JEE 11 (2) 2022 : 420-436

Journal of Economic Education

http://journal.unnes.ac.id/sju/index.php/jeec

The Impact of Fuel Price on Energy Consumption on Indonesia's Industries: A Firm-Level Analysis

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Article Info

Article History :
Received December 2021
Accepted March 202
Published June 2022

Keywords:
oil elasticity, coal elasticity, Indonesia manufacture

Abstract

This study aims to investigate the effect of energy price changes on energy consumption, especially oil and coal, for Indonesian manufacturing sectors. Unbalanced panel data analysis is utilized on firm-level data from 2003 to 2015 to examine the price elasticity of oil and coal demand. The estimation indicates that Indonesia's manufacturing sectors are sensitive to energy price. On the aggregate analysis, one percent oil price increase is significant to reduce the demand of 0.194 percent, while coal consumption is not significantly affected by its price. Coal regression illustrates different outcomes than oil estimation which shows a positive relationship between coal price and coal demand even though it is insignificant. This phenomenon can be possibly interpreted through several explanations: a small number of firms using coal, concentration of coal demand in a few sub-sectors, and meager price of coal relative to oil. For further understanding, sectoral analysis has been examined on five priority sub-sectors—food and beverage; textile, apparel and footwear; chemicals and pharmacy; electronics and optical device; and automotive and transport equipment. The sectoral evaluations suggest that price elasticity for oil demand is considered as inelastic, ranging from 0.184 to 0.387 in absolute value. Oil price changes have the most impact on textile, apparel, and footwear sub-sectors, while food and beverage is the most unaffected by oil shocks.

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p-ISSN 2301-7341
e-ISSN 2502-4485

INTRODUCTION

Energy prices, especially oil price, has been volatile since several decades. Increasing and decreasing oil prices have been interpreted in different ways. Historically, the rise of oil price, commonly described as oil shocks, has been acknowledged as being unfavorable to the economy (Hamilton, 1996; Lee & Ni, 2002; Rotemberg & Woodford, 1996), while the price drop offers the opposite effect.

Globally, the industrial sector dominantly consumes the amount of energy compared to all other end-use sectors (Abdelaziz, Saidur, & Mekhilef, 2011), and in the last decade, the Indonesian industrial sector is in accordance with the finding that it absorbs about 39% on yearly average on total national energy consumption (Ministry of Energy and Mineral Resources, 2018). Moreover, in the last 10 years, on average, the Indonesian industrial sector's share of energy consumption was dominated by oil at 32.9%, followed by gas, coal, and biomass at 31.3%, 23.7%, and 11.8%, respectively.

The effects of energy price changes in economics have been studied since the first OPEC oil embargo by its Arab members to the United States in the early 1970s. Research in this field has increased after the oil boom in the late 1970s (Lee & Ni, 2002). Most of them investigated the macroeconomic effects of oil shocks on a country or the microeconomics impact of a household or an individual. In the industrial sector, energy is considered as an intermediate output, and the increase in energy price influences production cost. This relationship is expected to affect the aggregate economy at the country or industry level as well as at the firm level.

However, few studies have been made to explore the effect of energy prices on its consumption on the industrial sectors in Indonesia. Furthermore, existing studies mostly focused on the industrial aggregate level despite the firm level.

This research investigates how energy price changes affects a firm's demand for energy and analyzes the price elasticity of demand for energy. Moreover, this study suggests a hypothesis that energy price changes affect the firm's consumption for energy and the increase in energy prices have a negative relationship with the firm's use for energy.

In an effort to shed light on energy consumption by industries, this research examines the relationship between energy price and energy consumption on a firm- level analysis. The short-run price elasticity of energy on a firm is reviewed. Furthermore, sub-sector estimations are performed in order to deepen the analysis. This study focuses on Indonesia's five priority industry sub-sectors based on the National Industry Development Masterplan 2015–2035, namely food and beverage, textile, apparel and footwear, chemicals and pharmacy, electronics and optical device, and automotive and transport equipment. Unbalanced panel regression is applied on medium- and large-sized industry statistics for the 13-year period 2003– 2015 to identify how energy price is associated with energy consumption. The estimation results argue that a positive relationship exists between energy price and energy consumption on a firm. Insights into this relationship can assist the policymakers in determining appropriate steps to maintain sustainable industry growth, encourage intensifying firm's energy efficiency, and enhance the utilization of clean energy.

There is literature concerning the determinants of energy consumption on industry issues. Some researches examine industrial output as a factor affecting energy demand in the industry (Zhao & Wu, 2007; Ziramba, 2009). Meanwhile, Zhao and Wu (2007) also suggest that energy production, especially from domestic resources, matters in determining the industry demand. Others argue that it is essential to measure the scale of economic activities in determining the industry's consumption of energy (Agnolucci, De Lipsis, & Arvanitopoulos, 2017; Lin & Chen, 2019). Moreover, Lin and Chen (2019) specifically emphasize that infrastructure development, as an essential element of economic activities, is responsible for influencing energy demand in industries. Additionally, the availability of other alternative resources of specific energy is also another factor that is analyzed with respect to energy demand (Sarkodie & Adom, 2018).

Concurrently, various studies assume energy price as the main determinant regarding industrial energy demand, even though others suggest that price is unrecognized as an essential factor affecting energy demand. Pindyck (1978) observed that energy demand was likely affected by its price. Moreover, this argument was followed by many studies in the last decade that underline price as the prominent consideration while estimating industrial energy consumption (Agnolucci, 2009; Andersen, Nilsen, & Tveteras, 2011; Bjørner & Jensen, 2002; Dasgupta & Roy, 2015; Hill & Cao, 2013; Polemis, 2007). However, Zhao and Wu (2007), in their research on China, stated that energy price is not regarded as a primary factor affecting energy demand.

