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Article

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The Nexus between Type of Energy Consumed, CO_2 Emissions, and Carbon-related Costs

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ABSTRACT

Reducing carbon emissions while minimizing carbon costs is the main objective of Indonesian carbon management. Using data from 2016, this article focuses on 475 Indonesian manufacturing firms with consumption >6,000 tons of oil equivalent mandated by regulation to reduce their emissions. This study examines the effect of the type of energy consumed on carbon-related costs, with CO_2 emissions as the mediating variable. The study decomposes the type of energy consumed, namely into coal, natural gas, diesel, and electricity. The results show that: (1) Coal, natural gas, diesel, have a positive effect on CO_2 emissions; electricity has a negative effect on CO_2 emissions; (2) electricity, and CO_2 emissions have a negative effect on costs; and (3) CO_2 emissions significantly mediated the effect of coal, natural gas, diesel, and electricity on costs. The findings imply that firms' investment in an efficient machine and technology required to reduce CO_2 emissions, as mandated by the regulation, has seemingly been unable to reduce the CO_2 emissions produced by fossil fuels but has been able to reduce CO_2 emissions from consumed electricity. Moreover, such investment seems able to reduce carbon-related costs. Policymakers should review the Indonesian energy mix from fossil fuels and socialize to firms that using the source of power from electricity is cleaner and cheaper than fossil fuels so that firms may be considered to shift fossil fuels energy into electricity. Hence, the government should ensure the availability of electricity supply generated from cleaner energy sources.

Keywords: CO_2, Costs, Electricity, Energy Management, Fossil Fuels, Path Analysis
JEL Classifications: Q4, Q51, L5

1. INTRODUCTION

It is no longer acceptable to state that in business, a firm can aim solely at maximizing its profits with no associated obligation to consider the impacts arising from its activities. Instead, firms today have to pay increased attention to the environment. In manufacturing firms, fossil fuels are very important concerning the production process. Yet the burning of fossil fuels produces carbon dioxide (CO_2), contributing to global warming, which in turn triggers climate change (Tietenberg and Lewis, 2011). Furthermore, Stern (2006) argued that rising year-on-year energy consumption renders energy efficiency efforts very important. This is also due to the finite and non-renewable nature of the world's fossil fuel resources. The inefficient use of energy results in not only increased energy consumption costs but also an increase in CO_2 emissions. Hatzigeorgiou et al. (2010) suggested that reducing the consumption of fossil fuels and electricity will reduce emissions. Accordingly, the intensity of CO_2 emissions has become one of the important benchmarks for evaluating the environmental performance of a firm's activities (DEFRA, 2006; WBCSD and WRI, 2004).

The immense pressure exerted by the global community to reduce global warming has led to many countries joining schemes aimed at reducing CO_2 emissions. To deal with this pressure, the Indonesian government has imposed regulation on energy management to meet its commitment to reduce its GHG emissions 29% by 2030 under business as usual and 41% with international support

(Direktorat-Jenderal-Pengendalian-Perubahan-Iklim, 2017). The ultimate goal of which is to reduce CO_2 emissions through the active participation of industrial sectors. The regulation obligates firms consuming more than 6,000 tones of equivalent oil, to implement energy management. The regulation has an implication to the targeted firms in which the firms are required to invest in an efficient and environmentally friendly machine. Although this energy management regulation has been in place since 2009, it thus far seems to have failed to produce sufficient impact; as such, the rate of growth in industrial carbon emissions exceeds the rate of industrial growth itself. From 2013 to 2015, the final energy consumption of the Indonesian industrial sector increased by about 5.47%. This increasing growth led to an increase in carbon emissions of 6% over the same period (Pusdatin-Kementerian-ESDM, 2015; 2016). However, the rapid growth in CO_2 emissions did not correspond exactly to the magnitude of industrial sector growth, which stood at around 5.32% (Sekretariat-Jenderal-Kementerian-Perindustrian, 2016).

There is an urgent need to reduce CO_2 emissions; however, Rokhmawati et al. (2018) argued that reducing CO_2 emissions should not result in an erosion of firms' competitiveness. Based on the decoupling framework introduced by Tapio (2005) and Wan et al. (2016), Rokhmawati et al. (2018) suggested that growth in firms' net income should exceed that of their carbon emissions. To reduce CO_2 emissions, firms should not only choose energy that produces low amounts of CO_2 emissions, but they should also consider reducing costs (Lestari et al., 2007). In other words, firms targeted by the Indonesian regulation on energy management that are required to invest in an expensive machine should be able to reduce their emissions as well as to reduce their carbon associated costs. Although choosing a suitable machine powered by a certain type of energy can reduce CO_2 and although, in reducing CO_2, firms should consider carbon-related costs; in practice, very little research has been conducted to examine the relationship between the type of consumed energy, CO_2 emissions, and carbon-related costs. In the context of Indonesia, firms targeted by the energy management regulation are required to make an expensive investment in an efficient and environmentally friendly machine; hence, the success of the investment should be viewed from the firms' ability to reduce their CO_2 emissions and carbon-related costs. The ability to reduce CO_2 emissions can be drawn from the type of firms' energy consumption. Accordingly, firms should be creative in dealing with the mandatory regulation of energy management by effectively utilizing energy sources to reduce CO_2 emissions while also minimizing costs. Hence, it is necessary to know which energy sources produce low CO_2 emissions and are low cost.

Previous research has decoupled the drivers of gross domestic product (GDP) by using the concept of elasticity. Tapio (2005) examined the relationship between GDP, traffic volume, and CO_2 emissions in the EU15 countries from 1970 to 2001. Wan et al. (2016) also used the decoupling framework developed by Tapio to analyze the association between CO_2 emissions and economic growth based on data for the equipment manufacturing industry in China for the period 2000-2014. The study found that industrial carbon emissions were strongly associated with an economic level, and carbon emissions and economic growth were strongly linked to energy consumption intensity. Wang et al. (2018) examined the factors influencing carbon emission reduction in China's transportation sector. The factors identified were the added value of transportation, energy consumption, and per capita carbon emissions. They found that the carbon emission intensity of energy was a significant factor in the reduction of carbon emissions. Madaleno and Moutinho (2018) decomposed the driving factors of carbon emissions. They concluded that rises in income per capita and population increase carbon emissions. Conversely, carbon emissions can be lowered by reducing the carbon intensity of fossil fuels, energy intensity, and enhancing conversion efficiency.

