and improve their sustainability has led firms to address environmental and ethical concerns (Prakash, 2002; Maas, 2018). Firms that avoid environmental costs and operate irresponsibly may face government sanctions, reputational damage, or inefficient production processes. For these reasons, the efforts of firms to reduce their environmental impact and increase their sustainability have increased significantly (Zammit-Cutajar, 2012). One way to reduce CE is through technological innovation. New technologies can improve energy efficiency and reduce CE. For example, electric vehicles have lower CE than fossil fuel-powered vehicles. Renewable energy technologies can replace fossil fuels and reduce CE. In addition to lowering CE, innovation can also improve firm performance. New technologies can provide firms with cost savings and competitive advantage (Pane Haden et al., 2009). However, according to Chang (2011) and Hillestad et al. (2010), the motivation for green innovation is not limited to profit and financial performance (FP); environmental initiatives of firms can also be implemented to meet societal expectations, which may indirectly affect the FP of firms.

Reducing CE is of increasing importance for firms in line with sustainability goals. Therefore, examining the relationship between CE and FP and understanding how innovation changes this effect is critical. In the existing literature, very few empirical studies test the relationship between innovation levels, FP, and CE, which may be due to the limitations of the available data. The data required to measure innovation is limited also in Türkiye. The present study focuses on R&D expenditures in measuring innovation to overcome this limitation. In addition, most of the studies in the literature have focused on the direct impact of innovation on FP or CE. However, this may be insufficient to fully explain the relationship between the innovation levels of firms and their FP and CE. This study examines the impact of CE on firm performance in addition to investigating how innovation can moderate this impact. This study aims to measure the contribution of innovation to the improvement of firms' environmental performance and to reveal the impact of improved environmental performance on FP by

focusing on firms' environmental performance and innovation power. For these reasons, the answers to the questions of whether the increase of CE of firms negatively affect their FP, and whether the innovation positively changes the effect of CE on FP.

The fact that CE in Türkiye has been on an increasing trend over the years and the recent planning of activities to reduce CE and the conduct of R&D studies in this direction raises the question of how it will affect FP. As a result of the literature review, no study considers developing countries in this aspect, and this reveals the importance of the present study. Innovation can play an important role in firms' efforts to improve environmental sustainability. Innovative products, processes, and firm models can help firms reduce environmental impacts and gain competitive advantage. Presenting these findings specifically for Türkiye, as a developing country, may contribute to the literature and encourage the implementation of measures and investments. In this way, developing countries such as Türkiye can be prevented from being negatively affected by the new conjuncture and regulations. In this context, the study proceeds to understand the impact of CE on firm performance and to explore how innovation can shape this impact. It will review the relevant literature and present the findings of empirical studies. It will also discuss the implications of the findings for firms and policymakers.

2. LITERATURE REVIEW

In this section, the literature review of the studies focusing on CE, FP, and innovation is included and hypotheses are determined by revealing their rationality.

2.1. The Relationship between Carbon Emissions and Financial Performance

CE have become an important issue as a result of increasing global environmental concerns due to climate change. In this context, firms face increasing pressure from stakeholders such as customers and governments to reduce CE. In the face of this problem, more and more politicians are turning to tax policies to reduce CE, such as carbon emission tax (Tu et al., 2022). On the other hand, customers have started to pay more attention to firms' carbon emission disclosures. Lu et al. (2021) argue that carbon emission disclosures do not contribute significantly to FP in carbon-intensive sectors but positively impact FP in non-carbon-intensive sectors. These pressures create an obligation for firms to manage their environmental impacts (Tu et al., 2022). For this reason, it is critical for firms to reduce CE in terms of both fulfilling sustainability goals and FP. Various studies in the literature examine the relationship between CE and FP.

Gallego-Álvarez et al. (2015) conducted a study with the data of 89 international firms for the years 2006-2009 and concluded that reducing CE affects FP positively. Miah et al. (2021) conducted a study with data covering the period 2011-2020 for 328 non-financial and 104 financial firms operating in 22 emerging economies. The results show that CE decrease the return on equity (ROE), Tobin's q, Z-score and credit rating of firms. Galama and Scholtens (2021) examined 34 studies conducted between 1997 and 2019 with the meta-analysis method. According to the results, firms with lower CE exhibit

better FP. In addition, it was observed that the sector in which the firms operate has an impact on the results. According to Galama and Scholtens (2021), it is claimed that CE have a greater impact on FP in countries with strict carbon policies. In the study by Houqe et al. (2022) which included from 2323 US firms for the years 2007-2016, the results show that firms with higher CE exhibit lower FP. In the study of Laskar et al. (2022) with the data of 100 firms traded on the Bombay Stock Exchange for the years 2016-2020, it was concluded that the effect of CE on FP is negative.