The link between energy price and its demand can be connected through the elasticity theory. Literature on price elasticity for energy focuses on two analysis levels—the aggregate level and individual level. On the aggregate level, it usually examines the country or industry demand as a whole entity. On the other hand, individual or disaggregate level puts the spotlight on examining households in a population or a firm in an industry.

Several aggregate demand studies have explored how energy consumption is influenced by price, with some emphasizing elasticity. Burke and Yang (2016), using natural gas consumption and prices on national-level data of 44 countries from the International Energy Agency (IEA), found that energy price influences the consumption amount. The aggregate elasticity of demand that was calculated by Burke and Yang (2016) is recognized as elastic on around -1.25. It is investigated to be more elastic than several previous research such as a study of price elasticity for natural gas of -0.9 in 60 countries from the 1980 International Comparison Project data (Brenton, 1997) and a price elasticity of -1.1 on aggregate for the world as a whole data by applying the cointegration analysis for 1973–1999 (Krichene, 2002). A study from Carfora, Pansini, and Scandurra (2019) on the relationship between energy prices and energy consumption in four Asian developing countries (India, Indonesia, Philippines, and Thailand) from 1971–2015 indicates that some bidirectional causal relationship between them have emerged. This result is the improvement and replication of prior research by Asafu-Adjaye (2000) that indicates a similar finding that energy and its price have mutual causal relationship in Philippines and Thailand but remained unobserved in India and Indonesia.

Furthermore, the study on aggregate elasticity is also quite much tested on various energy resources, one of them being coal. Burke and Liao (2015) examined the price elasticity of demand for coal in China, where half of the global coal consumption exists. In a 1998–2012 province-level analysis, Burke and Liao (2015) suggested that coal prices mattered to its consumption and found that in 2012, a 1% rise in coal prices led to a decrease in its demand of 0.3–0.7%, which was an increase from the prior years. There are also several studies on the relationship between energy prices, energy consumption, and elasticity regarding coal demand in China even though the analysis level, methods, and findings are diverse. Chan and Lee (1997) evaluated the long-run coal price elasticity of -0.7 to -0.9 when the 1953–1990 data in China was employed. Moreover, exploring the 1985–2004 China National data, Hang and Tu (2007) found that coal price elasticity of demand before 1995 calculated at around -0.3 and increased after 1995 to about -1.6.

The economic literature of aggregate price elasticity also holds concern on an industry level, which can deliver a more comprehensive range of understanding on the relationship between price and energy amount demanded. Lee and Ni (2002) argued that industries have a different response for the oil price fluctuations, and the oil price increase, commonly described as oil shocks, decrease the supply of oil for a significant cost share of oil industry such as chemicals and petroleum industry. On the other hand, oil shocks typically lessen oil demand for many other industrial sectors, especially the automobile industry (Lee & Ni, 2002).

Following Lee and Ni (2002), other studies have also focused on the elasticity of energy on the industry level concerning energy price. Agnolucci (2009), Andersen et al. (2011), and Dasgupta and Roy (2015) examined the responsiveness on energy consumption for energy prices. Agnolucci (2009), using industry sub- sectors in Germany and the UK in 1991–2004 data, showed that a negative elasticity of demand exists on -0.64. Meanwhile, a study on several OECD countries from 1978 to 2003 indicates that, in sub-sectors manufacture estimation, the price of demand elasticity varies from -0.06 to 0.6 (Andersen et al., 2011). Similarly, Dasgupta and Roy (2015) argued that the manufacturing sector in India, during 1973/74 to 2011/12 had a negative price elasticity of energy demand ranging at - 0.14 to -1.36.

The paper is organized as follows. The following section describes the literature review of energy price impact on energy consumption. Section three introduces the methodology and data being utilized in the research. Section four combines the estimation results and discussion for overall and sub-sector analysis. Finally, the concluding section presents the summary and policy recommendations.

RESEARCH METHODS

The primary analytical framework in this paper is an economic approach termed price elasticity. According to the economic theory, energy demand will decrease when the energy price increases and vice versa. The sensitivity and responsiveness to price changes can be assessed by the coefficient of price elasticity of demand which can be derived from estimating the percentage change in quantity demanded divided by the percentage change in price while all the other determinants of demand are held constant. In general, when the price elasticity of goods (in this case energy) shows a value of more than 1, the demand for goods is considered to be elastic where the number of goods demanded is strongly influenced by the price. Meanwhile, goods with an elasticity value of less than one are recognized as inelastic goods, which means the influence of the price on the demanded amount is not immensely significant.

Mathematically, price elasticity of demand (εp) is the percentage change of quantity demanded divided by percentage change of price; thus, it can be written as:

$$\varepsilon\varepsilon_{pp} = (\%\Delta QQ)/(\%\Delta PP)$$

$$\Delta QQ/QQ = \Delta PP/PP$$

Where ΔQ is the change of quantity demanded, and ΔP is the change in price.

Where

Price elasticity of demand theory stated that the quantity of goods demanded by a firm, in this case, energy, is a function of energy price. In order to obtain the objectives of this study, constant elastic demand function is utilized (Simon & Blume, 1994), and the model can be described as follows:

$$EE = kkPP^{\varepsilon\varepsilon}$$

Where E is the firm's energy consumption, P is energy price, k and ε are parameters. Taking the logarithmic transformation of both sides, the model turns into linear in parameter with the slope is elasticity ε.

$$\ln EE = \ln kk + \varepsilon\varepsilon \ln PP$$

Considering the characteristic divergence of each firm, some firms' characteristic variables are examined. A firm's production as a proxy of a firm's income is taken into consideration (Hill & Cao, 2013). The firm's size is often reviewed in an empirical estimation involving the firm as a subject (Andersen et al., 2011). To control the price variable, the real exchange rate is also analyzed.