Many studies have been carried out generally using the elasticity framework, with no statistical test to analyze the factors that influence CO_2 emissions and GDP (e.g. Madaleno and Moutinho, 2018; Tapio, 2005; Wan et al., 2016; Wang et al., 2017; Shahbaz et al., 2016; Ahmed et al., 2017). They decomposed carbon emission factors. Furthermore, the existing studies decomposing energies into the type of fossil fuels are implemented in power plants to get an optimum energy diversification (e.g. Costa et al., 2017; de-Llano Paz et al., 2014; Huang and Wu, 2008; Roques et al., 2008). Although the mentioned studies have used carbon emissions and energy intensity, few (if any) have decomposed the energies into the type of fossil fuels and electricity in the manufacturing industry. Indeed, different types of fossil fuels will produce different amounts of CO_2 emissions. If we can identify the energy sources that produce low amounts of CO_2 emissions, firms will then be free to select machines best suited to their manufacturing process. Moreover, the studies of Tapio (2005), Wan et al. (2016), Wang et al. (2017), Madaleno and Moutinho (2018) have connected CO_2 emissions to economic growth or GDP, where GDP is an income-based measurement. Meanwhile, a study conducted by Cadez and Guilding (2017) examined the relationship between costs based on the structure of firms' energy consumption and firms CO_2 emissions. There have been few studies connecting CO_2 emissions to carbon-related costs in which the costs comprise not only fossil fuel and electricity expenses but also the maintenance costs of machines, fines, and interest to capture the firms' stakeholders' response to the firms' carbon strategy. Finally, to our knowledge, there has been no study examining the driving factors of CO_2 emissions and the factors influencing carbon-related costs that combine the two models into a single structure in which CO_2 emissions as a mediating variable. This research will, therefore, seek to bridge the research gap. The study uses path analysis to examine the effect of consumed energy types on CO_2 emissions, analyze the effect of consumed energy types on carbon-related costs, and examine the effect of CO_2 emissions on mediating the relationship between consumed energy types and carbon-related costs. These variables (consumed energy types, CO_2 emissions, and carbon-related costs) are thus the main consideration in this research to accommodate the aim of the Indonesian "Energy Management" regulation; that is, to reduce CO_2 emissions without negatively impacting firms' competitiveness.

The rest of this article proceeds as follows. Section 2 contains material and methods. Then, the theory is presented in Section 3. The results are provided in Section 4, while Section 5 presents discussion of the article. Section 6 provides the conclusions and recommendations.

2. MATERIALS AND METHODS

The increasing integration of climate change mitigation into corporate strategy led to rising attention of scholars. Currently, climate change is a main environmental issue that has been widely addressed in the sustainable development literature (Linnenluecke et al., 2015; Milne and Grubnic, 2011). So far, climate change topics are focused on CO_2 emissions (Hartmann et al., 2013; Lee, 2012). Most studies are concern about the drivers of CO_2 emissions including the consumption of carbon-based resource (MacKenzie, 2009); while, another significant stream is concern about the effect of reducing CO_2 emissions on financial performance. These streams provide important information for firms' management in making decisions on, such as carbon technology investment, energy mix optimization, product pricing to pass the costs of carbon regulation compliance to consumers (Ratnatunga and Balachandran, 2009).

The study examines the effect of consumed energy types on CO_2 emissions, the effect of consumed energy types on carbon-related costs, and the effect of CO_2 emissions on mediating the relationship between consumed energy types and carbon-related costs. The study focused on the variables of consumed energy types as the reflection of firms' investment in technology, CO_2 emissions, and carbon-related costs.

2.1. Type of Consumed Energy

Carbon emissions have been the main issue in sustainability development in recent years. Hoffmann and Busch (2008) and Virtanen et al. (2013) claimed that CO_2 reduction and enhancement of carbon efficiency are the critical factors to maintain long-term development of carbon-intensive firms. Carbon efficiency will reduce costs and it can be improved through lowering carbon pollution (Figge and Hahn, 2013). Further, Tavoni et al. (2012) stated that firms' carbon pollution can be reduced through carbon technology improvement. Carbon technology adoption is reflected from firms' choice on machines in which the machine can be generated with various types of energy sources. Zhang (2000) stated that energy obtained from fossil fuels is highly polluting and is limited in terms of both its availability and sustainability; as such, it is extremely important to both optimize and adjust the type of energy consumed to cut down on energy costs and reduce CO_2 emissions. As a result, optimizing the type of energy consumed allows the industry to reach its desired levels of output at a lower cost and with less pollution (Reddy and Ray, 2010). Concerning Indonesia, insufficient attention has been paid in recent years to renewable energy; as a result, this research focuses on the type of energy consumed from fossil fuels such as energy obtained from burning coal, gas, and diesel, as well as electricity. In this context, the type of energy consumed is measured as the amount of each energy type consumed expressed as a metric unit.

2.2. CO_2 Emissions

More carbon-efficient in production processes is one of the sustainable concerns. Figge and Hahn (2013) stated that minimizing the ratio between CO_2 emissions and a business metric becomes the indicator to measure efficiency. While tons are the unit metric typically to measure CO_2 emissions, business metrics usually are measured in a unit of production, materials usage, sales, profit, and market capitalization (Hoffmann and Busch, 2008). Tang and Luo (2014) argued that the initiative of carbon management at the firm level is urgent to reduce global CO_2 since; such initiatives lead decisions relating to the output volume, capacity levels, and technology. These three factors are believed to be the drivers of CO_2 emissions (Hoffmann and Busch, 2008). The type of carbon-based resource consumed defines the type of emission released (Cadez and Guilding, 2017). Carbon emissions are released from carbon-burning combustion products such as in the burning of fossil fuels and the generation of electricity (Tietenberg and Lewis, 2011). This research measured carbon emissions as CO_2e (equivalent) intensity that is computed as CO_2e divided by firm sales. The CO_2e intensity was used to address the weakness of heterogeneity.

$$CO_2e\,\text{intensity} = \frac{CO_2e\,(\text{Kilogram})}{\text{Sales}} \tag{1}$$

The calculation of CO_2e follows the guidance developed by the Department for Business, Energy, and Industrial Strategy of the UK (Department-for-Business-Energy-and-Industrial-Strategy, 2018). The guidance computes CO_2e from Scope 1, Scope 2, and Scope 3. Scope 1 is direct emissions from activities owned by the firms. Scope 2 is energy indirect emissions released into the atmosphere that are related to firms' purchased electricity. However, this research only included CO_2e from Scope 1 and Scope 2. Scope 3 is excluded because Scope 3 is generated by activities carried out by a firm's contractors and outsourcing, thus meaning that the firm is unable to control these emissions (Department-for-Business-Energy-and-Industrial-Strategy, 2018). In the guidance, each type of fossil fuels is multiplied by a conversion factor. This research covers coal, natural gas, and diesel as well as electricity. Hence, CO_2e in this context is the CO_2e produced from all of these fuels.

$$C = \sum_{i=1}^{n} C_i = \sum_{i=1}^{n} H_i\,\delta_i \tag{2}$$

Where,

C: Carbon emissions from an individual firm

C_i: Carbon emissions produced from burning coal, natural gas, and diesel, as well as electricity

H_i: Energy consumption of energy i

δ_i: Coefficient of carbon emissions from energy i

n: Type of fuels or electricity.

