OECD Environment Working Papers No. 170

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https://dx.doi.org/10.1787/9ec54222-en

OECD

Organisation for Economic Co-operation and Development

ENV/WKP(2021)2

Unclassified **English - Or. English**

22 March 2021

ENVIRONMENT DIRECTORATE

Cancels & replaces the same document of 15 March 2021

Assessing the Impact of Energy Prices on Plant-Level Environmental and Economic Performance: Evidence from Indonesian Manufacturers

ENVIRONMENT WORKING PAPER N°170

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***Keywords**: energy prices, fossil fuel subsidy reform, carbon emissions reductions, firm performance, competitiveness*

***JEL codes**: Q52, Q54, Q58*

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Abstract

This paper provides an empirical analysis of the impact of energy price increases – induced notably by the removal of fossil fuel subsidies – on the joint environmental and economic performance of Indonesian plants in the manufacturing industry for the period 1980-2015. The paper shows that a 10% increase in energy prices causes a a reduction in energy use by 5.2% and a reduction in CO_2 *emissions by 5.8% on average, with more energy-intensive sectors responding more to the shocks. At the same time, energy price increases increase the probability of plant exit and reduce employment of large and energy intensive plants, but the estimated effect is very small (-0.2% for a 10% increase in energy prices). Morevoer, energy price changes have no significant influence on net job creation at the industry-wide level, suggesting that jobs are not lost but reallocated from energy-intensive to energy-efficient firms. Overall, the empirical evidence demonstrates that environmental fiscal reforms in emerging economies like Indonesia can bring about large environmental benefits with little to no effect on employment.*

Keywords*: energy prices, fossil fuel subsidy reform, carbon emissions reductions, firm performance, competitiveness*

JEL codes*: Q52, Q54, Q58*

Résumé

Ce papier présente une analyse empirique de l'effet de l'augmentation des prix de l'énergie – entraînée notamment par la réforme des subventions aux énergies fossiles – sur la performance environnementale et économique des entreprises indonésiennes du secteur manufacturier pour la période 1980-2015. L'étude montre qu'une augmentation de 10 % du prix de l'énergie diminue la consommation d'énergie de 5.2 % et les émissions de CO2 de 5.8% en moyenne, l'effet étant plus important pour les entreprises des secteurs les plus energivores. En même temps, l'augmentation des prix de l'énergie augmentent la probabilité de faillite et réduisent l'emploi des grandes entreprises énergivores, mais l'effet estimé est très faible (-0.2% pour une augmentation des prix de l'énergie de 10%). De plus, les changements de prix de l'énergie n'ont pas d'effet sur l'emploi agrégé au niveau sectoriel, ce qui suggère que les emplois ne sont pas détruits mais redéployés des entreprises intensives en énergie vers d'autres plus économes en énergie. Au total, l'analyse empirique démontre que les réfomes fiscales environmentales dans les économies émergentes comme l'Indonésie peuvent apporter des bénéfices environmentaux importants sans nuire à l'emploi industriel.

Mots clés : *prix de l'énergie, réformes des subventions aux énergies fossiles, réduction des émissions de carbone, performance des entreprises, compétitivité*

Classification JEL : *Q52, Q54, Q58*

Acknowledgements

The authors would like to thank Shardul Agrawala, Peter Hoeller, Giuseppe Nicoletti, and participants at the June 2019 meeting of the Working Party on Integrating Environmental and Economic Policies of the OECD Environment Policy Committee for useful comments and suggestions. This document has been produced with the financial assistance of the European Union. The views expressed herein do not necessarily reflect the official opinion of the European Union.

Table of contents

Tables (main text)

Tables (annexes)

Figures (main text)

Figures (annexes)

Assessing the Impact of Energy Prices on Plant-Level Environmental and Economic Performance: Evidence from Indonesian Manufacturers

Executive summary

This paper investigates the impact of higher energy prices on the environmental performance and competitiveness of Indonesian firms using plant-level data covering all medium and large enterprises in the Indonesian manufacturing industry for the period 1980-2015. The study exploits geographic, industrial and temporal energy price variations to identify the causal effect of price increases on the performance of firms.

The major results of the analysis are the following:

- The Indonesian manufacturing industry experienced sharp increases in energy prices starting in 2000. The increase coincides with the removal of subsidies for industrial users and ad hoc price increases in petroleum and diesel fuels, as well as tariff increases for electricity use.
- At the industry-wide level, there has been a decline in energy intensity over time, particularly in the post-2000 period, when fossil fuel reforms were implemented.
- A 10% energy price increase induces a reduction in energy use by 5.2% and a reduction in CO_2 emissions by 5.8% on average.
- The effect of energy price changes varies across sectors, with more energy-intensive sectors responding more to the shocks.
- Energy price shocks induce Indonesian plants to update their capital stock towards more energy-efficient and/or energy-saving machineries and vehicles.
- There is indication that energy price increases reduce employment but the estimated effect is very small (-0.2% for a 10% increase in energy prices). This negative impact is only valid for larger and energy intensive plants. The impact is not significant for less energy-intensive plants and positive for small plants.
- Energy price surges increase the probability of plant exit. The probability of exit is higher for plants that rely heavily on energy to produce their output.
- Energy price changes have no significant influence on net job creation at the industry-wide level, suggesting that jobs are not lost but reallocated.

Overall, the empirical evidence demonstrates that environmental fiscal reforms in emerging economies like Indonesia can bring about large environmental benefits with little to no effect on employment. There is a small negative effect on employment for larger and energy-intensive plants and through exit, but these job losses are compensated by job hires at other plants within the same sector.

1. Introduction

Developing countries account for more than half of global annual greenhouse gas emissions and that share will only rise as developing countries' economies keep growing. In 2017, six developing countries, including Indonesia, were included among the top 10 emitters of greenhouse gas globally (Friedrich, Ge, & Pickens, 2017). Thus, it is crucial that considerable efforts to curb emissions not only come from developed countries but also from developing countries to achieve the global climate targets of the Paris Agreement.

One of the major concerns amongst developing countries in implementing policies to reduce carbon emissions is the notion that these policies might adversely affect the growth of their economy. For example, there are concerns that the highly debated energy subsidy reforms (ESR)[1], which have been identified as one important avenue to engage in transformative emission reductions (Merill, Casier , & Bassi, 2015), might lead to employment and income losses because they increase the cost of energy across all end-users. However, little is known about how firms actually respond to energy price increases in the developing world, despite the important policy implications of such an analysis.[2]

Theoretically, the way in which firms may respond to energy price increases – brought about by increased energy taxes, carbon pricing mechanisms or energy subsidy reforms – is not straightforward (Rentschler & Kornejew, 2018). In the short run, affected firms may choose to absorb the shock, resort to pass-through, or anything in between. Depending on the ability of a firm to absorb price shocks, the firm may decide to continue operating without adjusting neither its pricing scheme nor its production processes, including, among others, its demand for intermediate inputs (e.g. energy) or reduce its operation in terms of output and/or employment. These costs may also be passed on to other firms that buy their products (i.e., pass-through) through an increase in output prices. Alternatively, a firm may decide to alter its technological process by resorting to other energy sources or to less energy-intensive modes of production. Firms may also respond to energy price shocks by improving energy efficiency, enabling them to produce the pre-reform output with lower energy consumption. Therefore, whether more ambitious environmental policies such as energy subsidy removals would be detrimental to the economy depends on how firms respond to the resulting energy price shock.

This study empirically investigates the impact of increased energy prices on the environmental and economic performance of Indonesian companies based on a large plant-level dataset covering all manufacturing plants with at least 20 employees in Indonesia between 1980 and 2015. The analysis exploits geographic, sectoral and temporal energy price variations to identify the effect of price increases on the performance of plants. The study analyses the heterogeneity of plant responses as well as the magnitude of energy price-induced reallocations across space and sectors. Finally, the study looks at the trend

[1] Environmental fiscal reforms (sometimes referred to as green fiscal reform, or ecological fiscal reform) is defined by the Organization for Economic Co-Operation and Development (OECD, 2017)), as "improved alignment of taxes and tax-like instruments with environmental damages coupled with socially productive ways of using revenues".

[2] An exception is the study by Rentschler & Kornejew (2017) who studied the effect of energy price changes on firm-level competitiveness in Indonesia. Their study, however, does not analyse the impact on carbon emissions and is limited to small enterprises, which only make up less than 20% of the country's industrial output (BPS, 2015).

of aggregate energy intensity and employment over time and examines the causes of these changes at the industry-level, thereby complementing the plant-level analysis. With this, the study provides insights into the post-reform dynamics of an environmental fiscal policy reform and documents how the entire industry may adapt to the policy shock.

The dataset used for the analysis includes detailed information on physical energy use, allowing calculating the average price each plant faces and its CO_2 emissions in any particular year. Building upon the work of Bartik (1991); Sato, et al. (2015); Marin and Vona (2017) and Dussaux (2020), the study exploits geographically-based (and arguably exogenous) variations in energy price to identify the effect of energy price shocks on plant-level environmental and economic performance.

The results suggest that energy price increases lead to significant reductions in energy use and CO_2 emissions with minimal negative effect on employment, and no strong adverse effect on real output. This unambiguously leads to significant improvement in energy intensity of output, which can be interpreted as improvement in energy efficiency (Rentschler & Kornejew, 2018). The study further shows that plants in Indonesia react to higher energy prices by updating their capital stock, and investing in new and presumably more energy efficient technology. As the price for energy increases, plants increase their purchases and sales of energy-using capital (e.g., machineries and vehicles).

The report also shows that the effects of energy price increases on plants' performance differ depending on their initial output and energy intensity, and on which industry they operate in. Initially, larger plants and those that rely relatively more on energy, reduce their energy use and emissions the most. In terms of output, larger plants are not affected, while smaller plants tend to produce more as energy prices increase. The same pattern holds when focusing the analysis within each sector. Energy price increases also tend to drive plants to exit; the tendency to exit is stronger for plants that rely relatively more on energy.

Finally, there is no strong evidence to suggest that energy price movements have any influence on employment. At most, a 10% increase in energy price is associated with a 0.2% decline in employment. This negative impact is only valid for larger and energy intensive plants. The impact is not significant for less energy-intensive plants and positive for small plants. At the sector level, however, energy price changes have no influence on net job creation or destruction, suggesting that jobs are not lost but reallocated, with jobs lost at particular plants compensated by job hires at other plants within the same sector.

The study is organized as follows. Section 2 provides the context of Indonesia's fossil fuel subsidies and its relation to energy prices. Section 3 provides a brief discussion of the data and methodology and highlights the applicability of the Indonesian manufacturing sector to study plant-level adjustments in response to energy price shocks. Section 4 provides the empirical strategy, building on earlier works and combining them to ensure reliability of the estimated impact. Results are presented in section 5. Section 6 concludes the study and provides areas for further research.

2. Indonesia's Fossil Fuel Subsidies and Energy Prices

Indonesia has been providing fossil fuel subsidies since the 1960s (Chelminski, 2018). Owing to large benefits from rising global oil prices following the 1973 oil shock, fossil fuel subsidies for domestic consumption were used to alleviate poverty, along with reducing the impacts of inflation. As a consequence, electricity tariffs do not reflect the true cost of service delivery and prices of fuel have been maintained at very low levels. The difference between the true costs and the actual price paid by consumers is shouldered by the government. Since the 1960s, energy subsidies account for 20-24% of overall government expenditure.

The lack of investment in the energy sector led Indonesia to a transition from a net exporter to a net importer of crude oil in 2004. Combined with increasing local demand for fossil fuel, the transition made fossil fuel subsidies economically unsustainable and detrimental to fiscal stability. This led the government to consider reducing subsidies and to let fuel prices rise close to global prices (see Table A. 2 for details of the timeline of reforms in Indonesia).