Therefore, the equation above becomes

$$\ln EE = \ln kk + \varepsilon\varepsilon \ln PP + \sum_{mm} \alpha\alpha_{mm} FFFF + \sum_{nn} \alpha\alpha_{nn} PPFF$$

Where FC is the firm characteristic variable that include the firm's production (*production*) and the firm's size (*size*). PC is the price control variable, and in this research, the real exchange rate (*rer*) is used. This research also generates the estimation for sectoral analysis by using a dummy variable *sector*. By replacing E with *enuse*, P with *enprice*, ln k with α0, and ε with α1, the equation above can be rewritten and rearranged as:

$$\ln eeeeeeeeee_{ii,jj,tt} = \alpha\alpha_0 + \alpha\alpha_1 \ln eeeeeeeeeeeeee_{ii,tt} + \alpha\alpha_2 \ln eeeeee_{tt} + \alpha\alpha_3 \ln eeeeppppeeeeppeeppee_{jj,tt} + \alpha\alpha_4 \ln eeeessee_{jj,tt} + \delta\delta_5 eeeeeeppppee_{jj} + \epsilon\epsilon_{ii,jj,tt}$$

enuse	quantity of energy i (oiluse for oil and coaluse for coal) used by firm j at year t
enprice	price of energy i (oilprice for oil and coalprice for coal) at year t
rer	real exchange rate at year t
production	value of total production of firm j at year t
size	number of workers of firm j at year t
sector	dummy industry sector
i	oil, coal
ϵ	error term

Ordinary Least Squares (OLS) regression is used to measure the firm's energy consumption regarding the changes in explanatory variables, especially energy prices. The unbalanced panel estimation is applied, and it considers the firm fixed effect and the year fixed effect. This research also adopts log-log models to construct the parameters into the linear models; thus, the regression coefficients can be directly interpreted as elasticity (Wooldridge, 2012). The regression will be employed on different firms based on energy types. The analysis was also conducted on two different levels—aggregate on the national level and disaggregate on the sectoral analysis.

Data for this study covers the period 2003–2015. The firm's energy consumption, production, and size data come from Annual Manufacturing Survey data by Statistics Indonesia (BPS). The annual survey composes information collected from medium- and large-scale manufacturing companies around the country. The survey portrays the firm's energy consumption by each energy resources, and each of them is broken into two separate components—quantity in the standard metric unit (liter or kilogram) and value in Rupiah. Energy consumption in the metric standard unit data is used in this study. The firm's production is measured by the sum of three components—the value of goods produced, domestic and foreign manufacturing services received, and other production activities such as the sale of unprocessed goods, non-manufacturing services, and sale of scrap waste.

The energy prices data are taken from the Annual Handbook of Energy and Economic Statistics of Indonesia by the Ministry of Energy and Mineral Resources. The energy price indicates the annual average price of each energy resource, and this research focuses on oil and coal because of the availability of the data. All of the data that contain Rupiah is deflated into the constant price on the base year 2010. The final dataset consists of 263,749 observations from all over the research period. Specifically, this research embellishes the literature by performing sub- sectors analysis in Indonesian manufacture. The study focuses on several priority sub-sectors, based on the Government Regulation No. 14/2015 about National Industry Development Masterplan 2015–2035. The sectoral analysis is worthwhile in assessing specific sub-sectors, whether it is prone to an energy price increase or it has low sensitiveness and responsiveness to the energy price shock.

RESULTS AND DISCUSSION

In this section, the result for each regression that consists of coefficient estimates, the level of statistical significance (p-value), the adjusted-R^2 value, and the number of observations is reported. The results present the calculation outcome into two different parts—aggregate on all the industries and sub-sector priority industries. Moreover, each part consists of two issues—oil and coal elasticity. However, this section starts with a concise overview of energy consumption in Indonesian industries.

In Indonesia, the final energy demand calculation is measured by categorizing the consumer into several main actors, i.e., household, industry, commercial, and transportation. According to the Ministry of Energy and Mineral

Resources (2018), in the last decade, as shown in Figure 1, the industrial sector shows a declining trend on energy consumption share although every year, it consumes at least around one-third of the total share. Moreover, in 2007, almost half of the total energy share was employed by the industrial sector, whereas the remaining portion was left to only about 30% in 2017. This condition is not compelled by the decrease in energy demand in the industry sector, yet the rise of energy consumption for transportation is rapid.

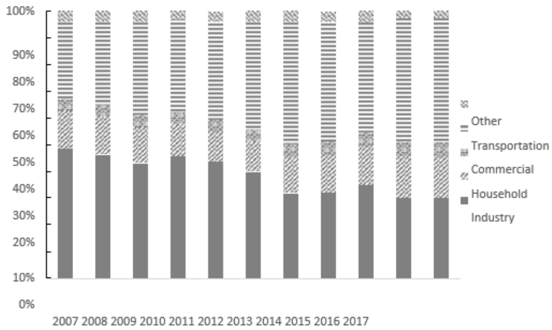

Figure 1. Share of Energy Consumption by Sector
Source: (Ministry of Energy and Mineral Resources, 2018)

Share of energy consumption in the industrial sector is compiled from four energy resources: oil, coal, gas, and biomass. This study excludes electricity as one of the energy resources. Oil looks favorable for the industry sector as the trends of oil usage has been upwards recently. Figure 2 illustrates that oil demand in the industry increased in the last 10 years, starting at only about 27% of the total share in 2007 to approximately 46% in 2017. To the contrary, coal consumption shows the opposite direction. In 2007, coal occupied 32% of total energy share; however, it halved after 10 years.