Table 1 provides the GHG conversion factors for firms' reporting. The conversion factors are adopted from the Department for Business, Energy, and Industrial Strategy of the UK (2018).

2.3. Carbon-related Costs

Financial performance can be improved by minimizing costs. Costs can be minimized through a reduction in the economic resources, measured in units of money, that either has occurred, are occurring,

Table 1: GHG conversion factors for firms' reporting

No.	Type of energy sources	Unit	GHG conversion factor Scope 1			$kgCO_2e$
			$kgCO_2$	$kgCH_4$	kgN_2O	
1.	Coal	Tons	2427.5	6.73	18.06	2452.29
2.	Natural gas	Cubic meters	2.04275	0.0027	0.00107	2.04652
3.	Diesel	Liters	2.6502	0.00042	0.03717	3.17799
No.	**Type of energy sources**	**Unit**	**GHG conversion factor Scope 2**			**$kgCO_2e$**
			$kgCO_2$	**$kgCH_4$**	**kgN_2O**	
4.	Electricity	kWh	0.28088	0.00066	0.00153	0.28307

Source: The Department for Business, Energy, and Industrial Strategy of the UK (2018)

or are likely to occur in the achievement of certain goals in a certain period time (Mulyadi, 2010). By considering Instrumental Stakeholder Theory (Jones, 1995), this research measures costs as carbon-related costs. Firms which want to sustain in the long run should consider the concern of stakeholders since stakeholders can make firms difficult to achieve their goal when the stakeholders respond negatively to firms, vice versa. The total costs used in this study include not only fuel and electricity costs but also machine maintenance costs, fines, and interest. The level of fuel and electricity expenses equates to the direct costs of consuming these types of energy. The maintenance costs of machines are those costs arising from the use of machines to support the production process and to meet the requirement of the regulation. Fines were employed to capture the negative response of the government if a firm fails to comply with the regulation. Interest was included to capture the response of lenders to the firm's risk level in respect of whether or not they comply with the regulation. All of these data were provided by an Indonesian Statistics survey that can be accessed by order. The formula for total cost is given as follows:

$$\text{Carbon\_related costs} = \sum_{1=1}^{n} \frac{E_i}{S_i} \tag{3}$$

Where:
i: 1, 2, 3, …. individual firm
E: A firm's costs in the form of fuel and electricity expenses, machine maintenance expenses, fines, and interest.
S: Firm sales.

This research use firm sales as devisor to address the heterogeneity issues of data, meaning that for example, when comparing the data, someone can argue that actually firm A with CO_2 emissions 20,000 kilograms is higher than firm B with CO_2 emissions 200 kilograms, but when firm A can generate sales of $200,000,000, and B can generate sales $20,000, then firm A is more efficient than firm B. Firm A only produce 0.001 kilograms CO_2 for every $1 sale and Firm B produce 0.01 kilogram CO_2 to for every $1 sale.

2.4. Methods

To address the research objectives, this research examined the following four areas: (1) The effect of the type of consumed energy on CO_2 emissions; (2). The effect of the type of consumed energy on carbon-related costs; (3). The effect of CO_2 emissions on carbon-related costs; and (4). The effect of the type of consumed energy on carbon-related costs mediated by CO_2 emissions.

The population of this study comprised all manufacturing firms in Indonesia for the year 2016. The choice of 2016 was made based on the fact that this was the latest year for which new data were available at the time the study was conducted. In selecting the samples, this research used a purposive sampling method based on certain developed criteria. These criteria included the following: The firms were targeted by the Indonesian energy management regulation based on them having an energy consumption equal to or more than 6,000 tons of oil equivalent (TOE) per annum; the firms provided energy consumption data, i.e., coal, natural gas, and diesel as well as electricity; and data were available pertaining to the firms' sales, fuel costs, and electricity expenses, as well as to their machine maintenance expenses, fines, and interest. The data were collected by the Indonesian Statistics Board through a census and the data can be accessed by order.

The study employed path analysis and approached it using Structural Equation Modeling (SEM) with partial least squares (PLS). This kind of regression does not require any classical assumption tests, i.e., linearity, residual normality, heteroskedasticity, multicollinearity, and autocorrelation (Ghozali, 2014). SEM techniques can simultaneously test complex structural models so that the results of path analysis can be executed in one regression analysis. The model of the structure is shown as follows:

$$Z = P_{ZX1}X_1 + P_{ZX2}X_2 + P_{ZX3}X_3 + P_{ZX4}X_4 + \varepsilon_1 \tag{4}$$

$$Y = P_{yX1}X_1 + P_{yX2}X_2 + P_{yX3}X_3 + P_{yX4}X_4 + P_{Zy}Z + \varepsilon_2 \tag{5}$$

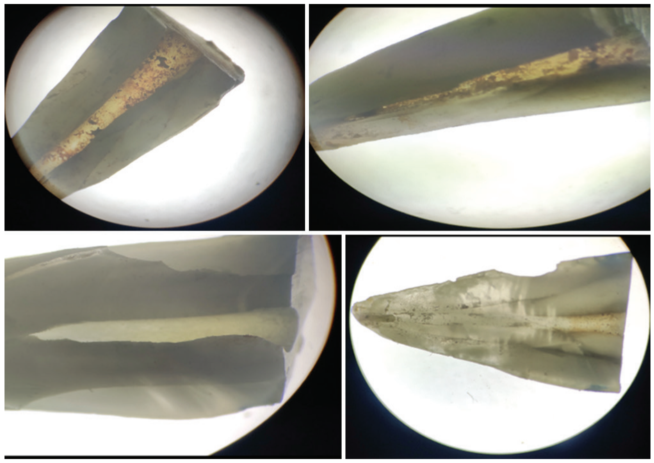
3. THEORY

In this section, the hypothetical relationships between the types of consumed energy and CO_2 emissions and carbon-related costs of firms are described. By drawing upon previous research on carbon emission drivers and firms' competitiveness, this section derives hypotheses for the empirical analysis. The conceptual framework is illustrated in Figure 1.