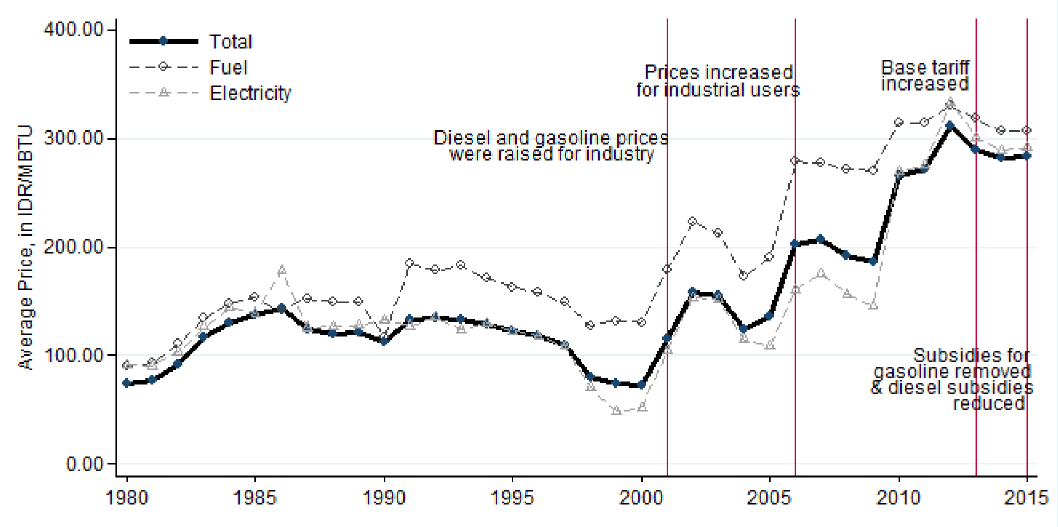
Figure 1 shows average energy price in the Indonesian manufacturing sector between 1980 and 2015 along with major energy subsidy reforms. The average price is obtained by averaging prices for four major energy sources (diesel, gasoline, lubricants and electricity) weighted by their proportion in final consumption. Industrial energy prices remained relatively flat at around 100 IDR/MBTUs (0.3 USD/TOE)[3] between 1980s and 2000. In 2001, industrial energy prices started to rise when subsidies for diesel and marine fuel for industrial users and sea transport were removed. During this year, fuel prices for large industry were increased to 50% of the international market levels (Chelminski, 2018), followed by another fuel price hike for gasoline and diesel. The government also introduced a semi-automatic fuel pricing for subsidized automotive gasoline and diesel products for the industry, transportation and fishery sectors.

In 2005, a presidential decree announcing the phasing out of the remaining subsidies was issued. For industrial energy users, access to subsidized diesel was halted. In 2006, fuel prices increased for industrial users by about 50% relative to 2005 levels. In 2013, base tariff increased by 15%, coupled with further increases in gasoline and diesel prices. Subsidies for gasoline were entirely removed and diesel subsidies were reduced substantially in 2015. However, world oil prices were historically low this year, thereby offsetting the price hike associated with the removal of subsidies.

Overall, Figure 1 clearly shows that the removal of fossil fuel subsidies led to increases in average energy prices. The objective of this study is to analyse the impact of these energy price increases induced by Indonesia's fossil fuel subsidy reforms on plant-level economic and environmental performance.

[3] 100 IDR = 0.0073 USD; 1 MTBU = 0.025 TOE.

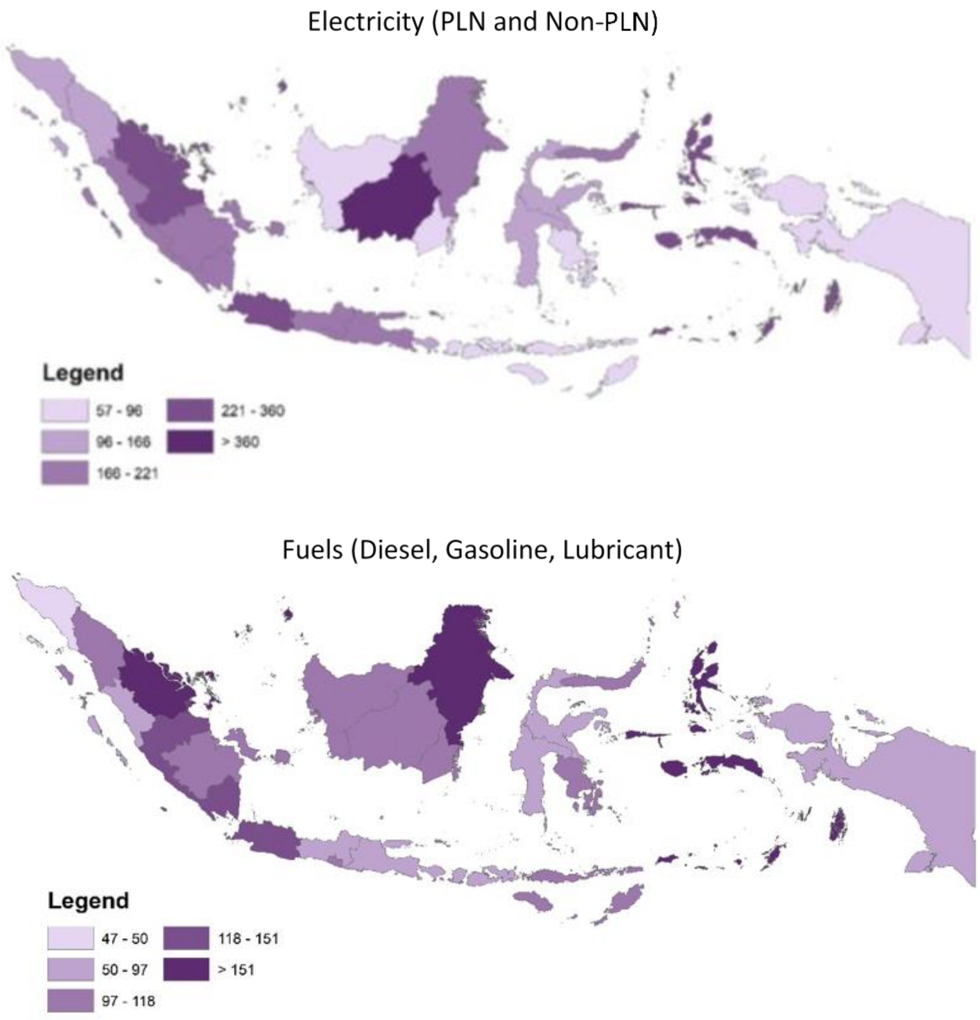
Figure 1. Trend of energy prices and fossil subsidy reform events in Indonesia, 1980-2015



Source: (1) raw data: *Industri Besar dan Sedang* (IBS), 1980-2015; (2) average prices: authors' calculations based on top 5 energy sources; (3) events: Chelminski (2018).

Another interesting feature of Indonesia's energy price changes, which is critical for the empirical analysis presented in this study, is their noticeable differences in growth pattern across different areas, as illustrated in Figure 2 for the period 1998-2015. This remarkable inter-province variation in electricity and fuel prices changes has been associated with the archipelagic nature of the country, leading to differences in transport costs, as well as with the presence of high-cost private suppliers in certain provinces (Cali, Cantore, Iacovone, Pereira Lopez, & Presidente, 2019). These logistical differences and infrastructure gaps in energy distribution across provinces in Indonesia provide an exogenous source of variation in energy prices which can be exploited to identify the effect of energy price changes on the performance of Indonesian manufacturers (Rentschler & Kornejew, 2018).

Figure 2. Percentage growth in select province-level energy prices in 2015 relative to 1998 level



Source: Extracted from Cali, Cantore, Iacovone, Pereira Lopez, & Presidente (2019).

3. Data and Methodology

3.1. Data Source

The main data source is *Industri Besar dan Sedang* (IBS), the Indonesian Census of Manufacturing for Medium and Large Enterprises maintained by the National Statistical Office (BPS, 2015). The dataset covers all manufacturing plants with 20 or more employees on an annual basis. The census has detailed information on fuel and electricity use, both in terms of values and physical quantities.[4] The sample spans the period 1980-2015 and covers more than 71,000 plants with 625,239 plant-year observations.

Plants are grouped into 5-digit industry classifications based on the *Klasifikasi Baku Lapangan Usaha Indonesia* (KBLI), which is compatible with ISIC Rev 3. For the survey period, the data covers 24 sectors based on 2-digit ISIC.[5] Nominal figures are deflated to reflect costs in 2015 Indonesian Rupiah (IDR) using the national consumer price index (CPI).[6] One of the main advantages of the dataset is the availability of detailed information on plant-level expenditures and physical usage (e.g., in metric tons, kWh or litres) for each energy input. The energy inputs consist of fuels and lubricants and electricity. Figure 3 shows the average share of each energy source in total energy use over the sample period. Electricity represents around half of total energy use for the average plant in Indonesia, while the rest is composed of fossil fuels and lubricants, including gasoline, diesel, diesel oil, kerosene, lubricant, bunker oil, coal, coke, public gas, liquefied petroleum gas (LPG), firewood, and charcoal. The data also includes information on the amount of fuel and lubricants used for electricity generation, as some of the plants produce electricity for their own consumption and for sale to other end users.[7]

The data set also includes information on the amount of electricity sold and the amount bought from the state-owned power company *Perusahaan Listrik Negara* (PLN) and from other independent power producers (non-PLN). Total electricity usage is calculated as total electricity purchased less electricity sold. Since some of the plants generate their own electricity, we also deduct the fuels used by plants to generate their own electricity to avoid double counting in the total fuel use.

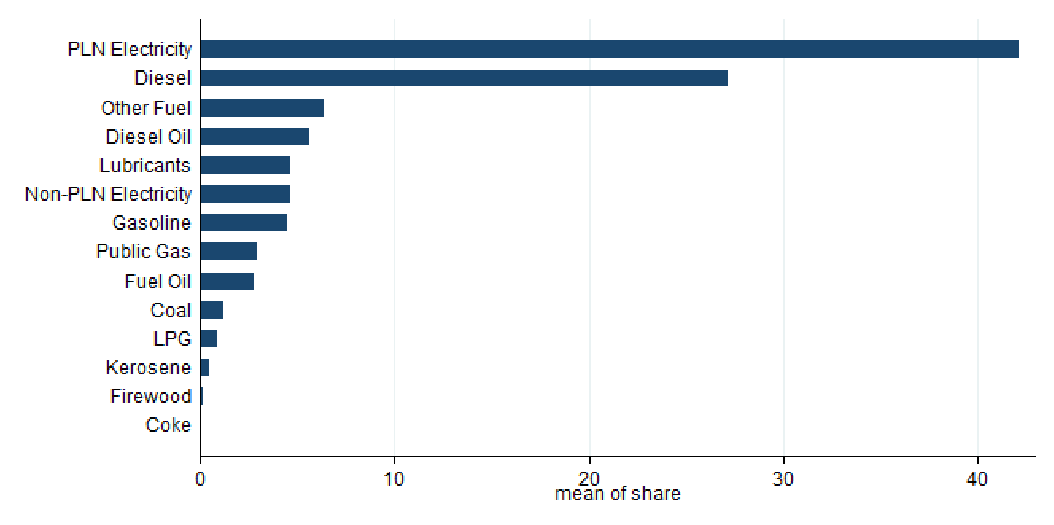
[4] The survey questionnaires and other relevant information about the dataset can be accessed online at http://www.rand.org/labour/bps/statistik_industri.html.

[5] The classification was adjusted to be consistent over the sample period.

[6] Ideally, price deflators should be constructed for each industry classification using wholesale price indices (WPI), CPI for energy and deflators for capital following Arnold and Javorcik (2009). Nonetheless, at the time of writing, we only had access to these indices for the period 1983-2001. However, including sector-specific trends in the estimated equations should control for differences in deflators across sectors.