There are also studies that use carbon performance instead of CE as a variable. He et al. (2016), using a sample of US S&P 500 firms, concluded that carbon performance positively affects FP. Ganda (2018) conducted a study on 63 firms operating in the Republic of South Africa and concluded that carbon performance positively affects ROE and return on sales (ROS). Yan et al. (2022) examined the relationship between carbon performance and FP using the Chinese energy sector as an example between 2014 and 2019. The results show that carbon performance positively affects FP. In the study conducted by Meng et al. (2023) with data covering 2013-2020 of 352 firms registered on the Chinese Stock Exchange, it was concluded that carbon performance positively affects FP. Meng et al. (2023) also found that carbon performance has a greater impact on FP in non-state-owned firms.

Contrary to these studies finding a positive effect of low CE and carbon performance on FP, there are also studies in the literature that claim that low CE have a negative effect on FP. According to Tu et al. (2022), the carbon emission tax implemented to encourage CE reduction reduces CE and improves environmental quality but slows down economic growth. Therefore, firms with lower CE may not always exhibit better FP. The finding of Busch et al. (2022) supports this prediction. The study of Busch et al. (2022) covers the data of 5.663 publicly traded firms from Reuters DataStream for the years 2005-2014. According to the findings of the study, FP is positively correlated with CE. The authors emphasize that more policy interventions are needed to pave the way for a low-carbon economy due to the negative FP of firms that reduce CE. Lewandowski (2017), using data from 1.640 international firms between 2003 and 2015, finds that carbon emission reduction increases ROS but is negatively related to Tobin's q. The findings of the study by Van Emous et al. (2021) also support the findings of Lewandowski's study (2017). According to the findings of Van Emous et al. (2021) with the data of 1.785 firms from 53 countries for the period 2004-2019, reducing CE increases return on assets (ROA), ROE, and ROS, but has no effect on Tobin's q and current ratio. In contrast to these findings, Wang et al. (2021) state that carbon efficiency has a positive effect on Tobin's q.

The impact of CE on FP has not been fully clarified in the literature. The majority of the literature concludes that CE negatively affect the FP of firms. However, this result may differ depending on the type of firm, the region of operation and the FP indicators used. Grounded on these, new studies are needed in different countries and sectors to clarify the connection between CE and FP. Accordingly, the following hypothesis is formulated and shown in Figure 1.

Hypothesis 1. The increase in firms' carbon emissions negatively affects their financial performance.

2.2. The Relationship among Carbon Emissions, Financial Performance, and Innovation

Innovation is defined by Slade and Bauen (2009) as the gradual, disruptive or radical change of new modern technology that can replace old technology. With increasing concerns about climate change, reducing CE has become increasingly crucial for firms in terms of both environmental responsibility and financial success. One way to reduce CE can be through innovation. Firms can benefit from innovation by reducing the negative impacts of environmental risk, pollution and resource use. In this way, firms can increase their efficiency by improving their goods or service production processes, organizational structures or management processes (Porter & Van Der Linde, 1995; Kemp & Pearson, 2007; Zhang et al., 2012; Long et al., 2017). On the contrary, the pressure of environmental regulations such as environmental taxes can also encourage innovation by increasing the R&D expenditures of firms (Hamamoto, 2006; Mensah et al., 2019; Zhu et al. 2020; Zhang et al. 2020). This, in turn, can accelerate the advancement of environmental technologies for CE reduction and sustainable development (Karmaker et al. 2021; Mensah et al. 2019).

While innovation provides cost savings, competitive advantage, corporate image and market opportunities for firms, it can also reduce their environmental impact (Hull & Rothenberg, 2008; Huang & Li, 2017; Duque-Grisales et al., 2020; Zhang et al., 2020; Wedari et al., 2023). Therefore, innovation can improve the FP of firms while reducing CE (Powell & DiMaggio, 1991; Powell & Bromley, 2015; Benlemlih & Girerd-Potin, 2017). Few studies in the literature examine the relationship between CE, innovation and FP.