3.1. Type of Consumed Energy and CO_2 Emissions

According to Hoffmann and Busch (2008), there are three CO_2 drivers, namely the volume of output, production capacity, and technology. CO_2 emissions will increase due to an increase in the number of unit productions; an enlargement of plant capacity; and the choice of technology. Under an environmental regulation such as Indonesian energy management, promoting a decrease in

Figure 1: Path diagram of the causal relationship X_1, X_2, X_3, X_4, to Z and Y



total CO_2 emissions of carbon-intensive firms can be achieved through investment carbon-efficient technology or machines. The choice of technology or machines can be reflected in the type of energy consumed by the chosen machines. Carbon-based resources producing CO_2 emissions during a manufacturing process can be categorized into two types: fossil fuels (e.g. coal, natural gas, and diesel) known as primary energy and electricity known as secondary energy. An important issue relating to the technology reflected from types of consumed energy is the deficiency gap. As complying with environmental regulation, firms are required to invest in carbon-efficient machines or technology; firms may have a different level of carbon intensity. This is because some firms may already invest earlier than other firms. In other words, the different level of carbon-intensity is caused by the diverse starting positions among firms because of past managerial decisions (Berrone et al., 2013). The gap is related to firms working in the conventional carbon standard. Firms which still heavily rely on carbon-intensive technology or machine (Edenhofer et al., 2009), provide lower CO_2 emissions through switching fuels, e.g. natural gas instead of coal (Oliver, 2008) or secondary energy source instead of primary energy. The potential to lower total CO_2 emissions through more efficient use of carbon-based resources can be made through the suitable choice of energy consumed to generate machine in the production process. Hence, it can be drawn a hypothesis that

H_{a1}: Coal, diesel, natural gas and electricity consumed by firms affect CO_2 emissions.

The direction of the relationship is expected to be negative, meaning that the increase in the consumption of the type of energy used will reduce CO_2e intensity.

3.2. Type of Consumed Energy and Carbon-related Costs

The type of consumed fuels may play an important role, since, according to Porter and van der Linde (1995), firms can enhance their competitiveness through the implementation of the least-cost strategy. The type of fossil fuels consumed by firms reflects the chosen carbon technology in its production process. A best suitable technology adopted of firms can allow the firms to reduce their costs. The adopted technology or machine needs a certain energy source to operate the machine. The best suitable type of consumed energy, therefore, becomes important to be considered by firms.

Cost minimization is the main consideration when choosing the type of energy to consume in the course of doing business. Several studies have examined the relationship between energy consumption and costs. Using electricity generation data, Zhang et al. (2007) developed a model to study the impact of different energy efficiencies on external costs under a scenario of environmental abatement policy initiatives. The result showed that the total energy requirement could reduce external costs. Shindell (2015) compared the social costs of burning coal for electricity generation compared to the use of other fuel types for firing generators, with the result showing that coal-fired power exceeded other types of electricity generation in terms of the social costs produced. Based on the description, it can be concluded that

H_{a2}: Coal, diesel, natural gas, and electricity consumed by firms affect carbon-related costs.

The direction of the relationship is expected to be negative, meaning that the increase in the consumption of the type of energy used will reduce carbon-related costs.

3.3. CO_2 Emissions and Carbon-related Costs

Instrumental Stakeholder Theory (Jones, 1995) states that stakeholders play an important role in the success of firms since how they respond to a firm can affect its performance. Hence, paying attention to the interests of stakeholders could ensure the sustainability of the firm. A firm's stakeholders are those individuals or entities that affect or are affected by the decisions taken by that firm. They can be shareholders, creditors, consumers, suppliers, government, society, analysts, and others. A negative response to a firm from its stakeholders will make it difficult for that firm to achieve its objective. The negative response of stakeholders to firms also carries a cost implication. For example, in the context of Indonesia, it is possible for firms to reduce the risks they face by reducing their CO_2 emissions since CO_2 emissions reduction is mandated by regulation for targeted firms. Firms can thus avoid litigation risk, namely the risk of disincentives (lost opportunities to secure fiscal incentives and an obligation to pay fines) from the government if they fail to comply with the regulation. Furthermore, the increasing risks will influence the costs of capital. Commercial banks will require such firms to pay a higher interest rate, which will have the effect of reducing their earnings after tax. Furthermore, equity investors will also require a higher cost of equity because the firm is exposed to greater risk. As a consequence, this will affect the feasibility of the firm's investment. This study uses carbon-related costs to capture whether CO_2 emissions affect direct and indirect costs. Hence, measuring costs covering such as costs of material, labors, and management is not suitable to capture carbon-related costs. According to Instrumental Stakeholder Theory, the costs include fuel and electricity costs, machine maintenance costs to capture the effect of required investment in an efficient and environmentally friendly machine; fines related to environmental violations; and interest to capture the lenders' response to the firms' compliance to reduce their emissions. Based on the description, it can be concluded that if the firms' stakeholders concern about CO_2 emissions, stakeholders will respond negatively to the increase in firms' CO_2 emissions, so that the carbon-related costs will increase. In contrast, stakeholders will respond positively to the decrease in firms' CO_2 emissions, so that the carbon-related costs will decrease. Hence, a hypothesis can be drawn that

H_{a3}: CO_2 emissions affects carbon-related costs.

The expected direction of the relationship is positive meaning that the increase in CO_2 emissions will increase carbon-related costs.

4. RESULTS

4.1. Descriptive Statistics

Descriptive statistics provide an overview or description of the data involved in a study to make the information clearer and easier to understand. This is achieved by identifying the minimum value, maximum value, mean, standard deviation, skewness, and kurtosis (Ghozali, 2014).

Table 2 shows that the number of samples (N) is 475, drawn from Indonesian manufacturing firms consuming more than 6,000 TOE per annum. The minimum value is zero, thus indicating that no firms refrain from the consumption of that type of energy as part of their manufacturing process. The skewness and kurtosis statistics reveal that the data are not normally distributed, thus indicating that the use of linear regression based on ordinary least squares (OLS) was not suitable. Hence, this research used partial least square (PLS).