[7] Plant-level output reported in the dataset includes revenues from selling electricity to other end users. To account for this, the amount received by the plant from this operation was deducted from total output.

Figure 3. Average share of each energy source to total energy use, 1980-2015



Note: PLN electricity is the electricity bought from the state-owned power company Perusahaan Listrik Negara (PLN) while non-PLN electricity are those bought from other independent power producers.
Sources: *Industri Besar dan Sedang* (IBS), 1980-2015.

3.2. Measuring energy usage and emissions

The energy content of each energy input (in British Thermal Units or BTUs) is calculated using conversion factors from the US Energy Information Agency and the US Environment Protection Agency (see Table A. 1 for details)[8], following Brucal, Javorcik, & Love (2018).

A sample calculation of the energy usage of a plant using 100 barrels of diesel fuel at a certain time period is illustrated below:

$$100\ barrels\ diesel \text{ x } \frac{5.825\ million\ BTUs\ (MBTUs)}{1\ barrel} = 582.50\ MBTUs \qquad (1)$$

We follow the same procedure for calculating CO_2 emissions (in kg CO_2). Using the same example above, we calculate CO_2 emissions as below:

$$582.50\ MBTUs \text{ x } \frac{71.80\ kg\ CO_2}{1\ MBTUs} = 41{,}845.04\ kg\ CO_2 \qquad (2)$$

Total energy used by a plant in a year is then calculated as the sum of energy use from the top 5 energy sources in a year. We restrict to those top 5 sources for two reasons. First, some of the other energy sources (e.g., natural gas) were included in the "Other Fuel"

[8] British Thermal Unit (BTU) is a traditional unit of energy. The US Energy Information Administration interprets BTU as the amount of energy needed to heat one pound of water from 39 to 40 degrees Fahrenheit (EIA, 2018).

category starting in 2001, making it impossible to calculate average energy prices for them. Second, other energy sources such as coke and firewood are not widely used in the industry, which can bring noise in the analysis. We follow the same approach for calculating total energy use for fuel and electricity.

The conversion factors used here are time-invariant. Yet, some firms may have resorted to more efficient conversion processes over time as a result of changes in environmental policies or technological improvements. Unfortunately, we do not observe the conversion processes in the data. However, to the extent that adoption of technology is correlated across plants within a sector, this will be captured by including sector-year fixed effects in the estimations.

Another key variable of interest is the energy intensity of the plant’s output. Following Brucal, Javorcik and Love (2018), energy intensity is defined as the total physical energy use (in MBTUs) per currency unit of output. We repeat the same process to calculate a plant's emissions intensity, which is defined as the total carbon dioxide emissions (in kg CO_2) per currency unit of output.

Table 1 presents summary statistics for the key variables in the dataset. It is interesting to note that there is substantial variation in energy price across plant-year observations, with variations in fuel price greater than in electricity prices. This can be explained by relatively more policy events that directly affected fuel prices over time. There is also significant variation in output, employment and energy intensity, which helps in identifying the changes in these variables associated with changes in energy prices.

Table 1. Summary Statistics

	Observations	Mean	SD
Total Energy Price (IDR/MBTUs)	552755	170	128
Fuel Energy Price (IDR/MBTUs)	466767	212	210
Electricity Energy Price (IDR/MBTU)	414136	170	111
Total Energy Use (billion BTUs)	625239	25.5	430
Fuel Energy Use (billion BTUs)	625239	8.22	170
Electricity Energy Use (billion BTUs)	625220	17.3	356
Total Energy Emission ('000 $KgCO_2$)	625239	603	12179
Fuel Energy Emission ('000 $KgCO_2$)	625239	587	12091
Electricity Energy Emission ('000 $KgCO_2$)	625220	16.6	342
Real Output (billion IDR)	625184	86.4	806
Employment	625239	187	706
Capital (billion IDR)	625218	6.79	1204
Energy Intensity, Total (MBTUs/IDR)	624814	.489	4.63
Energy Intensity, Fuel (MBTUs/IDR)	624814	.315	.977
Energy Intensity, Electricity (MBTUs/IDR)	624814	.299	4.47
Emission Intensity, Total ($KgCO_2$/IDR)	624814	13.9	53.2
Emission Intensity, Fuel ($KgCO_2$/IDR)	624814	13.6	52.4
Emission Intensity, Electricity ($KgCO_2$/IDR)	624814	.287	4.3
Energy/Output ('000 BTUs/IDR)	625239	96.4	4360
Capital-Labour Ratio (billion IDR)	625218	.0301	6.82

	Observations	Mean	SD
Share of Skilled Workers	547226	.312	1.25
No of plants (unique IDs)	71,119		

Source: *Industri Besar dan Sedang* (IBS), 1980-2015.

4. Empirical Strategy

Ideally, any study should identify the causal effect on any outcome variables by relying on exogenous variations in energy prices. Under a strict exogeneity assumption, the estimated coefficient can then be interpreted as the own-price elasticity of demand for energy.

The short-run effect of a change in the energy price on plants' environmental and economic performance is estimated using the following model:

$$\ln(y_{it}) = \beta_0 + \beta_1 lnp_{it} + \mu_i + \gamma_{st} + \theta_{prov-trend} + \epsilon_{it} \qquad (1)$$

where y_{it} is the dependent variable (e.g., plant i's output or energy use in year t); lnp_{it} is the log of energy price faced by plant i's year t, which is constructed by dividing total energy expenditure for each input by total physical energy use (in MBTUs) and then taking the average price across energy inputs weighted by the share of each input in total energy use; μ_i and γ_{st} are plant-specific and 2-digit sector-year fixed effects, respectively, $\theta_{prov-trend}$ are province-specific trends, and ϵ_{it} is the error which we assume as i.i.d.

The estimating equation addresses several potential endogeneity issues. First, it exploits the panel structure of the dataset by including plant fixed effects μ_i which capture time-invariant plant-specific characteristics that may be correlated with energy prices. These include, among others, differences across plants of varying sizes, different technologies, or different managerial capabilities, which may explain between-plants differences in energy prices. For example, a small plant in the textile industry will face different energy prices, and thus would have different energy use, compared to a large steel manufacturer.

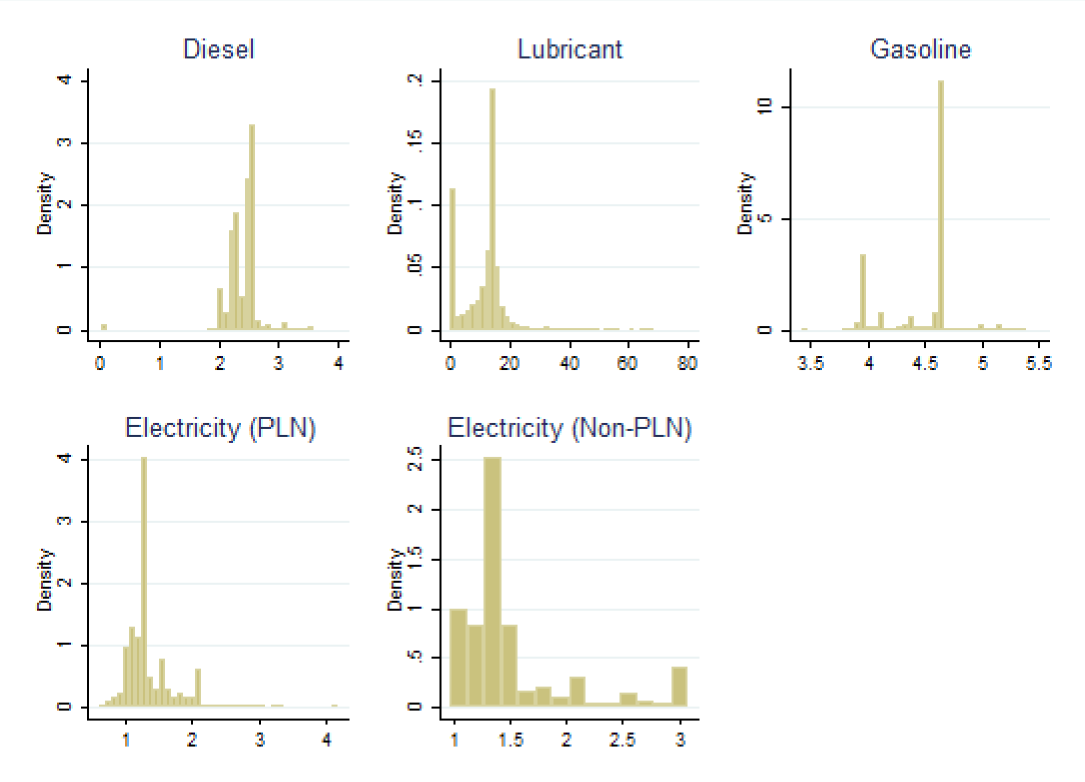
Second, the specification controls for potential shocks associated with sudden technological improvements, surges in demand or economic fluctuations. This is done by including sector-year fixed effects γ_{st} which control for any industry-specific shock that may occur in a particular year. We also add province-specific trends $\theta_{prov-trend}$, which capture any long-term province-specific development that may influence energy price, consumption and output of plants operating in the area.

For β_1 to provide an unbiased estimate of the impact of a unit change in energy price on any outcome variable, the energy price lnp_{it} faced by a plant in an area needs to be exogenous to the plant's decision process. Rentschler and Kornejew (2017) use the geographical features of Indonesia to highlight exogenous differences in prices brought about by logistical differences and infrastructure gaps in energy distribution across provinces in Indonesia. Therefore, exploiting geographical differences in energy prices across Indonesia can provide an unbiased estimate of β_1 assuming plants are small enough not to have any influence on the effective price they actually face. However, our dataset covers medium and large enterprises which may be eligible to quantity discounts or some form of bargaining, making energy price variations partially endogenous.

To determine whether our energy price variable is endogenous, we examine the distribution of energy prices in each province over the sample period. If energy prices are set at the national level and price variations come solely from logistical differences and infrastructure gaps across provinces, then we would not find significant variation in energy price after removing province-specific averages. To do this, we regress the unit price of each energy source against province-specific fixed effects.[9]

Figure 4 shows the distribution of province-demeaned unit prices for each energy source for the year 1990. While there seems to be a certain degree of concentration at a particular price level for each energy course, owing to the nationally-set energy prices, we still find significant variations, particularly in the left-hand side of the concentration. This suggests that there may be rigidities in terms of increasing prices but not so much in setting lower prices. Later, we also find that sectors relying more on energy, mostly bigger ones, generally face lower prices (likely as a result of bargaining between the plant and the energy supplier), suggesting that price levels even in the same province may still be correlated with energy use.

Figure 4. Distribution of province-demeaned energy prices for top 5 energy sources, 1990



Source: *Industri Besar dan Sedang* (IBS), 1990.

To address this potential endogeneity issue, the energy price lnp_{it} is instrumented with a fixed-weight energy price index (FEPI), following Sato, et al. (2015). We calculate FEPI for plant *i* in year *t* as follows:

[9] We used the 1980 classification of provinces, which contains 26 provinces. At present, the country has 34 provinces, eight of which were created since 1999, namely: North Maluku, West Papua, Banten, Bangka Belitung Islands, Gorontalo, Riau Islands, West Sulawesi and (in late 2012) North Kalimantan.

$$FEPI_{it} = \sum_{j} w_{i0}^{j} \ln(p_{kt}^{j}) \quad (4)$$

where w_{i0}^{j} is the share of energy source j to total energy use of firm i in the pre-sample year 0 and p_{kt}^{j} is the province k median price (in thousands IDR/MBTU) of energy source j in which firm i operates at year t.