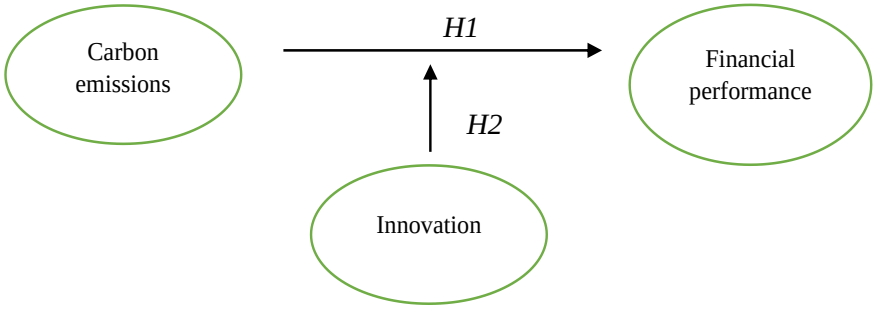
Lee and Min (2015), in a study on Japanese manufacturing firms, concluded that environmental innovation reduces CE. On the other hand, there are various studies reporting findings that environmental innovation has a positive impact on the FP of the firm (Lee & Min, 2015; Tariq et al. 2019; Wang & Wang, 2022; Yan et al. 2022, 9-10; Wedari et al. 2023). According to Yan et al. (2022), the interaction of carbon performance and technological innovation strengthens the effect on improving corporate FP. However, this effect does not apply to state-owned firms. The possible reason for this is that technological innovation of non-state-owned firms is more profit-oriented and technological innovation of state-owned firms may be more oriented towards meeting social responsibility needs (Yan et al., 2022).

Khalil and Nimmanunta (2022) tested the impact of traditional innovation and environmental innovation on firm value. The study, conducted with data of 462 firms from Asian countries for the years 2015-2019, emphasized that traditional innovation has a positive impact on firm value, but at the expense of the environment. However, according to the findings, green innovation positively affects both environmental performance and firm value.

Very few studies test the relationship between innovation levels, FP, and CE. According to the existing literature, this relationship differs depending on the type of firm and whether the innovation is environmental or standard innovation. The following hypothesis is formulated and shown in Figure 1 to contribute to the literature in clarifying this relationship

Hypothesis 2: Innovation positively changes the impact of carbon emissions on financial performance.

Figure 1. The relationship among carbon emissions, financial performance, and innovation



3. DATA AND METHODOLOGY

In this section, the research data set, the variables used in the research, the analysis results, and the findings of the research are included.

3.1. Data Set

Due to differences in countries' local environmental practices and policies and in their exposure to market pressures (Lee & Min, 2015), only one country was analyzed within the study's scope. In parallel with this, only Türkiye is included in the scope of the research. The reasons behind choosing this country lie behind factors such as Türkiye being a developing country, its high export rate to Europe, and its high amount of carbon emissions. Not including the other developing countries in this study might be considered a limitation. In addition, the purpose of the study is not to make comparisons between countries but to reveal the current situation in Türkiye, which is a developing country.

As greenhouse gas emissions data before 2017 and after 2021 could not be accessed, of the 77 firms in the Borsa Istanbul (BIST) Sustainability Index, the ones whose data consisting of uninterrupted total greenhouse gas (GHG) emission (Scope 1, Scope 2 & Scope 3) between 2017 and 2021 in their sustainability reports were analyzed. In this context, 31 firms in the BIST Sustainability Index have environmental performance data between 2017 and 2021. Among these firms, there are 14 firms with R&D expenditures. The data of these 14 firms between 2017-2021 were included in the scope of the research, and the list of these firms is given in Table 1.

Table 1. Firms Included in the Scope of Analysis

Name of the Firm	Name of the Firm
Arçelik A.Ş.	Brisa Bridgestone Sabancı Lastik Sanayi ve Ticaret A.Ş.
Aselsan Elektronik Sanayi ve Ticaret A.Ş.	Çimsa Çimento Sanayi ve Ticaret A.Ş.
Aygaz A.Ş.	Kerevitaş Gıda Sanayi ve Ticaret A.Ş.
Logo Yazılım Sanayi ve Ticaret A.Ş.	Otokar Otomotiv ve Savunma Sanayi A.Ş.
Pınar Süt Mamulleri Sanayii A.Ş.	Tofaş Türk Otomobil Fabrikası A.Ş.
Tüpraş-Türkiye Petrol Rafinerileri A.Ş.	Türkiye Şişe ve Cam Fabrikaları A.Ş.
Ülker Bisküvi Sanayi A.Ş.	Anadolu Isuzu Otomotiv Sanayi ve Ticaret A.Ş.

