

Relationship Between Carbon Footprint and Operational Cost in European Companies

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Abstract. This article uses econometric and sampling techniques to find the relationship between a company's carbon emission level (E) and its operational cost (OC). We conducted literature reviews in previous studies and found a gap to conduct our own research: to focus on the European regions and its companies to use precise data to analyze the relationship between the two factors. The OC of a company is the dependent variable that is affected by the components: E, output level (y) and input prices (w). We use these variables to construct a regression model and use this modeling technique to conclude the relationship between E and OC from the plotted graphs and coefficients calculated. The results show that E correlates negatively with OC. Also, y and w have a positive relationship with OC, with w as the most significant factor affecting OC. We carried out the empirical analysis using data of the variables in seven sampling European companies with a timespan of ten years (2014-2023).

Keywords: company's emission level, company's operational cost, input prices, output level, European companies, sustainability, reduce carbon footprint

1. Introduction

Carbon dioxide is one of the major components of the earth's atmospheric greenhouse gas that naturally forms to absorb radiating heat. However, the content of carbon dioxide has risen significantly in recent decades, mainly due to the enhancing level of industrial production. Processes involve burning excess of fossil fuels such as coal, oil and natural gas, emitting unprecedentedly large volumes of carbon dioxide into the atmosphere. As a result, too much heat and radiation are trapped in the atmosphere due to the abnormally high content of carbon dioxide. Global warming occurs and is followed by severe climate changes; this is called the greenhouse effect.

The European countries account for 22.3% share of global greenhouse gas emissions, with 49% of the emissions resulting from electricity and heat producers. Top emitters in Europe include Germany, who's responsible of 25% of the EU's total emission, and France, who's responsible of 10.7% of the total emission [1]. Large emitters in Europe such as Germany and France are all known for their advance development of technology and manufacturing. Industries such as car manufactures have high requirements on electricity and machines, contributing the largest to the exacerbating global warming. Comparing to the previous world share of greenhouse gas emission (from 2000 to 2021), the EU share has reduced 18%, to 22.3% in 2022. This disjunctive drop was

due to the efforts to declare relevant policies and transitions of the country's firms' capitals from non-renewable fuels to clean technologies.

This exponential reduction is a result of constant efforts by the European manufacturers taking actions to reduce their carbon footprint which refers to the total amount of greenhouse gases emitted into the atmosphere [2]. Multiple firms started taking actions to innovate on reducing carbon footprint, especially for the energy sector companies that are substantially capital-intensive, acting as the major sources of high carbon emission. Large energy companies in Europe are involving such transitioning costs into the firms' operational cost to develop ways to reduce carbon footprint during the production and transportation processes to minimize carbon emissions. Notably, EU is one of the first economies that started to act upon the green stimulus to improve on reducing carbon emission. This will undoubtedly be a shift for the company to change the original methods of processing on the outputs.

Operational cost is the expenses that support the business to conduct its day-to-day operations. It often includes payroll, rent, utilities, equipment maintenance and funding for research and development. Operational cost is directly related to business's operating efficiency [3]. Thus, it plays an important role in the operation of the companies. It can maintain the efficiency of the current operation and help the companies to identify deviations from it. By looking at the operational cost, it provides possibilities for the companies to improve the current operating efficiency. It is directly related to the profitability of the company as it impacts the business's bottom line. While having the operational cost low, the profit tends to maximize. Essentially operational cost contributes towards the company's decision making.

Operational cost can be affected directly by companies actions on reducing carbon footprint. At the same time, there are other factors that will shift the operational cost when companies adopt environmental strategies. These correlated factors will affect companies' financial performance. In this article, we tend to focus on the energy sectors in the EU after considering the list of contributors to the greenhouse gas emission by industries. The energy industry contributes 73.2% carbon emission [4].