Essentially, we fix the share of each energy source at the year we first observe a plant and then drop the first observation for each plant. The approach is similar to Marin and Vona (2017), who used a shift-share instrument (Bartik, 1991) by combining national energy prices with time-invariant plant-specific energy mix. The approach also shares similarities with (Linn, 2008) who used a fixed-weight energy price index calculated at the US state level. We differ from previous studies because we use median fuel price at the province level. Using nationwide fuel prices like Marin and Vona (2017) instead of province-level prices could lead to a weak instrument problem as fuel prices may differ significantly between provinces. This is particularly valid in the Indonesian setting where energy price variations are partially associated with differences in logistics and infrastructure gaps across provinces (Rentschler & Kornejew, 2018).

FEPI is calculated for overall energy use, fuel and electricity. To minimize noise, we limit the sources of fuel to diesel, lubricants and gasoline. Meanwhile, electricity consists of electricity from the state-owned power company Perusahaan Listrik Negara (PLN) and non-PLN sources. Overall, these energy sources comprise close to 90% of total energy sources (as shown in Figure 3).

Figure A. 1-Figure A. 3 in the Appendix show significant variations in the calculated energy price per unit of energy for the top energy sources (total), fuel and electricity. This suggests that there is indeed sufficient variation across provinces, which the identification strategy will be able to rely on. Moreover, we are confident that variations in energy prices across provinces are largely due to province-specific characteristics (e.g., varying level of infrastructure development that limits access to major sources of energy) that are considered exogenous to a plant's performance after controlling for plant-level characteristics.

5. Results from the econometric analysis

5.1. Main results

The effect of changes in energy price is formally tested by estimating equation (3), where lnp_{it} is instrumented by the fixed-weight energy price index (FEPI) shown in equation (4) using a two-stage least square estimator. Results, which are presented in Table 2, suggest that a 10% increase in energy price leads to a 5.2% decline in energy use (measured in physical units or MBTUs) and to a 5.8% reduction in CO_2 emissions, respectively. The parameter estimates are both statistically significant at the 1% level.[10] Notice as well that our instrument passes under-identification test; that is, we reject the null hypothesis that our instrument is not correlated with the endogenous regressor as shown by the

[10] Table A.4 shows that the results are robust to different ways of error clustering.

significance of the Kleibergen-Paap statistic. The instrument also passes that weak identification test with a very high Kleibergen-Paap F-statistic.

We find no evidence that energy prices affect plant-level output. The coefficient is close to, and not statistically different from 0. We find a negative effect on employment of 0.2% for a 10% increase in energy price and this effect is only marginally significant at the 10% level. These results are consistent with Martin et al. (2014) who find that a tax carbon in the UK (which approximately works like an energy price shock) does not have a strongly statistically significant effect on employment and revenues. This suggests that firms' reactions to energy price changes might not be very different between developed and developing countries.

Table 2. Effect of energy price on environmental performance and economic performance

Variables	Energy use	CO_2 emission	Output	Employment
Log(energy price)	-0.523***	-0.577***	0.017	-0.020*
	(0.027)	(0.037)	(0.021)	(0.012)
Kleibergen-Paap LM Statistic	6541	6541	6541	6541
KP LM stat p-value	(0.000)	(0.000)	(0.000)	(0.000)
Kleibergen-Paap F-stat	16479	16480	16470	16480
Observations	485621	485663	485646	485672
Plant FE	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	Yes
Province Trend	Yes	Yes	Yes	Yes

Notes: Log (energy price) is instrumented by fixed energy price index (FEPI). Robust standard errors clustered at the plant level are in parentheses. *, **, *** denote statistical significance at 10, 5 and 5 percent, respectively.

Overall, the above results suggest that an increase in the price of energy, which can be a result of an environmental policy (e.g. a fossil fuel subsidy reform or a carbon pricing mechanism), induces significant environmental benefits. Interestingly, the results do not substantiate the concerns (at least in the Indonesian context) about large negative effects of these policies on the size and/or overall economic performance of manufacturing plants, as measured by output and employment.

5.2. Energy intensity

In a perfectly competitive world, an increase in energy (or any factor) cost would lead to a worse plant-level performance. However, in the presence of distortions, Porter and van Linde (1995) argued that "properly crafted environmental standards can trigger innovation offsets, allowing companies to improve their resource productivity". In this subsection, we explore the validity of the so-called "Porter Hypothesis" (Brännlund & Lundgren, 2009) by examining the plants' energy and CO_2 emission efficiencies.

One way to measure energy and CO_2 efficiencies of a plant is to calculate its energy and CO_2 intensities. Energy and CO_2 intensities can be defined as the amount of energy used per unit of current output. This approach is similar to Rentschler and Kornejew (2018) and Brucal, et al. (2018).

Table 3 presents the results of estimating equation (3) with energy and CO_2 emission intensities as the dependent variables. Results show that a 10% increase in energy prices results in a reduction in energy intensity of about 5.4%. The same price change also leads to a reduction in CO_2 emissions per currency unit of output by 5.9%.

The third column of Table 3 shows the impact on energy use per worker. Results show that a 10% increase in price reduces energy per worker by 5.0%. These results clearly show that energy price increases bring in improvements in the production and/or management process by increasing the efficiency in energy use.

Table 3. Effect of energy prices on factor intensities

	Energy intensity	CO_2 intensity	Energy/worker
Log (energy price, fuel)	-0.540***	-0.594***	-0.504***
	(0.023)	(0.033)	(0.025)
Kleibergen-Paap LM Statistic	6541	6541	6541
	(0.000)	(0.000)	(0.000)
Kleibergen-Paap F-stat	16478	16479	16479
Observations	483716	483757	482741
Plant FE	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes
Province Trend	Yes	Yes	Yes

Notes: Log (energy price) is instrumented by fixed energy price index (FEPI). Robust standard errors clustered at the plant level and Chi-Sq. P value for the Kleibergen-Paap LM Stastistic are in parentheses. *, **, *** denote statistical significance at 10, 5 and 5 percent, respectively.

Having observed evidence of efficiency gains associated with energy price changes, it is natural to ask how these gains might come about. In other words, what might be the mechanism through which energy prices improve energy efficiency at the plant level? One possible mechanism could be that an energy price shock serves as an impetus that compels surviving firms to update their capital stock to improve production efficiency. In the absence of any shock, plants might not have any incentive to invest in energy-saving technologies due to management inattention or limited information (De Canio, 1993). With an exogenous energy price surge induced by the removal of fossil fuel subsidies and perhaps coupled with competitive pressures, plants are incentivized to invest in or adopt energy-saving technologies in order to survive in the industry.

Table 4 presents the results of estimating equation (3) with capital and the capital-labour ratio as dependent variables. Results show no statistically significant effect of energy price increases on the capital stock or the capital-labour ratio. The coefficients are not precisely estimated, however, suggesting considerable heterogeneity across plants in changes in capital caused by energy price fluctuations.

Table 4. Effect of energy prices on capital stock and capital-labour ratio

Variables	Capital	Capital-Labour Ratio
Log (energy price)	-0.047	-0.037
	(0.047)	(0.045)
Kleibergen-Paap LM Statistic	4096	5796
	(0.000)	(0.000)
Kelibegen-Paap F Statistic	9737	13023
Observations	252284	390135
Plant FE	Yes	Yes
Sector-year FE	Yes	Yes
Province Trend	Yes	Yes

Notes: Log (energy price) is instrumented by fixed energy price index (FEPI). Robust standard errors clustered at the plant level and the Chi-Sq. P value for the Kleibergen-Paap LM Stastistic are in parentheses. *, **, *** denote statistical significance at 10, 5 and 5 percent, respectively.

A limitation of looking at the capital stock is that the replacement of a machine by a new, more energy-efficient one might not significantly change the value of the assets held. Another way to examine the impact of energy price changes on the capital stock is to look at how Indonesian manufacturing plants purchase and sell energy-using durable goods and equipment. Our data contains plant-level purchases and disposal of energy-using capital goods, which makes analysis of the effect of energy price changes on these variables feasible.

Table 5 presents results of estimating equation (3) with purchases and sales of land, buildings, machines, and vehicles as dependent variables. The top panel uses purchases as the dependent variable and the bottom panel uses sales. Unsurprisingly, we do not find any significant effect on the purchases and sales of land. However, we find a strong, positive and statistically significant effect of increased energy prices on the purchases and sales of buildings and energy-using durables. In particular, we find that a 10% increase in the energy price leads to an increase in the purchases and sales of buildings by 1.36% and 1.15%, respectively. Similarly, plants increase the rate of purchases and sales of their machineries by 2.3% and 2.2%, respectively, and vehicles by 1.3% and 1.4%, respectively. We interpret this result as support to the hypothesis that energy prices provide an economic incentive for Indonesian manufacturing plants to update their energy-using capital towards newer and presumably more energy-efficient one.

Table 5. Effect of energy prices on purchases/sales of land, buildings, machinery and vehicles

Variables	Land	Buildings	Machineries	Vehicles
		(A) Purchases		
Log(energy price)	0.039	0.136**	0.233***	0.126*
	(0.048)	(0.069)	(0.081)	(0.069)
Kleibergen-Paap LM Statistic	6541	6541	6541	6541
	0.000	0.000	0.000	0.000
Kelibegen-Paap F Statistic	16480	16480	16479	16480
Observations	483788	483788	483785	483788
		(B) Sales		
Log(energy price)	0.031	0.115***	0.223***	0.139***
	(0.021)	(0.029)	(0.043)	(0.045)
Kleibergen-Paap LM Statistic	6410	6410	6410	6409
	0.000	0.000	0.000	0.000
Kelibegen-Paap F Statistic	16079	16079	16079	16075
Observations	461160	461160	461157	461156
Plant FE	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	Yes
Province Trend	Yes	Yes	Yes	Yes

Notes: Log (energy price) is instrumented by fixed energy price index (FEPI). Robust standard errors clustered at the plant level and Chi-Sq. P value for the Kleibergen-Paap LM Stastistic are in parentheses. *, **, *** denote statistical significance at 10, 5 and 5 percent, respectively.

5.3. Do initial plant size and energy intensity matter?

The evidence presented thus far suggests that energy prices lower energy consumption and emission levels per unit of output. Nonetheless, it is not obvious whether these effects are similar across all plants. It could be that the effect of price increases on plant-level environmental performance is stronger for plants that were initially smaller and less energy-efficient. In other words, the improvement in the production technique may be larger for plants that were initially further from the technological frontier and were just exposed to energy-saving technologies because of the energy price shock. Alternatively, plants that are initially bigger and more reliant on energy (e.g., steel manufacturers) could face greater incentives to reduce production costs by improving their energy use in the event of an energy price shock.[11]

[11] This alternative hypothesis is also validated using the sector-level analysis presented in section 5.7.

To test these hypotheses, we augment equation (3) with interaction variables between energy price and initial (pre-sample) values of output and energy intensity[12]. We use the estimates to illustrate the effect of an increase in the energy price at varying pre-sample output (see Figure 5) or energy intensity (Figure 6).[13] Estimation results reveal that changes in energy use as a consequence of higher energy prices vary greatly depending on the plant's initial output and energy intensity. Plants that are initially larger experience higher reductions in energy use as the price of energy increases. The same result holds for energy and CO_2 intensities, as well as for employment, capital and the capital-labour ratio.