Within the scope of the variables of the study, FP, innovation, and environmental performance data of 14 firms, presented in Table 1, between 2017-2021 were collected. The variables used in the research, the calculation method of these variables and the sources from which the data were obtained are shown in Table 2.

Table 2. Description of Variables

Variables	Description	Calculation	Sources Obtained
CO2	Carbon density	Total CE (tons)/total sales	Sustainability reports
TOBINQ	Tobin's q	(Market capitalization + total debt) /total assets	https://www.kap.org.tr/
ROA	Return on assets	Net profit/total assets	https://www.finnet.com.tr/
ROE	Return on equity	Net profit/equity	https://www.finnet.com.tr/
CAPINTENS	Capital Intensity	Total assets/total sales	https://www.finnet.com.tr/
LEV	Leverage ratio	Total debt/total assets	https://www.finnet.com.tr/
RD	R&D Intensity	R&D expenditures/total sales	https://www.kap.org.tr/
RDCO2	Moderator	R&D*CO2	
SIZE	Firm size	Natural logarithm of total assets	https://www.finnet.com.tr/

Carbon intensity is the independent variable of the models created to examine the impact of CE on the FP of firms. Carbon intensity variable has been used in many studies in the literature (Gallego-Álvarez, Segura, & Martínez-Ferrero, 2015; Lee & Min, 2015; Ganda & Milondzo, 2018; Mensah et al, 2019; Miah et al, 2021; Busch et al, 2022; Khalil & Nimmanunta, 2022). ROA, ROE and TOBINQ variables were used as FP indicators of the firms, and these variables were determined as the dependent variables of the models. ROA (Gallego-Álvarez et al, 2015; Akben-Selcuk, 2019; Tariq et al, 2019; Naranjo Tuesta et al, 2020; Zhang et al, 2020; Van Emous et al, 2021; Miah et al, 2021; Wang, Li & Zhang, 2021; Lu et al, 2021; Fourati & Dammak, 2021; Yan et al, 2022; Busch et al, 2022; Zhang & Gan, 2023; Wedari et al, 2023), ROE (Gallego-Álvarez et al, 2015; Ganda, 2018; Ganda et al, 2018; Tariq et al, 2019; Naranjo Tuesta et al, 2020; Wang, Li, & Zhang, 2021; Van Emous et al, 2021; Lu et al, 2021; Fourati & Dammak, 2021) and Tobin's q (Lee & Min, 2015; He et al, 2016; Lewandowski,

2017; Zhang et al, 2020;Van Emous et al, 2021;Miah et al, 2021; Wang, et al., 2021; Busch et al, 2022; Khalil & Nimmanunta, 2022; Yan et al, 2022; Houqe et al, 2022; Meng et al, 2023; Zhang & Gan, 2023) have also been used in many studies in the literature. Both internal and external performance measures can be used to assess FP. Accounting-based measures like ROE, ROA, and ROS are used to compute internal performance measures. However, accounting-based measures are susceptible to manipulation and therefore, Tobin's q, which reflects the market reaction to a firm's environmental activities, is also included (Houqe et al., 2022: 6). Tobin's q, which operationalizes stock performance, reflects the capital market's expectation of the future value of a firm (Wang et al. 2014). CAPINTENS (Lee & Min, 2015; He et al. 2016; Wang, Li & Zhang, 2021; Busch et al. 2022; Wedari et al. 2023; Meng et al. 2023), SIZE (Butselaar, 2020; Desai et al, 2021) and LEV (Lee & Min, 2015; He et al, 2016; Akben-Selcuk, 2019; Zhang et al, 2020; Wang, Li & Zhang, 2021; Fourati & Dammak, 2021; Busch et al, 2022; Laskar et al, 2022) variables have also been used in many studies in the literature.

In the literature, some studies have measured innovation with the number of patents owned by firms (Zhang & Gan, 2023; Karmaker et al., 2021; Zhang et al., 2020) and some studies have measured innovation with R&D expenditures (Lee & Min, 2015; Laskar et al., 2022; Khalil & Nimmanunta, 2022). Since it is not possible to access data on the number of patents on a firm basis in Türkiye, R&D expenditure data is used to measure innovation in this study. In the literature, some studies include R&D intensity in the model by proportioning R&D expenditures to total sales (King & Lenox, 2002; Lee & Min, 2015).