4.2. Fit Model of the Path Structures

The path structures developed in Equation (4) and Equation (5) were analyzed using WarpPLS. To ensure that the model is fit, we must check the model fit and quality indices from the results provided in Table 3.

The value of Average variance extracted (Solomon et al.) was calculated to check the convergence validity. The AVE value must be >0.50 to meet convergent validity (Ghozali, 2014). The AVE result was >0.50; thus, all of the variables met the requirement of convergence validity.

The value for full collinearity (VIF) was used to check the literal collinearity; that is, to check the collinearity among the predictor (independent) variables. The VIF value is also used to check for common method bias. The requirement is for VIF to be lower than 3.3 (Ghozali, 2014). The result shows that all of the VIF values (1.065) are below 3.3, thus meaning there is no collinearity among the predictor variables.

From Table 3, it can be concluded that all of the indices met the requirement, thus meaning that further analysis, that is, to check the latent coefficient of each variable, can be performed. The results can be seen in Table 4.

From Table 4, we see that the R-squared of CO_2 emissions is 0.177. This means that 17.7% of the variable CO_2 emissions can be explained by the variables of consumption level of coal, natural gas, diesel, and electricity. Furthermore, the R-squared of variable costs is 0.235, which means that variable costs can be explained by the consumption level of coal, natural gas, diesel, electricity, and CO_2 emissions by the amount of 23.5%.

The values for composite reliability and Cronbach's alpha were used to determine the reliability of the research instrument. The instrument is said to be reliable if the composite reliability value exceeds 0.7 and Cronbach's alpha is >0.6 (Ghozali, 2014). Hence, based on the results given in Table 4, the research instrument satisfies the requirement for reliability.

The value of Q-squared was used to check the predictive validity or the relevance of the latent predictor variables against the criterion variable. The value of Q-squared must be greater than zero (Ghozali, 2014). From Table 4, it can be seen that the value of Q-squared is greater than zero; hence, the predictive validity is acceptable.

4.3. Path Model Test

In this study, path analysis was divided into two substructures. The first substructure aimed to analyze the effect of the consumption level of coal, natural gas, diesel, and electricity on CO_2 emissions. Whereas, the second substructure sought to analyze the effect of the consumption level of coal, natural gas, diesel, and electricity, as well as CO_2 emissions, on costs. The following diagram was generated by WarpPLS based on the research data (Figure 2).

Source: WarpPLS output computed based on the research data

4.3.1. First substructure path analysis

The first substructure analyzes the effect of the consumption level of coal, natural gas, diesel, and electricity on CO_2 emissions. The results can be seen in Table 5.

Based on the results given in Table 5, the structural model can be developed as follows:

Table 2: Descriptive statistics

	n	Min	Max	Mean	SD	Skewness		Kurtosis	
						Stat	SE	Stat	SE
Coal	475	0	1079074082	12049329	72271616	11.387	0.112	144.292	0.224
Natural Gas (M^3)	475	0	124873247	821388	6214256	17.281	0.112	337.837	0.224
Diesel (L)	475	0	551684298	5548578	28933542	15.438	0.112	275.671	0.224
Electricity (Kwh)	475	0	4321404713	28138859	204768210	19.649	0.112	410.167	0.224
CO_2e intensity	475	0.00097	1.17324	0.0950050	0.16044015	3.408	0.112	13.796	0.224
Costs (IDR)	475	0.00013	1.00217	0.4992442	0.24865826	−0.168	0.112	−0.762	0.224
Valid N (listwise)	475								

Source: WarpPLS output based on the research data

Table 3: Evaluation of structural models for the inner model

Model fit and quality indices	Index	P-value	Acceptance criteria	Status
Average path coefficient	0.170	P<0.001	P<0.05	Accepted
Average R-squared	0.206	P<0.001	P<0.05	Accepted
Average adjusted R-squared	0.298	P<0.001	P<0.05	Accepted
Average block VIF	1.072		Acceptable if ≤ 5, ideally ≤ 3.3	Ideal
Average full collinearity VIF	1.065		Acceptable if ≤ 5, ideally ≤ 3.3	Ideal
Tenenhaus GoF	0.453		Small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36	Large
Simpson's paradox ratio	1.000		Acceptable if ≥ 0.7, ideally = 1	Accepted
R-squared contribution ratio	1.000		Acceptable if ≥ 0.9, ideally = 1	Accepted
Statistical suppression ratio	1.000		Acceptable if ≥ 0.7	Accepted
Nonlinear bivariate causality direction ratio	0.944		Acceptable if ≥ 0.7	Accepted

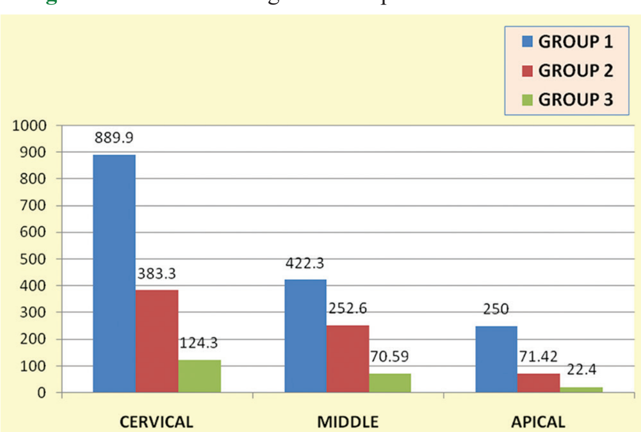
Source: WarpPLS output based on the research data

Table 4: Latent coefficient variables

	Coal (X_1)	Natural gas (X_2)	Diesel (X_3)	Electricity (X_4)	CO_2 emissions (Z)	Costs (Y)
R-squared					0.177	0.235
Adj. R-squared					0.170	0.226
Composite reliab	1.000	1.000	1.000	1.000	1.000	1.000
Cronbach's alpha	1.000	1.000	1.000	1.000	1.000	1.000
Avg. Var. Extrac.	1.000	1.000	1.000	1.000	1.000	1.000
Full. Collin. VIF	1.034	1.002	1.057	1.044	1.155	1.114
Q-squared					0.184	0.212

Source: WarpPLS output based on the research data

Figure 2: Path model diagrams with path coefficient and P-values



$$CO_2\text{emissions} = 0.139\,\text{Coal} + 0.108\,\text{Natural Gas} + 0.340\,\text{Diesel} - 0.141\,\text{Electricity} \quad (6)$$

The coefficients of all variables have a P < 0.05. Furthermore, the consumption levels of coal, natural gas, and diesel, all have a positive and significant effect on CO_2 emissions. The positive effect means that the higher the consumption level, the higher the CO_2 emissions, and vice versa. The consumption level of electricity has a negative and significant effect on CO_2 emissions. This negative effect indicates that the higher the consumption level, the lower the CO_2 emissions, and vice versa.