With the aim of providing a more comprehensive understanding of balancing company's environmental performance and operational cost, the article will identify the relationship between reducing carbon footprint and operational cost and how the subfactors caused by this action affect the operational cost in the energy industry. The article will include a general hypothesis regarding the published literature. We will reference the financial reports and companies' sustainability reports of 7 representative European energy companies between 2014 - 2023 for getting the financial performance and annual carbon emissions. Multiple regression will be conducted to find and display the relationship between the carbon emission and operational cost and data will be analyzed. Finally, the evaluation and general conclusion of the work is presented.

2. Background and literature review

2.1. Background information

2.1.1. Events happening between 2014 to 2023

The following table 1 shows the major events happening between 2014 to 2023 that have large impacts on the economy which can potentially affect company's performances.

Table 1. Major events between 2014 - 2023

Year	Event name	Impacts
2014 - 2016	Crude shock	Decline of oil price
2016	OPEC production cut	Reduction in crude oil, resulting some price increase
2020 - 2022	Covid 19 pandemic	Higher cost of raw material and manufacture, unemployment

2.1.2. EU regulations on carbon emission

EU has implemented a comprehensive regulatory framework to reach the goal of net-zero greenhouse gas emissions by 2050. By 2020, EU should reach 20% energy efficiency target. The EU states that, there should be a 55% of net greenhouse gas emissions reduction before 2023 compared to 1990. In the future, EU will set a climate target for 2040 based on the performance and the indicative greenhouse gas budget for 2030-2050.

2.2. Literature review

Cheney and McMillan [5] suggest that companies should reduce their investment in environmental projects as they will increase corporate costs. Rau and Adelman [6] argue that there is a continuous negative relationship between greenhouse gas emissions, specifically sulfur dioxide emissions, and the associated cost. This implies when the companies try to reduce emissions, the cost generally goes up. Huang's [7] study on the abatement cost states there is an opposite relationship between the action of carbon reduction and economic behaviors, suggesting that companies are going to spend money when trying to achieve a reduction in greenhouse gas. Caldeira and Brown [8] also mention fixing climate change-related problems such as emissions can increase the operating costs.

However, Caldeira and Brown also claim that from a long-term perspective, companies should spend money on greenhouse gas regulations to stabilize their future financial situations. This shows that better emission regulation leads to better financial performance in the future. Abba and his colleagues [9] hold the same idea, arguing that poor environmental operation will lead to high overall cost of capital financing. Robaina and Madaleno [10] also revealed a positive relationship between the emission and operating cost by examining the Portuguese companies.

Alvarez, Segura, and Ferrero [11] emphasized the importance of the social background about companies' actions upon reducing emission rates and their operational cost. They specifically focus on the financial crisis in 2008, providing insights into companies' financial performances and actions on environmental protection before and after this period.

There are some research gaps after reviewing all these literatures. The major limits among these investigations are the regional limits, which means that the samples gathered are either from one specific market system of a country or viewing data globally as a whole, little literature appears to include and evaluate one industry, and little connections are depth studies are conducted. Also, there is extensive research on the relationship between financial performance and environmental performance, yet none of the articles we read have focused specifically on finding the relationship between operational cost and carbon emission using data analysis.

3. Conceptual framework and hypothesis

3.1. Conceptual framework

The ways of decreasing pollution can be categorised in two major ways: innovation of technologies and output level cut. The first approach is through innovations on technologies in the factories such as transitioning to renewable technologies with the aim of reducing negative impacts on environment created during the production. The second approach is through decreasing the output, which directly reduces the use of raw materials and industrial processes, reducing the pollutants created during the process.

3.1.1. Abatement cost

The company's spending on reducing negative byproducts during production is called abatement cost, a component of operational cost.

When we look at the abatement cost independently, we hypothesized a negative relationship between the abatement cost and the emission. This means when there is less emission, or more quantity of greenhouse gases being reduced, the companies will spend more money.

By referencing to the nature of the marginal abatement cost curve (a graph demonstrates the relationship between the quantity of carbon reduction and the cost of the price paid for the carbon [12], the cost increases when the quantity of the carbon reduction increases. The left-hand side of the curve presents the most efficient and-cost effective ways to reduce emissions. The methods implemented after the simple ones will be relatively more expensive involving more complex technologies which requires higher investments. Therefore, with more reduction of the emission, there will be less greenhouse gas emission and higher abatement cost.