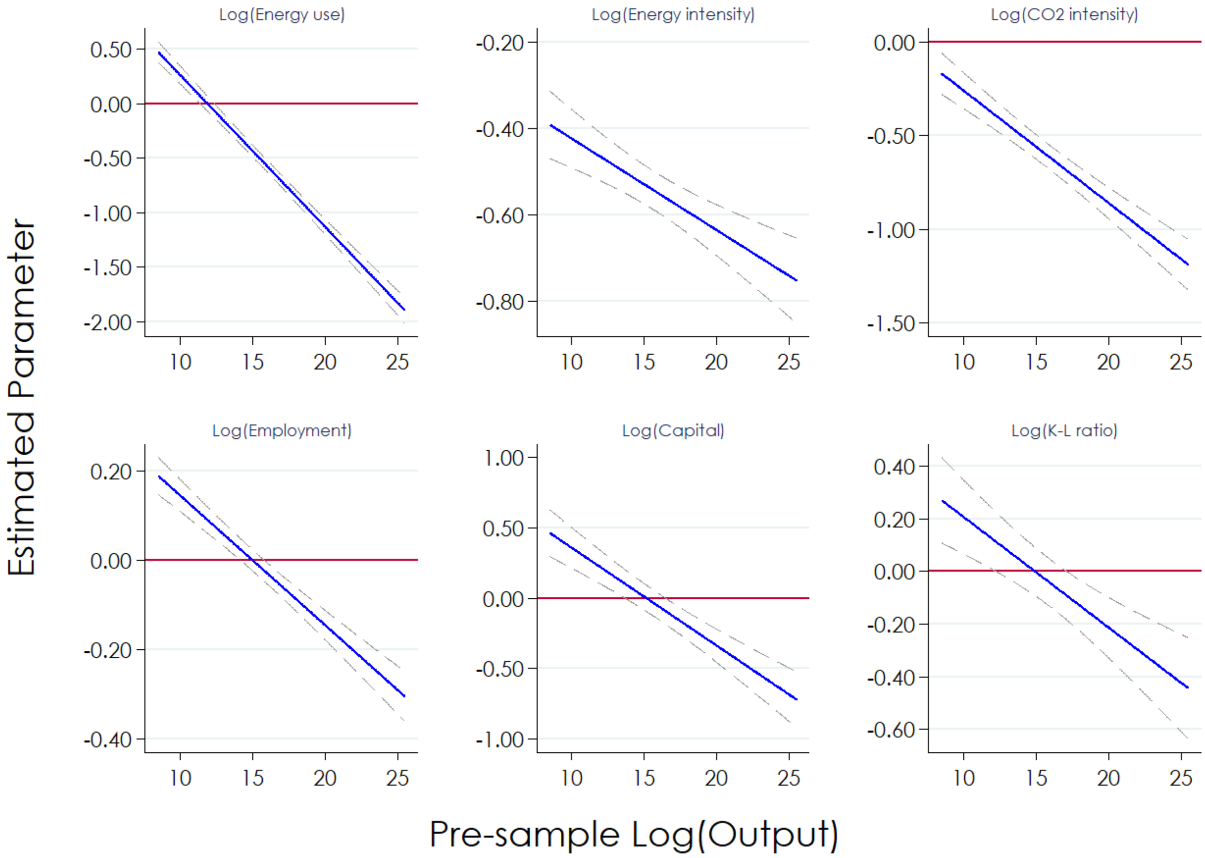
Interestingly, plants with initial output below 3.2 billion IDR (about 230,000 USD) are estimated to increase employment when energy prices increase. Small plants expand in size as energy prices rise: they also see an increase in the capital stock and in total energy use (but energy intensity improves). We conjecture that surviving small plants are more efficient and become more competitive in the event of an energy price increase, as they benefit from a reduction in the market share of larger firms. It could also be that inefficient smaller plants might be forced to exit the market, which then leaves small yet more efficient plants in the same industry with the opportunity to capture a bigger share in the market. We go back to this discussion in the next subsection.

At larger plants, capital and the capital-labour ratio decline as energy price increases, although for the majority of plants the effect is statistically insignificant. For sufficiently large plants, we interpret their response as a short-run adjustment towards less energy-using inputs. While we observe that both capital and labour decline for relatively bigger plants, capital declines faster in response to energy price increases. These results corroborate previous findings that larger plants adjust more to energy price shocks by updating their capital stock. In the short run, these plants sell their "old" capital to purchase new ones. There is likely to be a lag in terms of the updates, which explains why these plants appear to be "downsizing" in terms of their capital stock. In contrast, sufficiently small surviving plants expand as inefficient plants exit the market, giving them incentives to increase their capital stock.

[12] Pre-sample values of output and energy intensity are based on the first year a plant appears in the dataset. This first year is then dropped in the analysis.

[13] Table A.5 shows the results of the estimation for energy use, energy and CO_2 intensities, employment, capital and capital-labour (KL) ratio. The distribution of pre-sample output and energy intensity are illustrated in Figure A. 4.

Figure 5. Estimated effect of a unit in the energy price on energy use, energy intensity, CO_2 intensity, employment, capital and capital-labour ratio at varying pre-sample output



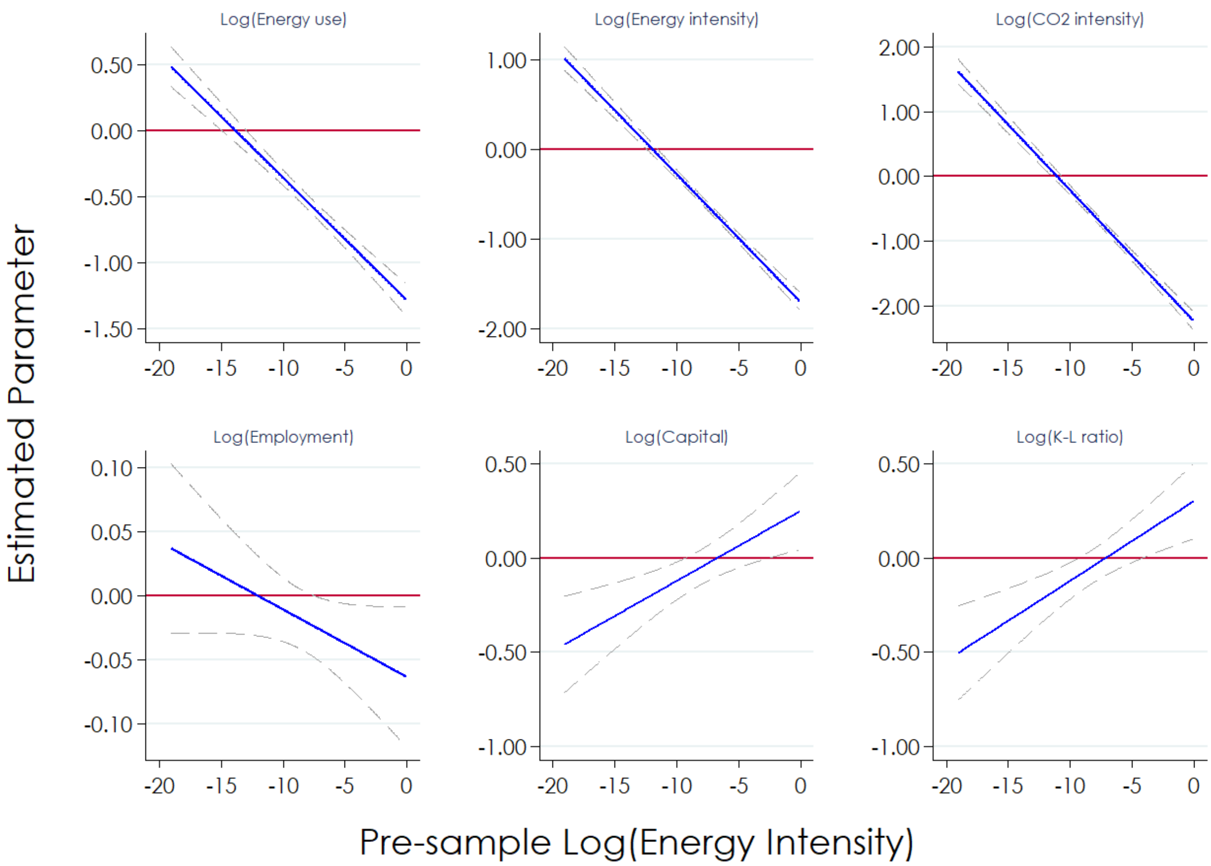
Note: the figure illustrates estimated coefficients of energy price (instrumented by the energy price index FEPI) interacted with pre-sample output. All variables are log-transformed. The dashed lines correspond to the 95% confidence interval.

Meanwhile, plants that are heavily reliant on energy (i.e., those plants whose log energy intensity is closer to zero) respond disproportionately more by reducing their energy use compared to those that are less energy-intensive (Figure 6). This result coincides with the decline in energy and CO2 emission per unit of output.

In terms of employment, we do not find strong evidence to suggest that less energy-intensive plants adjust their employment as a response to an energy price change. In contrast, we find a statistically significant reduction in employment for plants that are above the median energy intensity. Combined with earlier observations, this result implies that relatively bigger and more energy-intensive plants reduce employment in the face of higher energy prices.

The majority of plants do not adjust their capital and capital-labour ratio as the energy price increases. However, it is interesting to see that some less energy-intensive plants reduce their capital and capital-labour ratio when energy price increases.

Figure 6. Estimated effect of a unit in the energy price on energy use, energy intensity, CO_2 intensity, employment, capital and capital-labour ratio at varying pre-sample energy intensity



Note: the figure illustrates estimated coefficients of energy price (instrumented by the energy price index FEPI) interacted with pre-sample energy intensity. All variables are log-transformed. The dashed lines correspond to the 95% confidence interval.

Overall, we observe significant differences in the effect of energy prices on the various outcome variables, depending on their initial size and initial reliance on energy in their production processes. Our results may be reflecting the market structure of the Indonesian manufacturing industry, which is characterized by a number of distortions including some degree of market dominance and plant-level inefficiencies. Energy prices may be working as a catalyst for large and energy-intensive plants to adopt energy-saving production processes in the form of newer machineries and equipment; and may exert competitive pressure that drives small and inefficient plants out of the market.

5.4. Firm exit

The analysis so far has focused on how energy price changes affect various environmental and economic variables in surviving plants. Rather than adjusting energy use and production at the intensive margin, there is a concern that firms might respond to an energy price shock by closing down plants altogether (Rentschler & Kornejew, 2017) or by re-locating to non-regulated countries ("pollution havens") in the case of multinationals (Cole, Elliot, & Zhang, 2017).

We examine this by constructing a dummy variable EXIT which equals 1 in the year of exit (defined as the year following the last reported year) and 0 otherwise. To avoid recording dataset attrition as plant exit, we drop observations in the year 2015, the last year in the sample period. Note as well that the data contains all the business establishments in Indonesia with 20 or more employees. This leaves out the micro and small enterprises in the analysis, which roughly produce about 10% of total manufacturing output in Indonesia (BPS, 2015).

Similar to equation (3), we use an Instrumental Variable (IV) estimator that exploits variation in province-specific energy prices. In particular, we estimate the following probit regression, following Martin, de Preux, & Wagner (2014):

$$\Pr(EXIT_{it} = 1) = \beta ln\hat{p}_{it-1} + \varepsilon_{it} \quad (5)$$

where $ln\hat{p}_{it-1}$ is the time-varying log-transformed energy price index faced by each plant and instrumented by FEPI (as in equation 3) and ϵ_{it} is the usual error term. All regressions include province-specific trend, sector (2-digit ISIC) fixed effects, the age of the plant and its square, and dummy variables indicating whether the initial plant output is below median and whether the plant's initial energy efficiency is below median. We estimate Equation (5) using maximum likelihood estimation and robust standard errors clustered at the plant level. The estimated coefficient β has the interpretation of a local average treatment effect (LATE).

Table 6 reports the result from the IV probit model. Each column pertains to a separate regression; that is, total energy prices, price of fuel and price of electricity are included separately as alternative (instrumented) variables. In each of the exit regressions, the coefficient on initial output is positive and significant. This implies that smaller plants are more likely in general to exit in the market. Surprisingly, plants that are initially less energy-intensive (i.e. those that are below the median energy intensity) are also more likely to exit conditional on size, although the parameter estimate is much smaller compared to plants' initial size. This implies that, holding other things constant, within each 2-digit sector, plants that are relatively less reliant on energy are observed to leave the market more frequently.

We also find evidence that increases in energy prices raise the likelihood of plants to exit the market. This result is driven by increases in fuel prices. Meanwhile, changes in electricity prices do not increase the likelihood of exit.