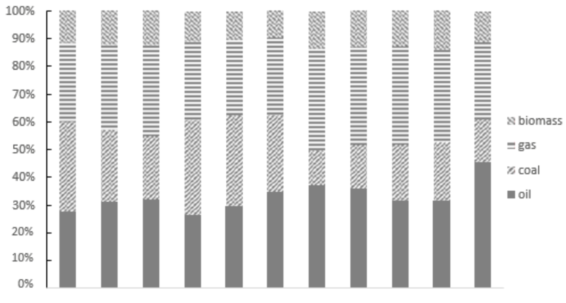

Figure 2. Share of Energy Consumption in Industrial Sector by Type
Source: (Ministry of Energy and Mineral Resources, 2018)

The data for this research is compiled on the descriptive statistics section as shown at Table 1 which comprises information on energy consumption, energy price, real exchange rate, the value of firm's production, and the sum of firm's employee. During the 13-year research period, 263,749 observations were examined to assess the relationship between oil price and oil consumption at the aggregate level. Meanwhile, to calculate the coal price elasticity at the national manufacturing level, only 19,644 observations dealt with the regression. Further analysis of the priority sector comprises 140,014 observations for oil and 14,214 observations for coal. Since this study explores medium- and large size industries, the number of workers, as indicated in variable *size*, varies between 20 to 57,384 employees, and it is in accordance with the government classification that medium- and large-sized firms employ at least 20 workers (Ministry of Industry, 2016).

Table 1.
Descriptive Statistics

		Number of Obs.	Mean	Std. Dev.	Min.	Max.
Dependent variables (All Manufacturing Sectors)						
oiluse	quantity of total oil used by a firm, liter	263,749	250,219.4	6,475,185	1	2.60e+09
coaluse	quantity of total coal used by a firm, kg	19,644	3,033,673	3.61e+07	1	1.93e+09
Dependent variables (All Five Priority Sectors)						

oiluse	quantity of total oil used by a firm, liter	140,014	270,442.1	7,814,627	1	2.60e+09
coaluse	quantity of total coal used by a firm, kg	14,214	1,559,466	8,973,336	1	3.30e+08
Independent variables						
oilprice	fuel oil price, US$/barrel	263,749	86.82	26.81	38.17	107.51
coalprice	coal price, US$/ton	19,644	65.56	14.35	28.63	96.37
Control variables						
rer	real exchange rate, Rupiah/US$	263,749	9,927.79	1,340.41	8,573.78	13,388.03
production	value of a firm's total production, thousand Rupiah (deflated 2010)	263,749	9.21e+07	6.87e+08	1,687.46	4.74e+10
size	number of workers	263,749	192.95	718.40	20	57,384

Source: Author's calculation

Aggregate analysis

In the aggregate analysis, three models of each energy resource—oil and coal—has been composed based on the firm's conditional consumption of energy. It defines how a firm consumes energy. Table 2 shows the six different models applied on the national estimation of a firm's energy demand. The independent variable for Models 1, 2, and 3 are the firm's oil consumption while Models 4, 5, and 6 use the firm's coal consumption. Models 2 and 5 are estimations which has

used only one type of energy solely, and conversely, Models 3 and 6 are models for evaluating firms using both oil and coal.

Table 2.
Models for aggregate analysis

Model	Main Variables		Conditional Consumption		
	Oil	Coal			
	ln_oiluse ln_oilprice	ln_coaluse ln_coalprice	Oil	Coal	Definition
Model 1	√		SUMOIL > 0		Firms using oil
Model 2	√		SUMOIL > 0	SUMCO = 0	Firms using ONLY oil
Model 3	√		SUMOIL > 0	SUMCO > 0	Firms using oil AND coal
Model 4		√		SUMCO > 0	Firms using coal
Model 5		√	SUMOIL = 0	SUMCO > 0	Firms using ONLY coal
Model 6		√	SUMOIL > 0	SUMCO > 0	Firms using oil AND coal

Note: SUMOIL is a firm's oil consumption and SUMCO is a firm's coal consumption
Source: Author's calculation

The overall price elasticity of demand for oil and coal in the Indonesian industries are calculated from the basic model and displayed in Table 3. The oil elasticity calculated in Models 1, 2, and 3 are reported to be statistically significant at the 99% confidence level at a range of -0.194 to -0.288 which are considered as inelastic where the absolute value of price responsiveness is recognized between zero and one (0<ε<1). This negative sign confirms the hypothesis and is also in accordance with the result of previous research (Burke & Yang, 2016; Lin & Prince, 2013; Schulte & Heindl, 2017) which suggest that oil price has a negative relationship with its demand. This study suggests that a one percent increase in oil price will reduce the oil demand for the industries at 0.194%. The real exchange rate coefficient in Models 1, 2, and 3 also show a negative value at -1.039, -0.933, and -0.910. The negative sign means that the firm's demand for oil decreases when

the real exchange rate increases. Meanwhile, firm production and firm size have both positive signs for all three oil models. These imply that an increase in a firm's production, as well as bigger firm size, will raise oil consumption. The last three variables, namely *rer*, *production*, and *size*, which match the hypotheses, are control variables and have a significance at $\alpha = 1\%$.

The estimation result also shows each R-squared in both models, as shown in Table 3. R-squared for oil models are estimated at above 83%. These mean that about 83% of the oil data close to the fitted regression line. The R-squared is a statistical measure of how close the data are to the fitted regression line. The R- squared also provides an estimate of the strength of the relationship between each model and the response variable. However, the formal hypotheses test for such a relationship can only be analyzed using the t-test for each variable.