3.1.2. Output level

The second approach mentioned in previous paragraph states that companies can achieve lower emissions through cutting their production quantities. Output level plays an important role in operational cost. When the output level increases, sometimes the cost per unit decreases due to the economies of scale, but the overall operational cost follows the trend of the output level and sometimes the cost even increases disproportionately with the rise of the output level when it exceeds a certain level [13]. Output acts as the most important subfactor caused by the reduction of the emission.

3.2. Hypothesis

Therefore, summing up the two perspectives, we proposed that there is a negative relationship between the operational cost and the emission with emission has a relatively low impact on the operational cost.

4. Methodology

We composed a regression model to find the relationship between the carbon emission and the opportunity cost. The following formula is our model for the relationship.

Regression Model:

$$OC_{it} = \beta_i + \beta_1 E_{it} + \beta_2 w_{it} + \beta_3 y_{it} + \beta_4 X_i + \varepsilon_{it} \quad (1)$$

Where:

y = annual input prices, in millions of euros

w = annual output level (quantity)

E = the company annual carbon emission, in million tons

X = omitted variable bias (eliminated using the first difference model)

OC = annual total operational cost, in millions of euros

By considering the operational cost component, we included three independent variables in our model. The input prices are represented with 'w' and the output level is represented with 'y'. The amount of carbon emission by the company is represented with 'E'.

We collected data through examining the annual financial report and sustainability report from companies. We covered 7 biggest multinational electricity companies in EU countries who generate and trade electricity globally with 10-year timespan from 2014~2023. These companies are Engie from France, Enel from Italy, E.ON from German, Iberdrola from Spain, Fortum Corp from Finland, Électricité de France (EDF) from France and RWE from German.

Usually, the financial report includes the input prices and output level as well as the operational cost. We looked at the section called 'cost' at first, which generally includes information about input prices and operational cost. The input prices are called "raw materials" or "supplies" in the section. These two are measured with the unit of 'millions of euros'. The output level we are looking for is the electricity production by each company, it can be found in different places in the report when looking at different companies. They are usually included in goals, business highlights, or production sections and measured with terawatt hour (Twh). The sustainability report will cover their annual carbon emission. The emission is measured in the unit of million or metric tons (Mt).

5. Data collection and data analysis

5.1. Data collection

Table 2 records the data for the variables of model (1) by referencing to the annual financial and environmental reports from different energy companies.

Table 2. Variables of the model [14-19]

ID	Year	w (million euro)	y (Twh)	E (Mt)	OC (million euro)
Engie	2014	44155	202.7	131.15	69640
	2015	39308	204	132.76	65646
	2016	36688	245	120.15	62629
	2017	31465	450	89.76	56281
	2018	32190	420	66.12	57381
	2019	NA	420	80	39404
	2020	1112	389	68	34967
	2021	1172	426	65	38861
	2022	1330	421.5	60	74535
	2023	1384	385.5	52	56992

Table 2 (continued)

Enel	2014	23317	283.1	115.5	59809
	2015	22218	284	119.5	60529
	2016	18514	261.8	106.7	55183
	2017	20011	284.8	108.8	59564
	2018	19584	295.4	95	59804
	2019	2755	322	151.5	71360
	2020	3775	298.2	117.5	56985
	2021	3296	119	125	62063
	2022	3646	124	132.9	11484
	2023	2126	207	94.3	67631
E.ON	2014	99916	215	95.7	125698
	2015	104211	202	76.8	134419
	2016	32325	198	82.8	46844
	2017	29788	175	79.2	42194
	2018	22635	134	69.1	41456
	2019	32126	214.1	109.82	44307
	2020	31029	371.1	117.97	43247
	2021	78096	372.8	113.72	113927
	2022	64228	261.7	88.84	189314
	2023	108627	204	70.7	133164
Iberdrola	2014	10600	138	50.21	34683
	2015	5930	137	51.58	30635
	2016	8225	142.47	46.5	27290
	2017	17899.2	137.55	47.6	32271
	2018	19640.7	145.61	62	35001
	2019	NA	151.71	69.76	34288
	2020	NA	162.84	72.73	33863
	2021	NA	164.26	65.9	37588
	2022	33750	163.03	55.7	51926
	2023	26033	168.59	51.63	47973
Fortum Corp	2014	1939	57.7	20.3	4075
	2015	1515	53.6	19.2	3702
	2016	1830	73.1	28.6	3632
	2017	2301	73.2	18.4	4520
	2018	2795	74.6	20.1	4483
	2019	2721	76.3	19.3	8063
	2020	44298	142	48.7	53043
	2021	3419	188	68.7	112301
	2022	5350	44.2	12.05	29598