Table 6. Results of exit regressions

	(1)	(2)	(3)
Log(energy price, total)	0.075***		
	(0.011)		
Log(energy price, fuel)		0.033***	
		(0.007)	
Log(energy price, electricity)			0.004
			(0.009)
Output < median = 1; 0 else	0.224***	0.222***	0.200***
	(0.006)	(0.007)	(0.007)
Energy Intensity < median = 1; 0 else	0.050***	0.046***	0.056***
	(0.006)	(0.007)	(0.007)
Chi-sq.	7313	6280	5160
Observations	469809	394746	346700

Notes: The table reports the results of IV probit regressions of exit at the plant level. The sample period ranges from 1980 to 2015. Coefficients are reported in terms of marginal effects w.r.t. the probability of exit, evaluated at the mean of the explanatory variables. All regressions include province-specific trend, sector (2-digit ISIC) fixed effect, age and age^2. Standard errors clustered at the plant level are in parentheses. *, **, *** denote statistical significance at 10%, at 5% and at 1%, respectively.

We are also interested in determining whether the response to energy prices in terms of exit is associated with the plant's initial output and energy intensity levels. To examine this, we split the sample into groups. The first division is between those that are initially small (i.e. below-median) and relatively larger (results are shown in columns 1 and 2, respectively of Table 7); and the second division is between those that are relatively less energy-intensive (column 3) and above-median initial energy intensity (column 4). Results show that plants, regardless of their initial output, are more likely to exit the market when energy price increases. In contrast, plants that are relatively energy-intensive (or less efficient) are much more likely to shut down in response to increasing energy prices compared to more energy-efficient plants.

Table 7. Results of exit regressions, split sample

	(1) $Output_0 < median$	(2) $Output_0 \geq median$	(3) $\frac{Energy_0}{Output_0} < median$	(4) $\frac{Energy_0}{Output_0} < median$
Log(energy price, total)	0.069***	0.077***	0.027**	0.128***
	(0.014)	(0.017)	(0.014)	(0.018)
Chi-sq.	2667	3321	2645	3262
Observations	208008	261801	224229	245580

Notes: The table reports the results of IV probit regressions of exit at the plant level. Columns (1) and (2) present results from plants with below and above median initial output ($Output_0$) values, respectively; columns (3) and (4) are for plants with below and above median initial energy intensity ($\frac{Energy_0}{Output_0}$), respectively. The sample period ranges from 1980 to 2015. Coefficients are reported in terms of marginal effects w.r.t. the probability of exit, evaluated at the mean of the explanatory variables. All regressions include province-specific trend, sector (2-digit ISIC) fixed effect, age and age^2. Standard errors clustered at the plant level are in parentheses. *, **, *** denote statistical significance at 10%, at 5% and at 1%, respectively.

5.5. Sectoral analysis

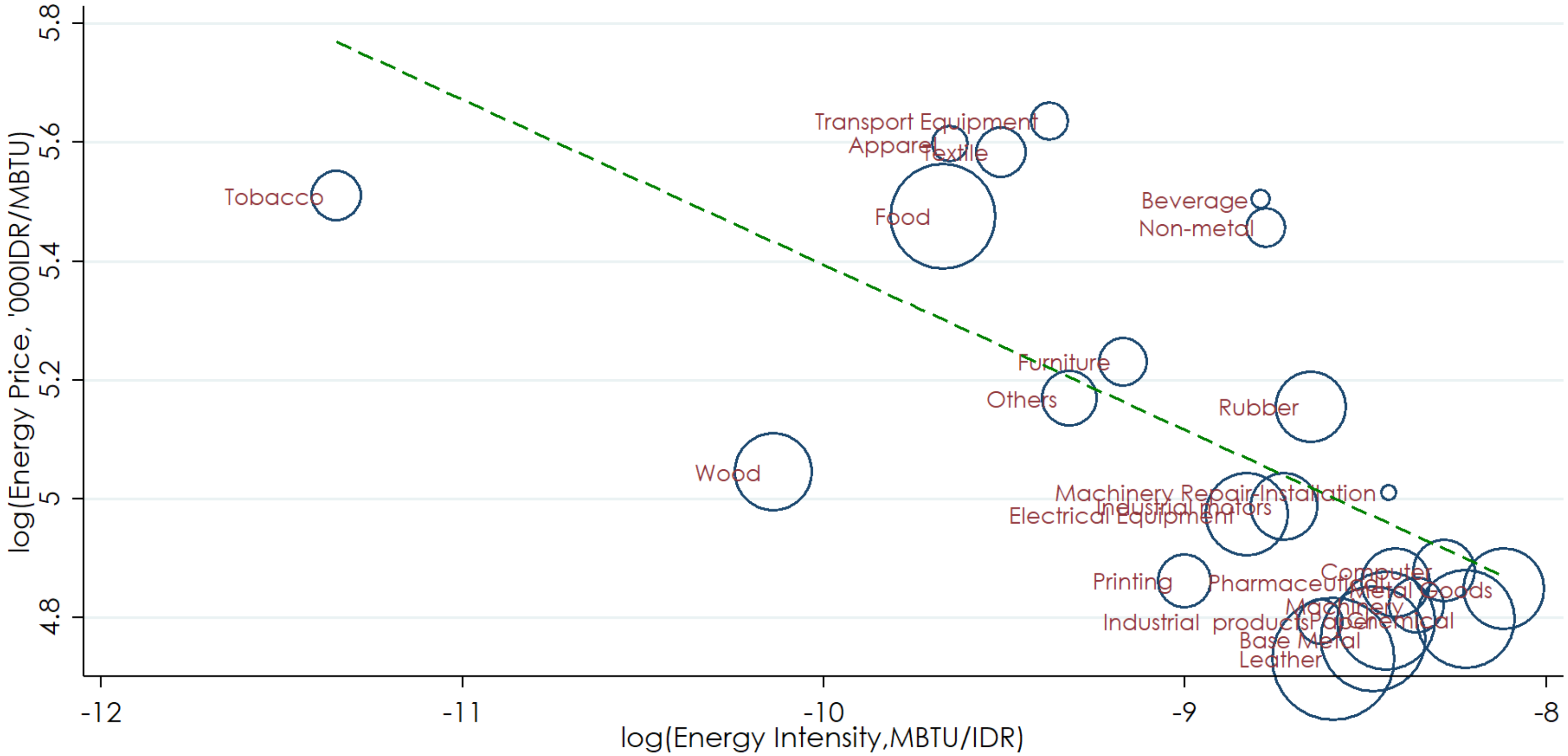
Our analysis has so far focused on the average impact across sectors. However, plants operating in different sectors may react differently to energy price increases. First, plants face different market situations (e.g. the intensity of competition) in different sectors, such that energy price shocks could impact them differently. Second, plants in different sectors also employ different technologies, which may influence their elasticity of demand or their demand for other energy sources.

Figure 7 substantiates the potential differences of plants belonging to different sectors by showing the correlation between energy prices and energy intensity at the industry level, where the size of the sector is represented by the size of the bubbles. First, it appears that sectors that are more energy-intensive generally face lower energy prices. Second, the largest sectors tend to be more energy-intensive (e.g., leather, chemicals and base metal). Thus, it would be interesting to see how these sectors behave in response to an energy price change, particularly as they impact overall employment and output.

Unlike other studies where the source of variation is at the industry level, we leverage on the fact that our identification relies on geographical differences, which then allows us to use our main estimating equation even at the industry level. We can therefore estimate equation (3) for each 2-digit sector level. The estimates are plotted on Figure 8 (the dependent variable is log energy use) and Figure 9 (dependent variable is log employment). In both figures, sector are sorted according to energy intensity and the size of the bubbles denotes the sector's average output. All control variables in the baseline estimation are included in each regression. Each point estimate can be interpreted as price elasticities with respect to the outcome variable.

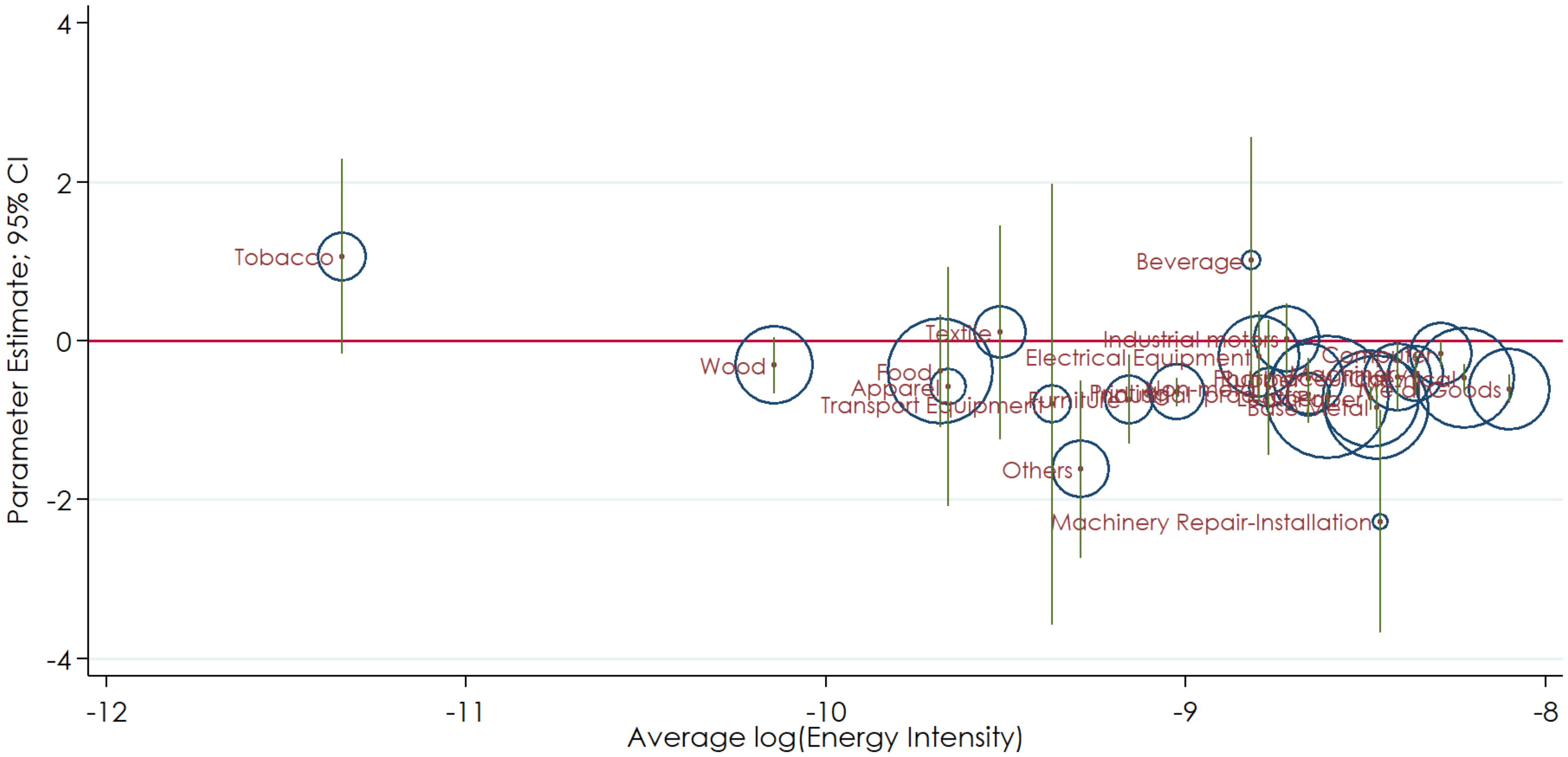
The results show that almost all sectors significantly reduce energy consumption when energy prices rise, and in particular all of the largest sectors with the exception of the food industry, for which the coefficient is negative but insignificant (Figure 8). Only a few sectors, typically non-energy-intensive sectors such as tobacco, textile or beverages do not reduce energy consumption significantly as energy prices increase. These findings also apply for total CO_2 emission (Figure A. 5).