Table 3.
Regression results for aggregate level analysis

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
ln_oilprice	-0.230***	-0.194***	-0.288***			
	(0.0106)	(0.0108)	(0.0497)			
ln_coalprice				0.708***	0.296	0.670***
				(0.118)	(0.301)	(0.126)
ln_rer	-1.069***	-0.933***	-0.910***	0.969***	-0.591	1.014***
	(0.0365)	(0.0367)	(0.181)	(0.220)	(0.523)	(0.235)
ln_production	0.805***	0.802***	0.865***	0.767***	0.760***	0.804***
	(0.00614)	(0.00623)	(0.0382)	(0.0325)	(0.0831)	(0.0356)
ln_size	0.113***	0.117***	0.124**	0.263***	0.114	0.238***
	(0.0114)	(0.0116)	(0.0486)	(0.0502)	(0.0850)	(0.0538)
Constant	6.844***	5.468***	4.314**	-15.66***	3.503	-16.69***
	(0.376)	(0.376)	(1.907)	(2.434)	(5.857)	(2.635)
Observations	263,749	246,271	17,478	19,644	2,166	17,478
R-squared	0.830	0.836	0.894	0.928	0.834	0.938

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1 Source: Author's calculation

Some points have emerged from the results presented above. First, oil is the essential energy resource for Indonesian industries, which can be illustrated from about 92% of all observations in this study using oil only as their primary energy resources. Only less than 1% of all observations consume non-oil as energy resources. In addition, the importance of oil can be seen as during the annual average throughout the research period, manufacturing sectors consume oil at 64% of total Barrel Oil Equivalent (BOE) energy as shown in Figure 3. Second, the finding that demand for oil is inelastic suggests that firms are less sensitive and responsive to the oil price changes. Firms consider oil as a necessity goods where a 1% increase in oil price affects only far less than 1% (only around 0.2% in this study) of oil consumption reduction. It implies that Indonesian manufacturing firms are greatly dependent on oil. Third, regarding the immense dependence on oil, Indonesian manufacturers are most likely vulnerable to oil price fluctuations as indicated in Figure 3 which shows that oil price widely varied from about US$ 38 to 107 per BOE during the 13-year research period. An oil shock will have a severe effect on Indonesian manufactures as they largely depend solely on oil; therefore, it seems challenging to switch to other energy resources.

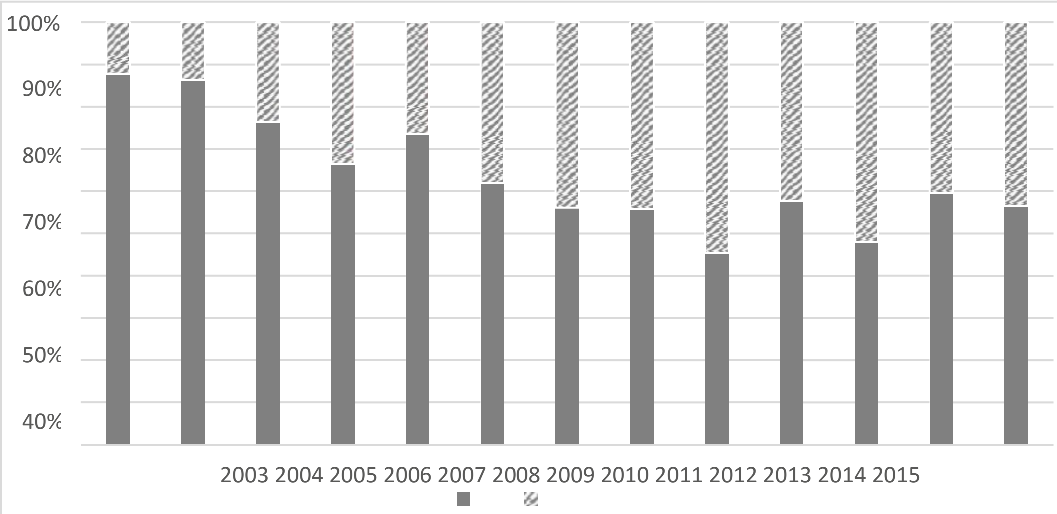

Figure 3. Oil and Coal Consumption Comparison on Indonesia Manufacturing Sector in Percentage of Barrel Oil Equivalent (BOE) standard.

Source: (BPS, 2016)

In contrast, the overall price elasticity of demand for coal is calculated positive for Models 4, 5, and 6 at 0.708, 0.296, and 0.670, respectively. Models 4 and 6 are statistically significant at a 99% confidence level, though Model 5 is not significant. Moreover, the real exchange rate coefficient is also positive. The result shows that the hypotheses are not satisfied for variable coal price and real exchange rate even though the variables firm production and firm size are in line with prior research that suggests a positive relationship between both firm production and firm size with firm consumption of oil (Agnolucci, 2009; Dasgupta & Roy, 2015; Hill & Cao, 2013).

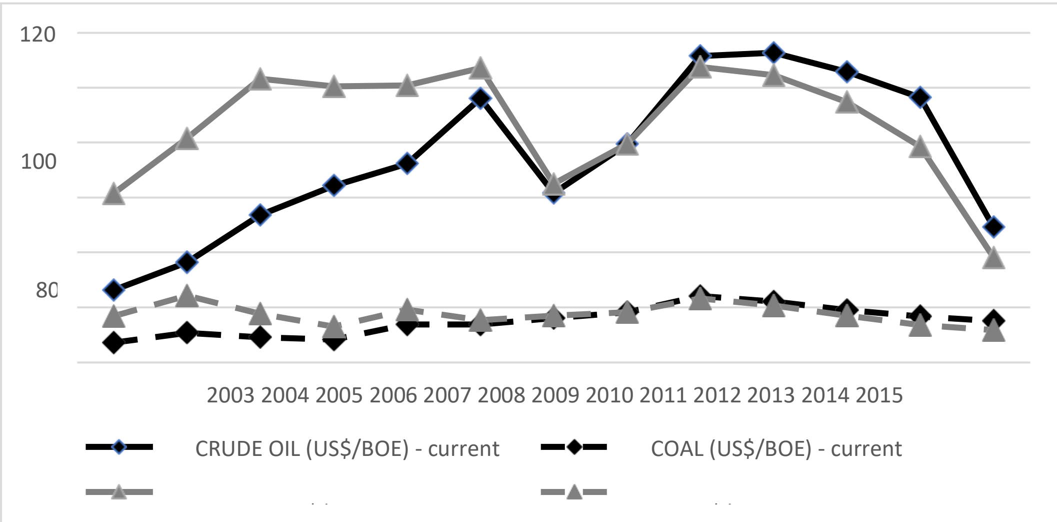

Figure 4. Crude Oil and Coal Prices.