Table 2 (continued)

EDF	2023	3808	47.0	14.84	11360
	2014	22858	557	428	48043
	2015	38775	618.3	265	64462
	2016	36050	529	292	61151
	2017	32901	182	321	57646
	2018	33012	357	147.5	59753
	2019	35091	557.6	152.3	72283
	2020	32425	501.9	135.3	73521
	2021	17606	360.7	129	28669
	2022	10733	279	120	16538
RWE	2023	12352	320.4	92	36071
	2014	33687	64.8	156.6	49106
	2015	33867	154.9	152.3	53603
	2016	33397	216.1	148.3	55679
	2017	10029	202.2	106	19082
	2018	10357	176	116.9	16594
	2019	9078	153.2	89	39846
	2020	9814	147	68.9	29801
	2021	17758	156	112.3	38113
	2022	31348	157	83	50800
	2023	20154	129	60.6	37438

5.2. Data analysis

We use the regression model to plot a series of graphs for each variable in each company as y-axis, and the timespan of ten years as x-axis. Observing from the table and graphs plotted, we discover a positive correlation between the output level and operational cost and a negative correlation between emission level and operational cost for most cases. The factor “w”, the input prices, has large coefficient and very small p-value, indicating a high statistical significance in our model. In almost every sample, the input prices largely affect the dependent variable (OC) and remain to be a positive relationship with the OC.