Three different models, namely Model (1), Model (2) and Model (3), were constructed with the variables given in Table 2. The models of the study are shown in Equation (1), Equation (2) and Equation (3) respectively.

$$ROA_{it} = \beta_0 + \beta_1 CO2_{it} + \beta_2 RD{*}CO2_{it} + \beta_3 SIZE_{it} + \beta_4 LEV_{it} + \beta_5 CAPINTENS_{it} + \varepsilon_{it} \quad (1)$$

$$ROE_{it} = \beta_0 + \beta_1 CO2_{it} + \beta_2 RD{*}CO2_{it} + \beta_3 SIZE_{it} + \beta_4 LEV_{it} + \beta_5 CAPINTENS_{it} + \varepsilon_{it} \quad (2)$$

$$TOBINQ_{it} = \beta_0 + \beta_1 CO2_{it} + \beta_2 RD{*}CO2_{it} + \beta_3 SIZE_{it} + \beta_4 LEV_{it} + \beta_5 CAPINTENS_{it} + \varepsilon_{it} \quad (3)$$

In the models, data for firm *i* in period *t* are expressed. In addition, a new variable is derived to measure the moderating effect of the innovation variable in the models. Since there is more than one unit and time dimension in the study, panel data analysis is used.

3.2. Empirical Analysis and Results

Under this heading, the analyses conducted to reveal how the environmental performance of firms affects their FP and the power of innovation in this possible effect are presented. Summary descriptive statistics of the study variables are shown in Table 3.

Table 3. Descriptive Summary Statistics

Variables	Number of Observations	Average	Std. Error	Minimum	Maximum
ROA	70	0.06	0.05	-0.05	0.19
ROE	70	0.19	0.17	-0.19	0.69
TOBINQ	70	1.49	0.65	0.65	4.28
CO2	70	0.00	0.00	0.00	0.00
RDCO2	70	-0.00	0.00	-0.00	-0.00
LEV	70	0.62	0.13	0.38	0.85
SIZE	70	22.73	1.33	19.76	25.38
CAPINTENS	70	1.39	0.57	0.45	2.87

When the summary statistics of the variables are analyzed, it is observed that the average value of ROA, which expresses the average ROA of the firms within the scope of the analysis, is 0.06. However, the maximum and minimum ROA are 0.19 and -0.05. Similar findings are observed for ROE and TOBINQ, where the minimum ROE is -0.19 and the maximum ROE is 0.69, while the minimum TOBINQ value is 0.65 and the maximum TOBINQ value is 4.28, indicating that TOBINQ values are higher than ROA and ROE performances. The minimum value of the CO2 variable is 0.000 and the maximum value is 0.003 and it is thought that the difference between the minimum and maximum values is due to the firms belonging to different sectors. Since the mean value of the LEV variable is 0.65, it is observed that sustainable firms generally finance their assets with borrowing. The minimum value of the SIZE variable is 19.76 and the maximum value is 25.38. Accordingly, no significant differences were observed between the sizes of the firms.

Table 4. Correlation Matrix

	1	2	3	4	5	6	7	8
1. ROA	1.00							
2. ROE	0.86***	1.00						
3. TOBINQ	0.54***	0.52***	1.00					
4. CO2	-0.00*	-0.06*	-0.22*	1.00				
5. RDCO2	-0.01	0.07	0.02	-0.83***	1.00			
6. SIZE	0.04	0.06	-0.30**	-0.03	0.25**	1.00		
7. LEV	-0.23**	0.16	0.10	-0.12	0.15	0.20*	1.00	
8. CAPINTENS	0.15	-0.03	0.06	0.32***	-0.36***	0.01	-0.28**	1.00

Note: ***p<0.01, **p<0.05, *p<0.10.

According to Table 4, no high correlation was observed between the independent variables. This situation prevents the multicollinearity problem (Liu et al., 2014). The multicollinearity problem means that there is a relationship between independent variables. The Variance Inflation Factor (VIF), which indicates whether there is a multicollinearity problem, is presented in Table 5.

Table 5. Variance Inflation Factor Results

Variables	VIF
RDCO2	4.21
CO2	3.78
SIZE	1.27
CAPINTENS	1.27
LEV	1.15
Mean VIF	2.34

Since the average VIF criterion presented in Table 5 is less than 10, there is no multicollinearity problem in the models (Studenmund, 2007). Table 6 presents the results of the Ramsey Reset, DeBenedictis and Giles Reset specification tests, which indicate whether the functional form of the models can be determined correctly.