Source: (Ministry of Energy and Mineral Resources, 2016)

To check whether the models for coal show results consistent with the initial result in Model 4, other models are proposed since many firms consumed both coal and oil at the same time. Model 7 is applied only for the firm having more coal consumption than oil. Meanwhile, Model 8 is the opposite of Model 7, in which the firm's demand for oil is higher for coal. Both Models 7 and 8 are calculated on the same standard of BOE. The regression results for Models 7 and 8 in Table 4 show similar findings to the initial Model 4 that coal price has a positive sign.

The estimation results for the coal model reveal that a positive relationship might exist between coal price and the firm's coal consumption. Models 4, 6, 7, and 8 indicate similar findings for coal estimations—all of them are statistically significant. The significance of these models is possibly caused by the interfering result of oil user firms. Model 4, involving 19,644 observations, and Model 6, covering 17,478 observations, are imposed to firms that consume coal and possibly oil at the same time. The number of observations on those models is six times higher compared to Model 5, which involves only 2,166 observations. Thus, Model 4 and 6 are statistically significant because of the possibility of a high number of observations using oil. Conversely, Model 5 is applied to firms that consume only coal and suggests that coal price insignificantly affects coal demand.

Table 4.

Regression results for coal

	(1)	(2)	(3)
VARIABLES	Model 4	Model 7	Model 8
ln_coalprice	0.708***	0.597***	0.371***
	(0.118)	(0.138)	(0.123)
ln_rer	0.969***	0.391	0.546**
	(0.220)	(0.240)	(0.217)
ln_production	0.767***	0.749***	0.945***
	(0.0325)	(0.0376)	(0.0545)
ln_size	0.263***	0.217***	0.0455
	(0.0502)	(0.0485)	(0.0818)
Constant	-15.66***	-7.339***	-14.41***
	(2.434)	(2.772)	(2.300)
Observations	19,644	9,979	9,665
R-squared	0.928	0.863	0.969

Robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$ Source: Author's calculation

A positive relationship exists between coal price and its consumption in Indonesian manufacturing sector; this finding implies that this phenomenon can be explained through several reasons. A limited number of firms using coal, unevenly spread of coal consumption between sub-sector, and the relative price of coal for oil are the factors that presumably induce this circumstance.

Only a small portion of observations show that around 7.4% utilizes coal as part of their production. Moreover, only 0.8% of observations use coal as a single resource. Distribution of sample data of firms that use only coal indicates that those firms mostly use a large amount of coal.

The small number of coal users in the Indonesian manufacturing sector is most likely because of the limited domestic coal supply. According to the Ministry of Energy and Mineral Resources (2017), Indonesia is a non-importer coal country, and all of its coal demand is domestically fulfilled. In 2015, Indonesia produced 461.6 million tons of coal, and only 20.7% or 95.8 million tons was supplied to the domestic market where the power plants utilize most of them. The rest, around 79.3%, was exported to various countries; thus, Indonesia is one of the largest coal exporters in the world, even though Indonesian coal reserves are only 3.1% of world reserves. The high coal exports indicate that coal together with natural gas are still becoming primary commodities to support the country's foreign exchange reserves (Ministry of Energy and Mineral Resources, 2017). Moreover, it implies that domestic supply is far less below the exports amount.

The next factor is that coal consumption in the Indonesian manufacturing sector, calculated on BOE standard, is concentrated on several sectors. Based on BPS (2016), cement industry (42.1%), textile industry (17.8%), paper industry (13.1%), chemical industry (9.1%), food industry (9.1%) were the top five sectors that use coal up to 91.2% on accumulation during the 13-year research period (See Appendix A). Contrary evidence appears in oil consumption, that in the same period, around 90% of oil was absorbed by the 13 sub-sectors, which exceeds coal, as illustrated in Appendix B.

The relative price of coal for oil possibly affects the positive relationship between coal price and its demand. As shown in Figure 4, coal price is regarded much lower than oil price, and the highest increase in coal price will not exceed the most profound drop in oil price. Hence, the firms assessed coal price to be more competitive than oil price. Furthermore, Figure 4 also illustrates that coal price is

more stable, whereas oil bears a more fluctuating price. This reason implies that the firms probably retain coal usage, although the price comes up.

Sectoral analysis

This section mainly discusses disaggregate level estimation on the sub- sector industry in Indonesia. The selected sub-sector indicates priority sector on the Indonesian manufacturing sector, including food and beverage, textile, apparel, and footwear, chemicals and pharmacy, electronics and optical device, and automotive and transport equipment. The Ministry of Industry (2015) declared these priority sectors as a part of long-term national industry development, in regard to the importance of these sectors on contributing 60% of GDP share on the manufacturing sector, supporting 65% of total exports, and absorbing 60% of the industrial workforce. Each sub-sector contains one or more sub-sector categories based on 2-digits ISIC Revision 4, as stated in Appendix C. In this part, the effect of the energy price and its magnitude is extensively examined.

Table 5 indicates the estimation results for the oil in the priority sectors, namely food and beverage, textile, apparel, and footwear, chemicals and pharmacy, electronics and optical device, and automotive and transport equipment. Each sector shows that the price elasticity of demand for oil is negative with respect to oil price and is in line with previous research results—that a negative relationship between oil price and its demand prevails (Bjørner & Jensen, 2002).