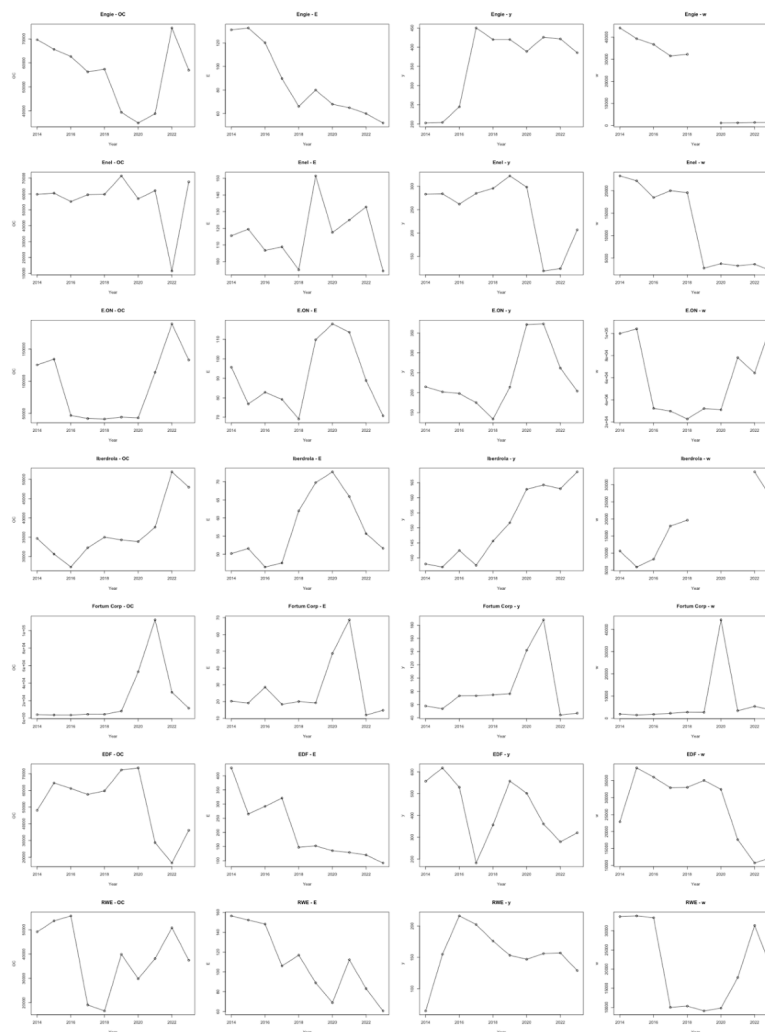


Figure 1. Plotted graph for all companies

Figure 1 is the graph plotted by R after inserting all the data values into the table.

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	9.634e+00	3.480e-01	27.683	< 2e-16	***
E	6.991e-04	1.472e-03	0.475	0.6367	
y	1.909e-03	8.404e-04	2.272	0.0270	*
w	1.841e-05	3.948e-06	4.663	1.97e-05	***

Figure 2. The coefficients for all the variables

Figure 2 are the information about coefficients and special points and statistical information after examining and calculating all the data values input into R.

Among the variables, there are similar trends shared between operational cost and output level. The output level has reached the peak during the years between 2020 to 2022. This is due to the slowdown of the raw material exploitation and finished goods production during the national lockdown of Covid 19 pandemic.

A similar trend can be observed between operational cost and input prices. By examining Figure 2, the operational cost is strongly related to the input prices which are mostly affected by the social events happening during each year. By excluding some of the anomalies, we can discover the input

prices are generally higher between 2016 due to the OPEC production cut. We also observed a small trend of decreasing between 2014 and 2016 indicating the influences of 'crude shock' which the average price of the oil has been lowered thus decreasing the price of the raw materials.

Here are some further explanations of the data we obtained:

5.2.1. Enel

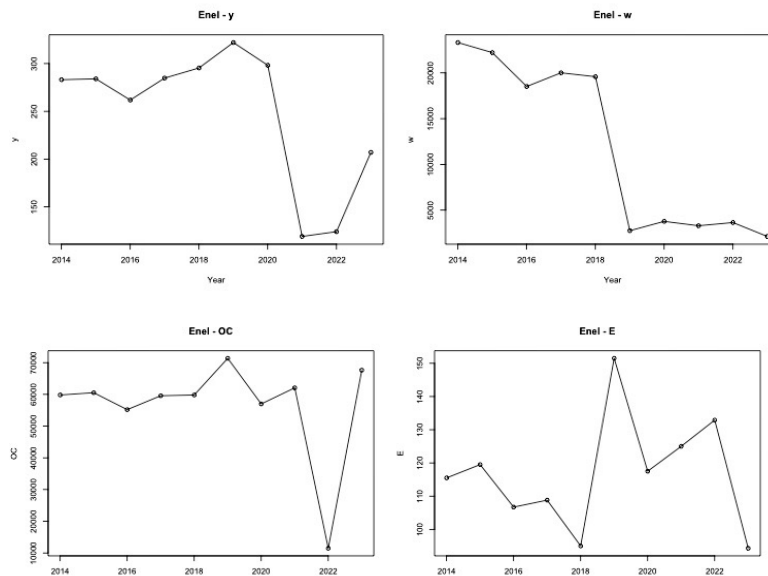


Figure 3. Data analysis of Enel

Figure 3 illustrates the trends of various variables for the company Enel over time

For Enel, from 2014 to 2019, output level remains to be high and constant while emission appears to be decreasing for these years. Emission level bursts from 95 to 151.5 million tons from 2018 to 2019. The operational cost and output level also increase a bit, this is because output level is still playing a major role affecting the operational cost. The slope of the increase in output has a similar increase trend with operational cost. This demonstrates that the two factors are highly proportional. After 2020, the operational cost appeared a small rise from 2020 to 2021 and a steep fall from 2021 to 2022; though from 2020 to 2021 output level also experienced a steep fall, there is a small lift from 2021 to 2022, this doesn't fit with the overall positive correlation between OC and y. This change in OC fits the negative correlation with E, when E rises from 125 to 132 million tons, OC drops from 62063 million to 11484 million euros. The rapid rise later in OC and y is also aligning with a relatively steep drop of E.