Figure 7. Correlation between energy price and energy intensity at the industry level



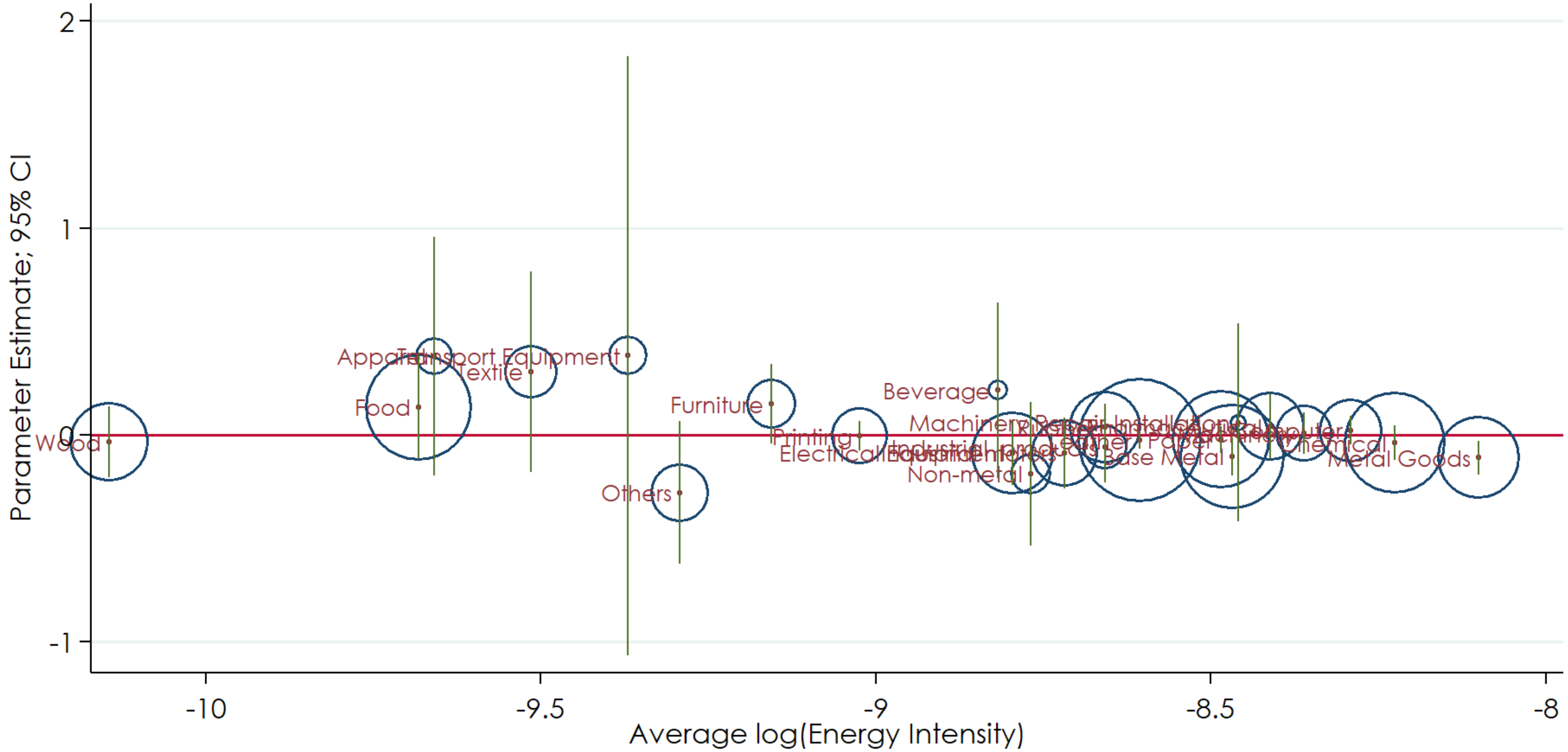
Notes: The figure presents the correlation between 2-digit ISIC sector average log (energy price) and average log (energy intensity). Each point is weighted by the sum of total output (in '000 IDR).

Figure 8. Results of IV regressions at the 2-digit ISIC sector level; Dependent variable = log energy use (in MTBUs)



Notes: The figure presents the parameter estimates from regressing the log-transformed energy use (in MTBUs) on the instrumented log-transformed energy price at the 2-digit sector level. Each point is weighted by the sum of total output (in '000 IDR) to reflect relative contribution to the entire industry. Sector 12 (Tobacco manufacturing) has been dropped to get better illustration. Vertical green bars are 95% confidence intervals.

Figure 9. Results of IV regressions at the 2-digit ISIC sector level; Dependent variable = log employment



Notes: The figure presents the parameter estimates from regressing the log-transformed employment (no. of workers) on the instrumented log-transformed energy price at the 2-digit sector level. Each point is weighted by the sum of total output (in ‘000 IDR) to reflect relative contribution to the entire industry. Sector 12 (Tobacco manufacturing) has been dropped to get better illustration. Horizontal green bars are 90% confidence intervals.

We also explore the heterogeneity of the response to higher energy prices in terms of employment (Figure 9). Interestingly, we find only one sector - metal goods - where an increase in energy prices is associated with a statistically significant (at the 10% level) reduction in employment. We also find similar results for output: for most sectors, energy prices are not associated with a statistically significant change in output, with the exception of the relatively less energy-dependent food sector, which experiences an expansion of output, while the more energy-dependent basic metal contracts in response to energy price increases (Figure A. 6).

5.6. Effect on net job creation

In this subsection, we estimate the effect of energy price changes on employment at the industry level. This analysis seeks to complement the previous analysis on surviving plants by accounting for between-plants adjustments in response to energy price changes. As discussed in the previous subsections, our data accounts for all medium and large enterprises with at least 20 employees. This allows us to measure the net effect of energy price on employment after incorporating the effect of entry and exit of plants within the sample period, as well as growth/contraction of surviving plants.

To analyze the effect of energy prices on employment for the entire Indonesian manufacturing industry, we use the job flow metrics popularized by Davis and Haltiwanger (1992). In contrast, however, we define growth rates at the province level and not at the industry level. This is particularly applicable to the Indonesian setting as energy prices are very much driven by geographic location and allows us to also exploit the panel nature of the dataset even at the relatively aggregated level.

As in Davis and Haltiwanger (1992), we first measure the size of plant *i* at year *t*, denoted by x_{it}, as a simple average of its employment in year *t* and *t-1*. We measure the time-*t* growth rate of plant *i*, denoted by g_{it}, as the change in employment between *t* and *t-1*, divided by x_{it}. If unweighted by output, only about 20% of the annual growth rate observations are coming from entry and exit (Figure A. 7). The share of entry and exit is much smaller at about 14% in the output-weighted frequency distribution (see Figure A. 8).

After calculating the employment growth rates for each plant, we now proceed with the calculation of the gross job creation in a particular province *p* at year *t*, denoted as POS_{pt}, and job destruction, NEG_{pt}. We can write these job flow metrics as follows:

$$POS_{st} = \sum_{i \in Ipt} \frac{x_{it}}{X_{pt}} g_{it} \text{ if } g_{it} > 0 \qquad (6)$$

$$NEG_{st} = \sum_{i \in I} \frac{x_{it}}{X_{pt}} |g_{it}| \text{ if } g_{it} < 0 \qquad (7)$$

In addition, we can also specify the net job creation, $NET_{pt} = POS_{pt} - NEG_{pt}$. A negative NET_{pt} would imply that there are more jobs being destroyed than being created in an area and time period. We then use this job flow metrics to estimate the overall impact of energy price changes on employment taking into account entry, exit and surviving plants in the empirical analysis. We estimate the following equation:

$$y_{it} = \alpha + \beta p_{pt} + \gamma_t + \varphi_p + \varepsilon_{pt} \qquad (8)$$

where $y_{pt} \in \{POS_{pt}, NEG_{pt}, NET_{pt}\}$ is the job flow metric in province p at time t while p_{pt} is the price metric (i.e. the average firm-specific energy price or the $FEPI_{pt}$ as previousy defined). φ_p and γ_t capture province- and year-specific effects, respectively. The above estimation will indicate the effect of energy price movements on the variables of interest.

Results from estimating equation (8) are presented in Table 8. We find no evidence that energy price movements have an influence on either job creation or job destruction at the aggregate level. More importantly, energy price variations have no effect on net job creation, consistent with the findings at the within-sector analysis in the previous subsection. The results are robust regardless of whether we use the average of the energy price faced by plants (top panel) or the FEPI based on geographical drivers of price movements (bottom panel). These results suggest that jobs lost, as identified in the firm level analyses (either at large energy-intensive plants or through plant exit), are reallocated, with jobs lost at particular plants compensated by job hires at other plants within the same sector.

Table 8. Job flow metrics regression results

	POS	NEG	NET	SUM	MAX
Log(energy price)	-0.033	-0.019	-0.014	-0.052	-0.071
	(0.084)	(0.045)	(0.101)	(0.088)	(0.083)
R-sq. adj.	0.356	0.242	0.115	0.598	0.592
Observations	961	961	961	961	961
Log(FEPI)	0.030	-0.022	0.052	0.009	0.009
	(0.049)	(0.039)	(0.064)	(0.061)	(0.055)
R-sq. adj.	0.281	0.213	0.160	0.349	0.305
Observations	961	961	961	961	961
Province FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes: POS = gross job creation; NEG = gross job destruction; NET = net job creation. Robust standard errors clustered at the province level are in parentheses. *, **, *** denote statistical significance at 10%, at 5%, and at 1%, respectively.

6. Conclusions and possible future work

In this paper, we provide new evidence on the effect of energy price changes on firm-level environmental and economic performance using a unique dataset utilizing micro-level information from all medium and large plants in the Indonesian manufacturing industry. Our analysis combines established methodologies from previous studies which seek to extract variations in energy prices that are independent of plant-level decisions. In particular, we exploit regional differences in prices that are rooted in the logistical and infrastructure gaps across different provinces in Indonesia, which have a large influence on cross-sectional energy price variations. We deal with the endogeneity of energy prices by employing a fixed weight energy price index as an instrumental variable, which accounts for potential substitution associated with plant-level technical change.

Results show that energy use and emissions of surviving plants, both in levels and per unit of output, decline significantly in response to an energy price increase. We do not find any strong evidence to suggest that energy price movements have detrimental effect on employment and output, in general. To some extent, plants that are initially small tend to expand their size and capital. We interpret these results as a potential consequence of comparable plants exiting the market, thus giving opportunities for surviving plants to expand. Meanwhile, larger plants do not contract in size when energy price increases. They also respond by updating their capital towards newer and presumably more energy efficient machineries and equipment.

Across sectors, we find significant differences in the response of plants when faced with higher energy prices. We find that large and heavily energy-reliant sectors tend to reduce energy consumption significantly; we do not find such a strong response for plants that have less energy-intensive output. These large and more energy-dependent plants also tend to contribute more to total output and employment. We do not find any statistically significant response across sectors in terms of employment and output (except for the food and basic metal sectors).

Our approach highlights the importance of considering not only surviving firms but also entry and exit when analyzing the effects of energy price policies. At the micro-level, we find that higher energy prices increase the likelihood of plant exit. This response is also higher in magnitude for plants that are relatively more energy-intensive.

Given the above analysis, it is natural to consider the overall effect of increased energy price on employment, taking into account entry and exit, as well as growth and contraction of plants, in the analysis. Results show that energy prices have no detrimental effect on industry-wide employment. While we observe some degree of employment losses due to plant exit, this is compensated by an increase in the size of plants that survive the energy price shock.

The empirical evidence presented in this study suggests that environmental fiscal reforms in an emerging economy, which would increase the price of energy faced by firms, would have large environmental benefits while not inducing employment losses. At worst, the effect on employment is minimal, even after considering the effect of potential plant exits.