4.3.2. Second substructure path analysis

The second substructure analyzes the effect of the consumption level of coal, natural gas, diesel, electricity, and CO_2 emissions on costs. Table 5 contains the coefficients for all variables. Based on the results in Table 5, the structural model can be developed as follows:

$$\text{Costs} = -0.018\,\text{Coal} - 0.010\,\text{Natural Gas} - 0.073\,\text{Diesel} - 0.439\,\text{Electricity} - 0.439\,CO_2\text{emission} \quad (7)$$

Looking at the results in Table 5, the coefficients of coal and natural gas have P > 0.05 and their path coefficients are negative. This

Table 5: Path coefficient and P-values

Causal relation	Path coefficient	P-values	Acceptance status
Path coefficient and P-values of first substructure			
Causal relation	**Path coefficient**	**P-values**	**Acceptance status**
Coal => CO_2e	0.139	<0.001	Accepted
Natural gas => CO_2e	0.108	0.004	Accepted
Diesel => CO_2e	0.340	<0.001	Accepted
Electricity => CO_2e	−0.141	<0.001	Accepted
Path coefficient and P-values of second substructure			
Causal relation	**Path coefficient**	**P-values**	**Acceptance status**
Coal => Costs	−0.018	0.332	Rejected
Natural gas => Costs	−0.010	0.403	Rejected
Diesel => Costs	−0.073	0.037	Accepted
Electricity => Costs	−0.266	<0.001	Accepted
CO_2 emissions => Costs	−0.439	<0.001	Accepted
Indirect effects and P-values			
Causal relation	**Indirect effect**	**P-values**	**Acceptance status**
Coal => CO_2 emissions => Costs	−0.061	0.017	Accepted at sig 5%
Natural Gas => CO_2 emissions => Costs	−0.047	0.050	Accepted at sig 10%
Diesel => CO_2 emissions => Costs	−0.149	<0.001	Accepted at sig 5%
Electricity => CO_2 emissions => Costs	0.062	0.016	Accepted at sig 5%

Source: WarpPLS output based on the research data

indicates that the consumptions level of coal and natural gas do not have a significant effect on costs. Furthermore, the coefficients of diesel, electricity, and CO_2 emissions have a $P < 0.05$ and their path coefficients are negative, thus indicating that diesel, electricity, and CO_2 emissions have a negative and significant effect on costs. The negative effect means that the higher the consumption levels of diesel, electricity, and the higher of CO_2 emissions, the lower the costs, and vice versa.

4.3.3. Mediating effect (indirect effect)

The purpose of the mediating effect is to understand how CO_2 emissions mediates the effect of the consumption level of coal, natural gas, diesel, and electricity on costs. Costs in this context are carbon-related costs, including the number of fuel expenses and electricity expenses, the maintenance expenses of machines, fines, and interest. The statistical results are shown in Table 5.

From Table 5, it can be seen that the effect of the consumption level of coal on costs indirectly passes through CO_2 emissions by the amount of −0.061 and with a $P = 0.017$, which is <0.05. Hence, it can be concluded that CO_2 emissions negatively and significantly mediates the effect of the consumption level of coal on costs. In respect of the other variables, the effects of natural gas, and diesel, on costs are all negatively and significantly mediated by CO_2 emissions. Natural gas is significant at the 0.05 significance level. Conversely, the effect of electricity on costs is positively and significantly mediated by CO_2 emissions.

5. DISCUSSION

5.1. The Effect of Coal, Natural Gas, Diesel, and Electricity on CO_2 Emissions

The consumption of coal, natural gas, and diesel has a positive and significant effect on CO_2 emissions. This positive effect means that an increase in the consumption of coal, natural gas, and diesel is followed by an increase in CO_2 emissions. Conversely, a decrease in the consumption level of coal, natural gas, and diesel is followed by a decrease in CO_2 emissions.

In contrast, the result also shows that the consumption level of electricity has a negative effect on CO_2 emissions. This means that an increase in electricity consumption will reduce CO_2 emissions. Electricity is a clean source of energy in comparison to fossil fuels. The negative impact of electricity consumption on CO_2 emissions can be explained as follows. Firstly, the negative impact may be due to the supply of electricity being provided by the state electricity company. Since Indonesia has not developed GHG conversion factors for purchased electricity, this study used GHG conversion factors developed by the Department for Business, Energy, and Industrial Strategy of the UK. Although the GHG conversion factor for purchased electricity has been developed based on the energy mix of the UK electricity generators, the result may not be significantly different from Indonesia energy mix. Since, the Indonesian state electricity company known as PLN, a monopoly company, has been strictly obligated to reduce its dependence on fossil fuels to reduce import as well as PLN are mandated to reach a target of reducing national GHG emission. Consequently, PLN is required to reach a target energy mix that reduces fossil fuel usage and to increase the usage of renewable energy sources. Nevertheless, the result of this research should still be interpreted with caution. PLN should develop a detailed database about energy balance and energy mix so that enables scholars to develop emission conversion factor from purchased electricity that best suitable for Indonesia condition. Furthermore, to ensure the carbon emission factor low, PLN should achieve the target of the energy mix that adds renewable energy in a higher proportion than before. Nevertheless, PLN should still consider the costs of generating electricity since renewable energy generators are much more expensive than the traditional one.

Secondly, According to Hoffmann and Busch (2008), there are three drivers of CO_2 emissions, namely output volume, capacity level, and technology. When the number of outputs increases, firms need more energy. Accordingly, CO_2 emissions will increase. The relationship should be positive but the statistical result is negative. The negative impact of the result is as predicted if firms implemented carbon-efficient technology. In this case, CO_2 emissions produced by firms are from purchased electricity. Hence, it implies that the PLN has already shifted its energy mix by reducing fossil fuels to less carbon energy sources as mandated by the Indonesian Regulation No. 79/2014 about "Energy Management."' By 2025, PLN is mandated to provide electricity per capita equal to 2,500 kWh that is equal to 400 billion TOE in which the target should be met from the energy mix of oil (25%), natural gas (22%), coal (30%) and renewable energy (23%) (Sekretariat-Kabinet-RI, 2014). Furthermore, the research measures CO_2 emissions as CO_2e per sales. It indicated that the level of production and sales increases the consumption of electricity also increases but the increase in electricity consumption is lower than the increase in CO_2e per sales.