5.2.2. EDF

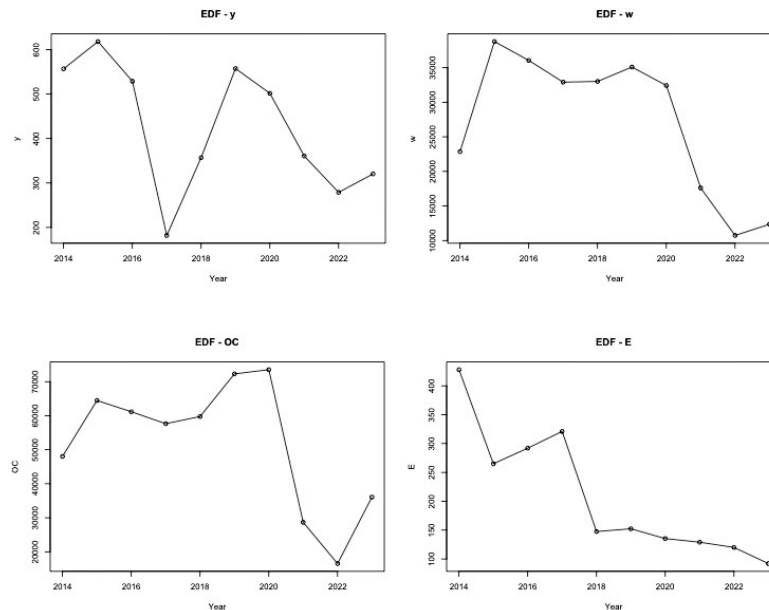


Figure 4. Data analysis of EDF

Figure 4 shows different trends of variables in the model of EDF over time.

For EDF, the OC and E data from 2015 to 2018 remains to be negatively correlated; there's an increase in OC from 2014 to 2015 and a decrease from 2015 to 2017 while it's the vice versa for E. While the y data is not presenting a relationship with OC. OC starts to follow the trend of y after 2020, with a decrease and a slight increase for both. The general shape of w remains aligned with OC.

6. Conclusion

There are some limitations in our model. First, our sample size is relatively small which only contains 7 companies. This is due to the lack of accesses to the resources and lack of carbon disclosure of the companies. Yet, the 7 companies we examined are very representative and important energy companies in the EU. Second, there is not a section called 'input price' in company's financial report. Therefore, we used cost of materials to represent the input price to get its shadow price. Third, the energy output level cannot be easily summarized in a single result due to the different categories of the output. To fix this problem, we choose energy production to represent the output level instead of the quantity of energy transportation.

Yet, we included a long-time span of 10 years and used professional coding languages to analyse the data, increasing the reliability of the result and conclusion.

Overall, the results support our hypothesis with the "Emission" level trending inversely proportional with the total operational cost of the company, meaning lower emission level is aligning with a higher operational cost. At the same time, both input prices and output level have a huge impact on operational cost which fluctuates with the social events happening each year.

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Appendix

Coding of the R studio application. Code:

```

1 file_path <- "/Users/ashley/Desktop/Table1.csv"
2 data <- read.csv(file_path)
3 View(data)
4 plot(data)
5 table(data)
6 summary(data)
7 regression<-lm(OC~E+y+w+as.factor(ID),data=data)
8 summary(regression)
9 regression
10
11 r1 <- lm(log(OC)~E+y+w+as.factor(ID),data=data)
12 summary(r1)
13
14 png("test.png", width=1500,height=2000)
15 par(mfrow=c(7,4), par=c(2,2,2,2))
16 for (i in unique(data$ID)) {
17   for (v in c("OC", "E", "y", "w")) {
18     plot(data[data$ID==i,c("Year",v)], type="o", main=paste(i,"-",v))
19   }
20 }
21 dev.off()
22
23

```