The regression results show varied elasticity magnitude for each priority sector. All five priority sectors in this study involve 140,014 firms using oil, and its demand elasticity is estimated at -0.277. Within all priority sub-sectors, oil elasticity is expressed as inelastic, where one percent of price increase influences on only 0.277 percent firm's consumption drop. Hence, it indicates that the priority sectors as a whole still highly rely on oil as their energy resources.

Table 5.
Regression results for oil in priority sectors

	OIL					
		(1)	(2)	(3)	(4)	(5)
VARIABLES	ALL PRIORITIES	FOOD & BEVERAGE	TEXTILE, APPAREL & FOOTWEAR	CHEMICALS & PHARMACIES	ELECTRONICS & OPTICAL DEVICE	AUTOMOTIVE & TRANSPORT EQUIPMENT
ln_oilprice	-0.277***	-0.184***	-0.387***	-0.244***	-0.256**	-0.300***
	(0.0146)	(0.0206)	(0.0241)	(0.0512)	(0.128)	(0.0642)
ln_rer	-1.227***	-1.238***	-1.331***	-1.116***	-0.346	-0.695***
	(0.0499)	(0.0687)	(0.0856)	(0.183)	(0.420)	(0.208)
ln_production	0.776***	0.702***	0.841***	0.810***	0.918***	0.828***
	(0.00886)	(0.0124)	(0.0149)	(0.0280)	(0.0648)	(0.0429)
ln_size	0.118***	0.197***	0.0188	0.165**	0.0659	0.0167
	(0.0156)	(0.0219)	(0.0257)	(0.0642)	(0.0934)	(0.0528)
Constant	9.002***	9.910***	9.457***	7.095***	-2.324	3.451
	(0.520)	(0.717)	(0.884)	(1.901)	(4.293)	(2.276)
Observations	140,014	65,381	52,956	12,322	2,891	6,464
R-squared	0.830	0.818	0.825	0.787	0.812	0.852

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1 Source: Author's calculation

Meanwhile, the estimation on the elasticity of each sub-sector generates varied values, ranging from 0.184 to 0.387 in absolute value. Each sector's estimation is considered as inelastic, that is in accordance with all priority calculation, even though it possesses a different degree in price elasticity. In absolute value, the effect of oil price can be determined by its value (Pindyck & Rubinfeld, 2013). The food and beverage sector experiences the smallest value among others; thus, this sector is the most unaffected by the oil shock. Therefore, one percent of oil price surge leads only 0.184 percent of decrease in demand. The

textile, apparel and footwear sector, with 0.387 of elasticity in absolute value, also acquires inelastic oil demand with respect to the price; nevertheless, it encounters the most considerable impact than other priority sub-sectors. These varied results suggest that between zero and one in absolute value ($0<\varepsilon<1$), the higher magnitude of price elasticity for oil delivers a higher impact on oil consumption reduction.

Almost all of the estimation result for real exchange rate, production, and size in Table 5 indicate that the coefficients match the hypotheses with the level significance of 99% except for some points. These circumstances suggest that those three control variables convey essential implications on the firm's consumption behavior for energy, particularly oil in this case, and prior studies indicate the same (Andersen et al., 2011; Hill & Cao, 2013). Only the electronics and optical device sub-sector shows that real exchange rate does not significantly affect the firms' oil consumption. Moreover, the firm size in two sub-sectors—electronics and optical device and automotive and transport equipment—delivers minor significance to the oil utilization for their industrial processes.

The regression result also shows each R-squared in models which is almost the same high for all sectors at around 80%. Commonly, R-squared or goodness of fit of a model describes the fitness of the model that the variation ratio of dependent variable related to its independent variable (Wooldridge, 2012), even though some studies suggest that the correlation between the dependent variable and the independent variables cannot be concluded solely by its R-squared (Figueiredo Filho, Silva, & Rocha, 2011; King, 1986). Hence, in this estimation, around 80% of the phenomenon in the model can be represented by its independent variables.

Correspondingly, oil price, real exchange rate, firm's production, and firm's size as a whole indicates around 80% of the firm's oil consumption determinant.

Table 6.

Regression results for coal in priority sectors

	COAL	(1)	(2)	(3)	(4)	(5)
VARIABLES	ALL PRIORITIES	FOOD & BEVERAGE	TEXTILE, APPAREL & FOOTWEAR	CHEMICALS PHARMACY	ELECTRONICS & OPTICAL DEVICE	AUTOMOTIVE & TRANSPORT EQUIPMENT
ln_coalprice	0.760***	0.834***	0.754***	0.456	0.558	0.198
	(0.136)	(0.214)	(0.187)	(0.498)	(2.098)	(0.455)
ln_rer	1.061***	1.292***	0.909***	0.763	-2.757***	0.271
	(0.250)	(0.393)	(0.349)	(0.826)	(0.0248)	(0.790)
ln_production	0.742***	0.642***	0.813***	0.767***	1.957***	1.055***
	(0.0379)	(0.0671)	(0.0509)	(0.0849)	(0.0650)	(0.143)
ln_size	0.278***	0.356***	0.197***	0.521***	-6.344	0.247***
	(0.0576)	(0.105)	(0.0688)	(0.173)	(5.518)	(0.0747)
Constant	-16.16***	-17.53***	-15.25***	-13.57	27.46	-15.78
	(2.764)	(4.299)	(3.872)	(9.524)	(17.21)	(10.17)
Observations	14,214	5,632	6,895	1,492	19	176
R-squared	0.923	0.918	0.923	0.910	0.974	0.987

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1 Source: Author's calculation

Contrary, the estimation results for each sector for coal demand in Table 6 displays the opposite results for oil. The relationship between coal price and the coal demanded is positive for all sub-sectors even though it is significant only in food and beverage, textile, apparel and footwear, and chemicals and pharmacy sub- sectors. The electronics and optical device sub-sector cannot statistically be interpreted because the number of observations (19) does not conform to the minimum number for regression (Wooldridge, 2012). The R-squared also similar between the model for each sector that indicates more than 90% of each sub-sector data is close to the fitted regression line.