Conversely, coal, natural gas, and diesel have a positive effect on CO_2 emissions. It may be explained as follows. Firstly, coal, natural gas, and diesel are produced from fossil fuels and these characteristically produce high volumes of CO_2 emissions. Taking the emission factor of each fuel types provided in Table 1, coal is the dirtiest source, followed by natural gas, diesel, and electricity. Hence, an increase in fossil fuel consumption will increase CO_2 emissions.

Secondly, an increase in the consumption level of fossil fuels produces an increase in CO_2e intensity per sales. The result implies that firms may have been inefficient in their implementation of the required energy management measures; as such, they are producing a greater level of CO_2e than they are offsetting via the saving on fossil fuels through the use of more environmentally friendly and efficient machines. It may also imply that many firms have yet to invest in such machines.

From the explanation, it can be concluded that the mentioned energy types are not environmentally friendly. The firms that made up the sample all consumed more than 6,000 TOE per annum, which means they were the target of the regulation obliging firms to conduct energy management. In this regard, it would not be unreasonable to assume that those firms had invested in environmentally friendly and efficient machines and technologies. However, the statistical results show that there was an increase in CO_2e intensity per sales when fossil fuel consumption increased. This implies that these types of fossil fuels should not be burned without the application of any prior treatment. Coal, for example, will produce fewer CO_2 emissions if it is first treated using a liquefaction or purification process (Pusdatin-Kementerian-ESDM, 2017). In contrast, the result also shows that the consumption level of electricity has a negative effect on CO_2 emissions, meaning that an increase in electricity consumption will reduce CO_2e intensity per sales. Furthermore, fossil fuels are a dirty source of energy; hence, if firms wish to continue using them, then a shift from using coal to natural gas would help them to reduce CO_2 emissions, although a much better solution would be to replace fossil fuels with electricity generated from renewable energy sources.

This finding has an implication for policy. Although regulation to reduce CO_2 emissions by investing in efficient machines may reduce the consumption level of fossil fuels, an increase in the scale of production leads to an increase in CO_2e per sales. Hence, for as long as they continue to consume fossil fuels, firms' investments in environmentally friendly and efficient machines and technologies are not sufficient to reduce CO_2 emissions due to the inherently high emission factor that is a characteristic of fossil fuels. The regulation should thus focus on a shift from the consumption of fossil fuels (as dirty fuels) to increased consumption of electricity that is generated from cleaner energies from renewable sources, i.e., wind, solar, hydro, nuclear, and bioenergy.

5.2. The Effect of Coal, Natural Gas, Diesel, Electricity, and CO_2 Emissions on Costs

The consumption of diesel and electricity has a negative and significant effect on total costs. This negative effect means that an increase in the consumption of fuel will reduce costs per sales. Costs in this research refer to carbon-related costs that include fuel and electricity expenses, machine maintenance expenses, interest, and fine related to the environmental violation. We can point to various potential reasons for the negative effect of these fuels on costs. Firstly, the firms may have invested in an efficient machine to enable them to reduce costs. Furthermore, firms may appear to function at such an economic scale to enable them to achieve a minimum cost per sales. Secondly, to a certain degree, the Indonesian government continues to subsidize fossil fuels, thus helping firms to reduce their fuel costs. Thirdly, stakeholders have not assessed risk based on the firms' fuel consumption, wherein the fuel consumption level will affect how the stakeholders respond to the firms' efficiency and CO_2 pollution. For example, lenders, as one of a firm's stakeholder groups, will assess the risk level facing the firm when considering whether or not to provide financing. If lenders do not consider the firm's level of fossil fuel consumption to be an exposure to risk, they will not include this type of risk when assessing the costs of capital, which means that the interest will remain at a lower level.

CO_2 emissions also has a negative and significant effect on costs. The negative impact of CO_2 emissions on costs means that an increase in CO_2 emissions will lead to a decrease in costs per sales. The negative impact may be caused, firstly, because firms' CO_2 emission figures are not publicly available, meaning that stakeholders have not noticed the issue. For example, a bank is the main stakeholder providing finance for firms. If the bank does not consider CO_2 emissions to be a risk exposure, then it will not consider that risk when calculating the interest rate to charge to firms. Hence, firms with both high and low CO_2 emissions are deemed to face the same level of risk. Banks seem to be interested only in firms' profitability; thus, as long as firms can pay their liabilities, the banks will be happy. Secondly, customers have not responded to the issue of CO_2 emissions produced by firms. They do not appear to be interested in firms' CO_2 emission levels, which is most likely due to a lack of awareness surrounding the impacts of climate change. Customers are thus unlikely to focus on how a product comes to be provided at a low price as Indonesian people are mostly yet to pay full attention to environmental issues. They prefer to focus on products with low costs than being concerned with favorable environment impacts (Rokhmawati and Gunardi, 2017) due to their low annual income levels of around \$3,540. This amount is far lower than the incomes found in developed countries, with the annual average income in the US standing at \$58,270, Germany \$43,490, and Australia \$51,360 (World-Data, 2015). Thirdly, investment in an efficient machine seems to have had an impact on costs per sales but not on CO_2e per sales. Firms have been able to reduce their costs per sales but not their CO_2e per sales. This result is in line with that obtained by Rokhmawati et al. (2018), who asserted that while some firms have effectively implemented the regulation on energy management, others have not been able to improve their competitiveness. As such, some firms have been able to improve their competitiveness while reducing their CO_2e per sales and others have not; in this respect, the unsuccessful firms outnumber the successful ones (Rokhmawati et al., 2018). Hence, the finding of this research can be concluded that investment in efficient machines and technology is able to reduce costs but is not able to reduce CO_2e per sales, thus indicating that a reduction of fossil fuel use is important to reduce CO_2 emissions. In terms of policy formulation, the Indonesian government should review the possibility of firms to use electricity generated from cleaner energy sources.

5.3. The Effect of Coal, Natural Gas, Diesel, and Electricity on Costs Mediated by CO_2 Emissions

The results showed that the estimation of CO_2e per sales negatively and significantly mediated the effect of the consumption levels of coal, natural gas, and diesel, on costs. This means that an increase in the consumption level of coal, natural gas, and diesel will increase CO_2e per sales but reduce costs per sales. The results show that an increase in CO_2e per sales will reduce carbon-related costs per sales. We can outline the following as potential reasons for this.