Table 6. Specification Test Results

	Model (1)	Model (2)	Model (3)
Ramsey ResetF1	2.90*	2.42	4.44**
Ramsey ResetF2	1.49	1.82	4.25**
Ramsey ResetF3	1.07	1.20	3.23**
DeBenedictis - Giles ResetL1	0.52	0.61	1.64
DeBenedictis - Giles ResetL2	0.27	0.48	1.29
DeBenedictis - Giles ResetL3	0.80	0.31	1.18
DeBenedictis - Giles ResetS1	0.40	0.83	1.27
DeBenedictis - Giles ResetS2	0.50	0.44	0.98
DeBenedictis - Giles ResetS3	0.50	0.41	1.46

Note: ***p<0.01, **p<0.05, *p<0.10.

According to the findings of the specification tests of the models given in Table 6, The H_0 hypotheses stating that the models are correctly constructed cannot be rejected in general and the models are correctly specified.

It is necessary to examine whether there are unobservable unit or time effects in the panel. If there are unit and/or time effects, they should be included in the models (Papke & Wooldridge. 2023). The F test is a test to determine whether it would be appropriate to use the classical model using the fixed effects model. The LR test is a test to determine whether it is appropriate to use the classical model by considering the maximum likelihood estimator for random effects.

Table 7. Unit/Time Effects Results

	Model (1)	Model (2)	Model (3)
F- two-way	1.95**	1.59*	2.22**
F-unit	10.50***	8.84***	6.91***
F-time	0.48	0.37	2.01
LR - two-way	31.62***	27.48***	35.00***
LR-unit	31.48***	27.48***	26.12***
LR-time	0.00	0.00	0.81

Note: ***p<0.01, **p<0.05, *p<0.10.

Accordingly, Table 7 presents the results of the F and LR test for the unit and/or time effects analysis of the models. The H_0 hypothesis of the F test is "there are no unit and time effects". According to the findings of the F test, there is a unidirectional unit effect in Model (1), Model (2) and Model (3). The H_0 hypothesis of the LR test is "there are no unit and time effects". According to the findings of the LR test, the H_0 hypothesis is rejected for unit effect for Model (1), Model (2) and Model (3) and there is a unit effect in the models. However, H_0 hypothesis cannot be rejected for the time effect and the models have no time effect. According to the findings of F and LR tests, the models are one-way unit effect models. Accordingly, in models where the classical model is not valid, the Hausman test is used to decide whether fixed effects or random effects should be preferred. The findings of the Hausman test are presented in Table 8.

Table 8. Hausman Test Results

Hausman Test		
Model (1)	Model (2)	Model (3)
2.05	1.90	0.86

Note: Coefficients are given in the table. ***p<0.01, **p<0.05, *p<0.10.

The H_0 hypothesis of the Hausman test is "there is no correlation between the explanatory variables and the error term". In this case, both fixed effects and random effects estimators are consistent, but the random effects estimator is inefficient. Accordingly, when the Hausman test results presented in Table 8 are analyzed, H_0 hypotheses cannot be rejected, and random effects estimators are effective in the models. As a result of the analysis, it is decided that the models are one-way unit-effect random effects estimators. Accordingly, the findings of heteroskedasticity, autocorrelation and the cross-sectional dependence tests, which are the basic assumption tests of the random effects estimator, are presented in Table 9, Table 10 and Table 11. In addition to the traditional tests for equality of variances, Brown and Forsythe (1974) proposed a robust heteroskedasticity test that can be used in the absence of a normal distribution.

Table 9. Heteroskedasticity Test Results

Brown & Forsythe	Model (1)	Model (2)	Model (3)
W0	2.94***	3.19***	3.04***
W50	1.32	1.56	2.14**
W10	2.94***	3.19***	3.04***

Note: Coefficients are given in the table. ***p<0.01, **p<0.05, *p<0.10.

According to Table 9, the null hypothesis H_0 stated as "variances of the units are equal" is rejected and there is heteroskedasticity in the models. For the autocorrelation test, which is another assumption test, the Durbin Watson (DW) test of Bhargava, Franzini and Narendranathan (1982) and the Locally Best Invariant (LBI) test of Baltagi-Wu (1999), which can be preferred in the random effects model, are applied. Table 10 presents the autocorrelation test findings.