Sectoral estimation for coal indicates that, in absolute value, all priority sub- sectors recognize coal price as inelastic. The elasticity magnitude spreads from

0.198 to 0.834. Among all sub-sectors, automotive and transport equipment is the most unaffected by the coal price increase, whereas food and beverage is considered as the most vulnerable sub-sector.

CONCLUSION

This paper investigated the effect of energy price changes on energy consumption for Indonesian manufacturing sectors. Two types of energy resources—oil and coal—were emphasized on the unbalanced panel data analysis. For a more in-depth investigation, this research also inspected the firm's behavior on energy consumption with respect to the energy price on selected priority sub-sectors. The priority sub-sectors, namely food and beverage, textile, apparel and footwear, chemicals and pharmacy, electronics and optical device, and automotive and transport equipment, have been decided by the Ministry of Industry, considering their ability to generate high national income and to absorb labor force. Utilizing firm-level data, this study obtained evidence that energy consumption, especially oil, in the Indonesian manufacturing sector is sensitive due to its price. The estimation suggests that a one percent increase in oil price resulted in a reduction of the demand by 0.23 percent. Meanwhile, the sub-sector analysis also indicates that a negative relationship significantly exists between oil price and the firm's oil consumption where the price elasticity for oil demand ranged from 0.184 to 0.387 on its absolute value. The elasticities are considered as inelastic as one percent of increasing price merely affected the consumption far less than one percent.

The estimation results for oil elasticity suggests that the Indonesian manufacturing sectors have a high dependency on oil as their primary energy resource. It is an unfavorable circumstance because of the high volatility of oil price in the last decades; therefore, the manufacturing sector becomes prone to oil shocks. On the other hand, coal regression shows different outcomes than oil estimation. The analyses indicate that in some models, a positive relationship appears in term of relationship between coal price and coal demand even though the others show an insignificant effect of the coal price on its consumption. This phenomenon has resulted possibly because of the following reasons: a small number of observations using coal, concentration of coal consumption in a few sub- sectors, and meager price of coal relative to oil. Moreover, this result implies that coal has not been optimized in the manufacturing sector.

Based on the findings, several policies can be implemented on how energy can stimulate a beneficial response in the industrial sector. The finding indicates that the Indonesian manufacturing sector acquires significant reliance on oil despite limited domestic supply and fluctuating price. To reduce the impact of the oil shock, firms can partially shift to the other energy resources. It is challenging for the firms because changing energy type might affect the equipment changes and probably the entire production process. Gradual conversion by utilizing more low-priced, efficient, and environmentally friendly energy resources is an advantageous long- term move that firms do.

At the same time, the government should stimulate the shifting by providing sufficient alternatives energy and creating usage opportunities on utilizing other resources. Existing programs, for instance, Industrial Equipment Restructuration Programs and Green Industry Award (Ministry of Industry, 2015), should be intensely elaborated to gain the optimal result. Newly developing industrial zones need to be equipped with abundant energy in terms of electricity; thus, firms can conveniently approach their energy demand.

In the energy sector, one of the government policy directions is that energy, in the long term, is considered as the vital part of national development capital, not as part of trading commodities for increasing national income (Ministry of Energy and Mineral Resources, 2017). Based on the National Energy Masterplan 2017, recently, annual domestic coal consumption barely reaches 20% of national production, and the rest is exported. Accordingly, a vast amount of exported coal is induced by high-intensity mining (Prasetyawan, 2017). Hence, Indonesia's coal self-sufficiency highly comes up to around 400% in recent years. For instance, in 2017, domestic coal production of coal was recorded as 1.9 million BOE while domestic supply marked only 400.000 BOE (Ministry of Energy and Mineral Resources, 2017). Meanwhile, the government's long-term masterplan requires zero coal export or full absorption in the domestic coal market in 2045.

Following the energy policy above, the government might use abundant coal production to develop the manufacturing sector, even though this policy has to be considered as the last resort. Building new power plants and increasing existing power plants' efficiency are several possible ways in escalating energy supply in the form of electricity. Regarding the relatively low price of coal, abundant domestic coal offers opportunities to produce low price electricity in a massive amount. Figure 4 above indicates that on an annual average, coal price is reported to be one-fifth of oil price. Moreover, according to Ram et al. (2018), the electricity- generating cost for coal in Indonesia is far below the other unrenewable energy resources such as oil and natural gas. Providing cheaper and sufficient electricity will encourage a reduction in oil dependence.

On the other hand, instead of exaggerating the usage of the unrenewable resources, the government should expand renewable utilization as the long-term strategy. According to Tasri and Susilawati (2014), Indonesia has high potential in developing renewable resources, including hydropower, geothermal, solar, wind energy, and biomass. These resources comply several criteria for Indonesia on the future development of renewable resources such as quality and sustainability, socio- politic and economic prospect, and also technology and environmental aspect (Tasri & Susilawati, 2014).

In the long term, renewable resources should be prominently promoted as the generating electricity cost will be decreased for those kinds of sustainable resources. Ram et al. (2018), in their study on G20 countries, indicate that in the near future, the generating electricity cost for renewable resources is predicted to achieve much lower price than today, and in many countries, renewable resources is going to be more feasible than unrenewable resources. The cost of electricity generation for renewable resources is already cheaper in more developed countries such as the US, EU, and Australia. Nevertheless, it supposes to be followed by other developing countries, including Indonesia, Mexico, and Brazil, as they start to emphasize renewable energy resources investment (Ram et al., 2018).

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