Firstly, fossil fuels inherently produce high amounts of CO_2 emissions, which means that consuming large quantities of fossil fuels will also increase the CO_2e per sales; thus, even if firms have already made investments in environmentally friendly and efficient machines, the increase in fossil fuel consumption still increases CO_2e per sales. This finding implies that the Indonesian government should consider reducing fossil fuels and promoting the usage of electricity generated from cleaner energy sources such as solar, wind, hydro, biomass, geothermal, and nuclear energies.

Secondly, a rise in fossil fuel consumption will increase CO_2e per sales and decrease carbon-related costs per sales. Cadez and Guilding (2017) suggested that the capacity level is the driver of carbon-based resource consumption. The costs are largely fixed within a relevant range so that the cost per unit will reduce. This indicates that firms may work on an economic scale. A large number of units produced will reduce the cost per sales. It might thus be possible for the cost increase to be covered by the increased saving due to efficiency.

Thirdly, stakeholders have not yet responded to firms' fossil fuel consumption levels, or their CO_2 emissions, since firms have not publicly reported their energy consumption and production of CO_2 emissions. Hence, stakeholders have not noticed that some firms may be producing larger quantities of CO_2 emissions, whereby CO_2 emissions is a leading cause of climate change. According to Instrumental Stakeholder Theory (Jones, 1995), stakeholders will respond negatively to firms if the latter ignore their interests; conversely, they will respond to firms positively if they address their interests. Positive stakeholder responses will make it easy for firms to achieve their goals since positive responses can signal opportunities or the potential for cost reduction. In contrast, negative stakeholder responses will make it difficult for firms to achieve their goals since such negative responses typically mean costs will be incurred. Investors and lenders will respond negatively if firms are perceived as having increased their exposure to risk. Such an increase in firm risk signifies that lenders will increase their required rate of interest and equity investors will raise the cost of equity, which will affect the firms' cost of capital. An increase in the cost of debt will reduce earnings after tax, while an increase in the cost of both debt and equity will affect the feasibility of investment. To reduce the information asymmetry between investors as well as lenders and the management teams of firms, the firms should, therefore, look to report the information on energy management as required by the regulation. Such disclosure of the management energy report will provide a fair assessment of a firm's risk level.

In contrast, CO_2e per sales negatively and significantly mediated the effect of electricity consumption on costs per sales. This means that an increase in the consumption of electricity will reduce CO_2e per sales and reduce costs per sales. This result indicates that among the sources of energy used in this research, it is only electricity that has a negative effect on CO_2e per sales and costs per sales. This implies that electricity is the cleanest source of energy for firms and is also low cost. Furthermore, in terms of maintenance expenses, firms have lower costs because such firms purchase electricity from PLN. Therefore, the government should encourage firms to shift from using fossil fuels to electricity while also ensuring the availability and sustainability of the electricity supply. Nevertheless, PLN should provide electricity generated from cleaner energy sources so that the problem of shifting CO_2 emission from carbon-intensive firms to the electricity supplier (PLN) can be avoided. Furthermore, to reduce the dependency on fossil fuels, of which Indonesia is still an importer, a shift from fossil fuels to the types of renewable energy that are available in abundance in Indonesia becomes an important consideration.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Based on the results, it can be concluded that all of the fossil fuels examined in this research (coal, natural gas, and diesel) have a positive and significant effect on CO_2e per sales. In contrast, electricity has a negative and significant effect on CO_2e per sales. This implies that fossil fuels are a dirty source of energy and thus their consumption is not recommended to reduce CO_2 emissions. In contrast, electricity is a clean form of energy, the consumption of which is recommended to reduce CO_2 emissions. This implies that investment made by firms in environmentally friendly, efficient machines and technologies has not been able to reduce

CO_2e per sales. The implication of this result is that to reduce CO_2 emissions, the government should encourage firms to treat fossil fuels before they are burnt. The government should consider the possibility of firms to shift their energy consumption away from fossil fuels and toward electricity.

Furthermore, coal, natural gas, diesel, electricity, and CO_2 emissions have a negative and significant effect on carbon-related costs. This means that increased consumption of these fossil fuel types and electricity will reduce costs. It indicates that firms' investment in an efficient machine and technology has likely been able to reduce costs. In terms of reducing costs, consuming fossil fuels, particularly coal, natural gas, and diesel, as well as electricity, is efficient. Hence, firms should consider electricity as their source of energy since it offers the ability to reduce both CO_2 emissions and costs. Moreover, CO_2 emissions has a negative and significant effect on costs, which means that an increase in CO_2 emissions will reduce costs. Likely, stakeholders have not responded to this increase in CO_2 emissions.

CO_2 emissions was found to negatively and significantly mediate the effect of fossil fuels and electricity on costs. Fossil fuels have a positive impact on CO_2 emissions and a negative impact on costs. In contrast, electricity has a negative impact on CO_2 emissions and a negative impact on costs. This means that electricity is the only source of energy that is both clean and reduces costs. Hence, if firms want to reduce both CO_2 emissions and costs, they should increase their use of electricity while reducing that of fossil fuels. This result also has an implication for the government; that is, to ensure the availability and sustainability of the electricity supply that the generators should be from a clean source of energy.

6.2. Recommendations

The findings of the present research have an implication for practice, namely that to reduce CO_2 emissions and costs, firms should consider shifting from the use of fossil fuels to electricity. As an implication for policy, the government should encourage firms to publish data on their energy management performance so that their stakeholders can assess the firms' risk level. Hence, they can assess the fair cost of capital. The government should also encourage firms to reduce their consumption of fossil fuels and replace them with electricity; the government should thus seek to ensure there is an abundant and sustainable supply of electricity that is generated from cleaner sources of energy. For future research, it may be interesting to include renewable energy if the relevant data are available as renewable energies enable a reduction in CO_2 emissions in addition to being sustainable. Moreover, the technology of renewable energy generators also have implication to generating costs; it would be interesting if future research can find a result of what type of energy sources that can reduce CO_2 emissions and reduce carbon-related costs. It would also be useful for future research to consider the amount of investment included in the research model. If the data are available, it may be useful to determine the energy portfolio that minimizes costs while considering the agenda of CO_2 emission reduction. Furthermore, it is recommended to use time-series data to understand the trends.

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