Table 10. Autocorrelation Test Results

	Model (1)	Model (2)	Model (3)
DW	1.93	1.30	1.77
LBI	1.37	1.81	1.84

Note: Test statistic values are given in the table.

According to the findings in Table 10, since the LBI and DW test statistics are less than 2, it can be stated that there is autocorrelation in the models. To test for the presence of inter-unit correlation in the models, Pesaran (2004) proposed the CD test, which can be applied when the time dimension is smaller than the unit dimension (T<N). Table 11 presents the inter-unit correlation, in other words, the cross-sectional dependence test results of the models.

Table 11. Cross-Section Dependence Test Results

	Model (1)	Model (2)	Model (3)
CD	0.81	1.52	6.41***

Note: Coefficients are given in the table. ***p<0.01, **p<0.05, *p<0.10.

According to Table 11, for Model (1) and Model (2), the null hypothesis of "no correlation between units" cannot be rejected and there is no correlation between units. However, in Model (3), the H_0 hypothesis is rejected and there is horizontal cross-section dependence. As a result of the tests, the Huber (1967), Eicker (1967) and White (1980) estimator, which can be used for robust standard errors, is applied in Model (1), Model (2) and Model (3). The results of Huber, Eicker and White robust estimators are presented in Table 12.

Table 12. Results of Robust Regression

Variables	Model (1)	Model (2)	Model (3)
CO2	-240.76***	-29.49**	-216.34
RDCO2	10386.93***	25954.96***	-12509
SIZE	0.01*	0.03	-0.17*
LEV	-0.29***	-0.44*	0.86
CAPINTENS	-0.02	-0.06	0.11
Cons.	-0.09	0.32	4.86*
Wald ist.	81.74***	58.99***	21.01***

Note: Coefficients are given in the table. ***p<0.01, **p<0.05, *p<0.10.

According to the findings of Model (1), where ROA is the dependent variable, the effect of CE on ROA is statistically significant and negative. However, innovation turns the effect of CE on ROA into positive. SIZE variable statistically affects ROA positively at 10% significance level. The effect of LEV variable on ROA is statistically significant and negative. The CAPINTENS variable, which expresses capital intensity, has no statistically significant effect on ROA. According to the findings of Model (2), where ROE is the dependent variable, the effect of CE on ROE is statistically significant and negative. Innovation, on the other hand, turned the effect of CE on ROE into a positive one. The effects

of SIZE and CAPINTENS variables on ROE are not statistically significant. LEV variable has a negative effect on ROE at 10% significance level. In Model (3), where TOBINQ is the dependent variable, there is no statistically significant effect of CE and the impressive power of innovation on TOBINQ. While LEV and CAPINTENS variables have no statistically significant effect on TOBINQ, the effect of SIZE variable on TOBINQ is negative at 10% significance level.

It has been observed that the profitability of firms with higher carbon intensity relative to their total sales declined. Türkiye has close trade relations with the EU, and the EU has a large share in Türkiye's exports. Based on their carbon content, the 2023 CBAM envisages a "carbon emission tax" on certain EU imports at the border. Although this practice has not been implemented in the period covered by the dataset, EU firms may prefer firms with lower carbon intensity in their trade relations with Türkiye. This is because once CBAM is implemented, costs will increase as additional taxes will be imposed on trade with firms with high CE. EU countries that do not want to have problems in finding suppliers may change their preferences in advance. This may explain why firms with higher carbon intensity have lower ROA and ROE ratios. According to the findings, it is also observed that innovation turns this negative effect into a positive one. As a developing country, firms in Türkiye need to make innovative investments to produce with cleaner energy sources and to increase their energy efficiency. Firms that make and continue to make these investments can gain a more advantageous position in the market within the scope of CBAM. Since innovation is thought to reduce carbon intensity in the long run, firms that invest in innovation may become more preferred by EU firms, even if their carbon intensity is high. This may increase the profitability of these firms. Moreover, firms with low CE may have access to lower-cost sources of financing. In addition, firms are also offered low-cost financing opportunities to invest in green innovation. This has an impact on firms' profitability. Our finding on the leverage ratio supports this finding. According to the findings, a high leverage ratio negatively affects profitability. Therefore, reducing borrowing costs can increase profitability. Consumers' impact on these findings is thought to be low. The fact that CE do not significantly affect Tobin's q supports this idea. Investors and consumers in Türkiye may not value environmental performance or may not yet have this awareness.

4. CONCLUSION

CE, one of the primary contributors to global warming/climate change, are increasing concerns about environmental degradation day by day. Due to climate problems, many countries have introduced legal regulations for the disclosure of CE to the public. Public acknowledgment of CE has encouraged firms to investigate the relationship between CE and FP. The aim of this study is to examine the relationship between CE and FP of firms and to reveal whether innovation has a regulatory effect on the direction of the relationship between CE and FP. The study analyzes firms that carry out sustainable activities in Türkiye. However, in developing countries such as Türkiye, public disclosure of CE information is still limited, which constitutes the limitation of the study. In this context, the study

analyzed the data of the firms in the BIST Sustainability Index that disclosed their CE data between the periods 2017-2021. Among the firms disclosing CE data, firms making innovation investments were selected, and 14 firms were included in the analysis.

According to the analysis findings, firms' CE reduce their ROA and ROE. These findings are in line with the findings of Van Emous et al. (2021), Gallego-Álvarez et al. (2015), Galama and Scholtens (2021), Laskar et al. (2022), Houqe et al. (2022) and contrary to the findings of Busch et al. (2022) and Rokhmawati et al. (2015). Innovation, on the other hand, positively changes the decreasing effect of CE on ROA and ROE. This finding is in line with the findings of Yan et al. (2022), Khalil and Nimmanunta (2022). Activities carried out to reduce CE and investments in innovation are expected to increase the FP of firms as they reduce their costs in the long run. In addition, by conducting activities to prevent environmental degradation and disclosing these activities to stakeholders and the public, it is expected that the FP and market value of firms will increase due to the increase in corporate image and reputation, trust in stakeholders, and fulfillment of their responsibilities towards society. On the other hand, there is no statistically significant effect of CE and innovation on Tobin's q value. This finding is in line with Van Emous et al. (2021). This finding is consistent with Van Emous et al. (2021), but contrary to the findings of Shuwaikh et al. (2022), Faria et al. (2022), and Kurnia et al. (2021).

The findings of the study are important for firms to determine their strategies. This study shows that firms' innovations both improve their environmental performance and increase their FP. Firms' environmental performance and innovation are among the key elements that will enable them to gain a competitive advantage. Accordingly, firms can improve their financial performance by enhancing their innovation and their environmental performance. It shows that firms must adopt proactive environmental strategies and organize their resources and investments to manage their environmental and FPs well. For firms and managers, improving their environmental performance means investing in green technology. Although the integration of firms in this process may seem to bring additional costs in the first place, according to the findings of this study, it means that they will have a good environment and FP in the long run and will benefit in the long run.

Previous studies suggest that the market "penalizes" firms based on the idea that unless firms reduce CE, they harm the environment, living beings and society (Lee et al., 2015). However, according to the findings of this study, the environmental performance of firms in the market with an investor profile in a developing country like Türkiye is not yet fully known. At this point, governments should introduce some regulations for firms in terms of environmental policies and legal practices. Policymakers can make public disclosure of non-financial information on environmental performance, such as carbon emission data, mandatory or incentivized. Mandatory carbon emission reporting encourages the adoption of proactive environmental strategies and corporate environmental management activities. Firms should measure and report the benefits and costs resulting from environmental management and improved environmental performance. To adapt to climate change and

reduce CE, firms should reduce their use of coal and liquid fossil fuels and switch to renewable energy sources. They should conduct R&D activities to increase energy efficiency, in short, they should invest in green innovation. Firms may need financial resources to do all this. Therefore, it would be extremely beneficial for policymakers to create budgeting and financing mechanisms and provide tax advantages for firms to increase their green innovation activities and reduce carbon emissions. In addition, training and communication activities should be carried out to increase knowledge, skills and awareness of climate change, and national and international cooperation should be strengthened.

Considering the limitations of the study, it should be kept in mind that these comments provide a general framework, and further studies should be conducted to investigate different aspects of the issue. Future studies can compare developing countries with developed countries or include energy structure and industry profile as variables in developing countries where access to data is more accessible. There is also a need for comprehensive studies that evaluate the socio-economic effects on the relationship between CE and FP in developing countries such as Türkiye.

The study does not necessitate Ethics Committee permission.

The study has been crafted in adherence to the principles of research and publication ethics.

The authors declare that there exists no financial conflict of interest involving any institution, organization, or individual(s) associated with the article. Furthermore, there are no conflicts of interest among the authors themselves.

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