The work could be extended in several directions:

- First, it could be of interest to look at the potential effect of energy prices on the distribution of wages over time. As surviving plants adopt newer and energy-saving technologies, it is unclear how this may influence demand for skilled and unskilled labour, and consequently wages for each group. It is usually claimed that eliminating fossil fuel subsidies may adversely impact the poor, and it is possible that there may be indirect negative income effects of energy price changes on poorer people through changes in demand for unskilled labour that are not accounted for in this analysis.

- Second, further analysis could consider potential differences in the response of plants with respect to foreign ownership. Energy prices can put foreign-owned firms at a competitive advantage due to their superior technology over domestic plants. How foreign-owned respond to energy price shocks in terms of environmental and economic performance could be worth analysing, particularly when they have the option to offshore production, exit or contract operation.

- Third, the dataset holds information on workers by gender which could be exploited further. Environmental fiscal reforms might affect men and women differently through changes in the labour distribution. In the context of sustainable development goals, there may be opportunities to explore the interlinkages between environmental policies and equality between men and women.

References

ADB. (2015). *Fossil Fuel Subsidies in Indonesia: Trends, Impacts and Reforms.* Manila: Asian Development Bank.

Arnold, J. M., & Javorcik, B. (2009). Gifted kids or pushy parents? Foreign direct investment and plant productivity in Indonesia. *Journal of International Economics, 79*(1), 42-53.

Bartik, T. (1991). *Who Benefits from State and Local Economic.* Kalamazoo, MI: W.E. Upjohn Institute for Employment Research. Retrieved from https://doi.org/10.17848/9780585223940

Beaton, C., & Lontoh, L. (2010). *Lessons Learned from Indonesia's Attempts to Reform Fossil-Fuel Subsidies.* Geneva: International Institute for Sustainable Development.

Bound, J., Jaeger, D. A., & Baker, R. M. (1995). Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak. *Journal of the American statistical association, 90*(430), 443-450.

BPS. (2015). *Badan Pusat Statistik*. Retrieved from IBS: https://mikrodata.bps.go.id/mikrodata/index.php/catalog/IBS

Brännlund, J., & Lundgren, T. (2009). Environmental Policy without costs? A review of the Porter Hypothesis. *International Review of Environmental and Resource Economics, 3*, 75-117.

Brucal, A., Javorcik, B., & Love, I. (2018). *Energy savings through foreign acquisitions? Evidence from Indonesian manufacturing plants.* Working Paper No. 289, Grantham Research Institute on Climate Change and the Environment, London. Retrieved January 2019, from http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/01/Working-Paper-289-Brucal-et-al-1.pdf

Cali, M., Cantore, N., Iacovone, L., Pereira Lopez, M. D., & Presidente, G. (2019). Too Much Energy : The Perverse Effect of Low Fuel Prices on Firms. *World Bank Policy Research Working Paper WPS 9039*.

Chelminski, K. (2018). Fossil Fuel Subsidy Reform in Indonesia: The Struggle for Successful Reform. In J. a. Skovgaard, *The Politics of Fossil Fuel Subsidies and their Reform* (pp. 1983-211). Cambridge University Press.

Cole, M., Elliot, R., & Zhang, L. (2017). Foreign direct investment and the environment. *Annual Review of Environment and Resources, 42*, 465-487.

Davis, S., & Haltiwanger, J. (1992). Gross Job Creation, Gross Job Destruction, and Employment Reallocation. *The Quarterly Journal of Economics, 107*(3), 819-863. doi:http://hdl.handle.net/10.2307/2118365

De Canio, S. (1993). Barriers within firms to energy-efficient investments. *Energy Policy, 21*(9), 906-914.

Dussaux , D. (2020). The joint effects of energy prices and carbon taxes on environmental and economic performance: Evidence from the French manufacturing sector. In *OECD Environment Working Papers.* OECD Publishing, Paris. doi:https://dx.doi.org/10.1787/b84b1b7d-en

Friedrich, J., Ge, M., & Pickens, A. (2017, April 11). *This Interactive Chart Explains World's Top 10 Emitters, and How They've Changed.* Retrieved from World Resources Institute: https://www.wri.org/blog/2017/04/interactive-chart-explains-worlds-top-10-emitters-and-how-theyve-changed

IEA. (2016). *Fossil Fuel Subsidy Reform in Mexico and Indonesia.* Paris: International Energy Agency.

IMF. (2013). *Case Studies on Energy Subsidy Reform: Lessons and Implications.* Washington, DC: International Monetary Fund.

Kojima, M. (2016). *Fossil Fuel Subsidy and Pricing Policies: Recent Developing Country Experience.* Washington, DC: The World Bank.

Linn, J. (2008). Energy Prices and the Adoption of Energy-Saving Technology. *The Economic Journal, 118*(533), 1986-2012.

Marin, G., & Vona, F. (2017). *The Impact of Energy Prices on Employment and Environmental Performance: Evidence from French Manufacturing Establishments.* Fondazione Enrico Mattei. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3089662

Martin, R., de Preux, L., & Wagner, U. (2014). The impact of a carbon. *Journal of Public Eco-, 117*(C), 1-14.

Merill, L., Casier , L., & Bassi, A. (2015). *Fossil-Fuel Subsidies and Climate Change: Options for policy-makers within their Intended Nationally Determined Contributions.* Copenhagen: Norden, Nordic Council of Ministers.

OECD. (2017). *Environmental fiscal reforms: Progress, prospects and pitfalls.* Organisation for Economic Co-operation and Development. Retrieved from http://www.oecd.org/tax/tax-policy/environmental-fiscal-reform-G7-environment-ministerial-meeting-june-2017.pdf

Olley, G., & Pakes, A. (1996). The Dynamics of Productivity in the Telecommunications. *Econometrica,, 64*(6), 1263-1297.

Pavcnik, N. (2002). rade liberalization, exit, and productivity improvements: Evidence from Chilean plants. *The Review of Economic Studies, 69*(1), 245-276.

Pischke, J. (2018, October 19). *Weak Instruments.* Retrieved from The London School of Economics: http://econ.lse.ac.uk/staff/spischke/ec533/Weak%20IV.pdf

Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives, 9*(4), 97-118.

Rentschler, J., & Kornejew, M. (2017). Energy price variation and competitiveness: Firm level evidence from Indonesia. *Energy Economics, 67*, 242-254.

Rentschler, J., & Kornejew, M. (2018). Energy price variation and competitiveness: Firm level evidence from Indonesia. In J. Rentschler, *Fossil Fuel Subsidy Reforms: A Guide to Economic and Political Complexity* (1st Edition ed., pp. 75-106). London: Routledge. doi:https://doi.org/10.4324/9781351175821

Sato, M., Singer, G., Dussaux, D., & Lovo, S. (2015). *International and sectoral variation in energy prices 1995-2011: how does it relate to emissions policy stringency?* London: Grantham Research Institute on Climate Change and the Environment.

Annex A. Additional tables and figures

Conversion Factors

Table A. 1. Sources of Conversion Factors

Conversion to Energy (in MBTUs)	
Gasoline	Silverman, D. (Univ. of California, Irvine)
Diesel	US Energy Information Administration
Fuel Oil/Bunker Oil	US Energy Information Administration
Kerosene	US Energy Information Administration
Lubricants	US Energy Information Administration
Coal	US Environmental Protection Agency
Coke	US Energy Information Administration
Public Gas	US Bureau of Mines
Liquefied Petroleum Gas	US Environmental Protection Agency
Firewood	Silverman, D. (Univ. of California, Irvine)
Charcoal	Oak Ridge National Labouratory
Electricity	US Energy Information Administration
Conversion to CO_2 (Kg)	
Gasoline	US Energy Information Administration
Diesel	US Environmental Protection Agency
Fuel Oil/Bunker Oil	US Environmental Protection Agency
Kerosene	US Environmental Protection Agency
Lubricants	US Energy Information Administration
Coal	US Energy Information Administration
Coke	US Energy Information Administration
Public	US Energy Information Administration
Liquefied Petroleum Gas	US Energy Information Administration
Firewood	US Energy Information Administration
Charcoal	Akagi et al. (2011)
	US Environmental Protection Agency

Source: (Brucal, Javorcik, & Love, 2018).

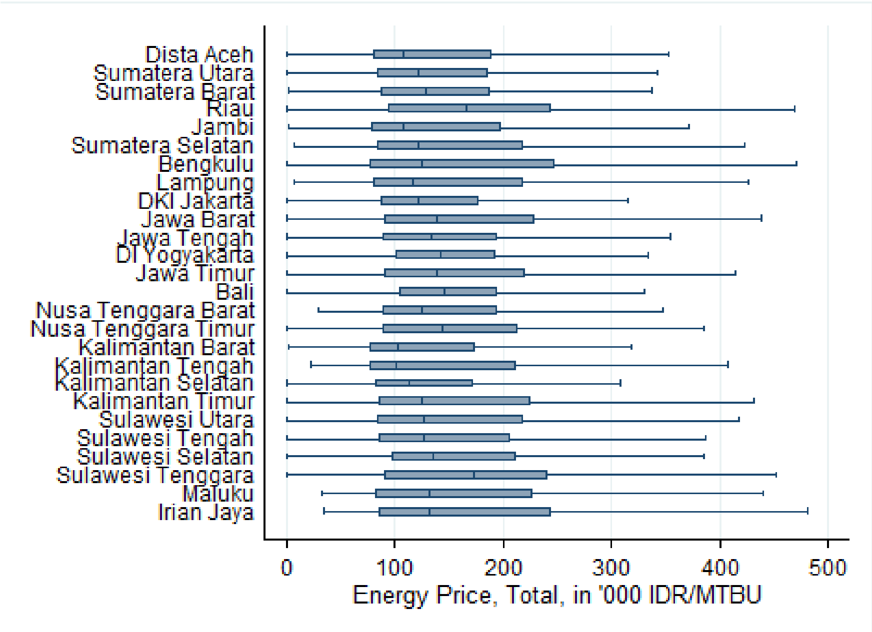
Table A. 2. Timeline of fossil fuel subsidy reforms in Indonesia

Date	Pricing reform
1997	Following the Asian financial crisis, government increased kerosene, diesel and gasoline prices by 2, 60 and 71 per cent, respectively.
2000	Kerosene, diesel and gasoline prices were raised for households despite violent demonstrations.
2001	Kerosene, diesel and gasoline prices were raised for industry.
2003	An attempt was made to link movements in domestic fuel prices and international prices.
2005	Prices increased by 29 per cent in March and 114 per cent in October. Industry was no longer eligible to access subsidised diesel.
2006	Prices increased for industrial users.
2007	Introduction of kerosene-to-LPG conversion programme encouraged LPG use, and the kerosene subsidy was phased out.
2008	Prices increased in May of 33 per cent for gasoline, 28 per cent for diesel and 25 per cent for kerosene. Gasoline and diesel prices were lowered in December by 20 and 15 per cent, respectively, as international oil prices eased.
2009	Prices lowered in January by 11 per cent for gasoline and 7 per cent for diesel, leaving gasoline prices the same as diesel prices (close to 2005 levels).
2013	One-off price increase averaged 40 per cent.
2013	Base tariff increased by 15 per cent over 2013 (households consuming more than 450 to 900 volt-amperes were not included).
Jan-14	An attempt was made to raise prices of 12-kilogram cylinders, but the price increase was rolled back.
Nov-14	Government initiated price increases of 31 per cent for gasoline and 36 per cent for diesel.
Jan-15	Subsidies for gasoline were entirely removed, but low oil prices result in a price decline of 12 per cent. Diesel subsidies reduced to IDR 1,000 per litre.
2016	Diesel subsidy was removed.

Sources: (Beaton & Lontoh, 2010); (IMF, 2013); (ADB, 2015); (IEA, 2016); (Kojima, 2016)

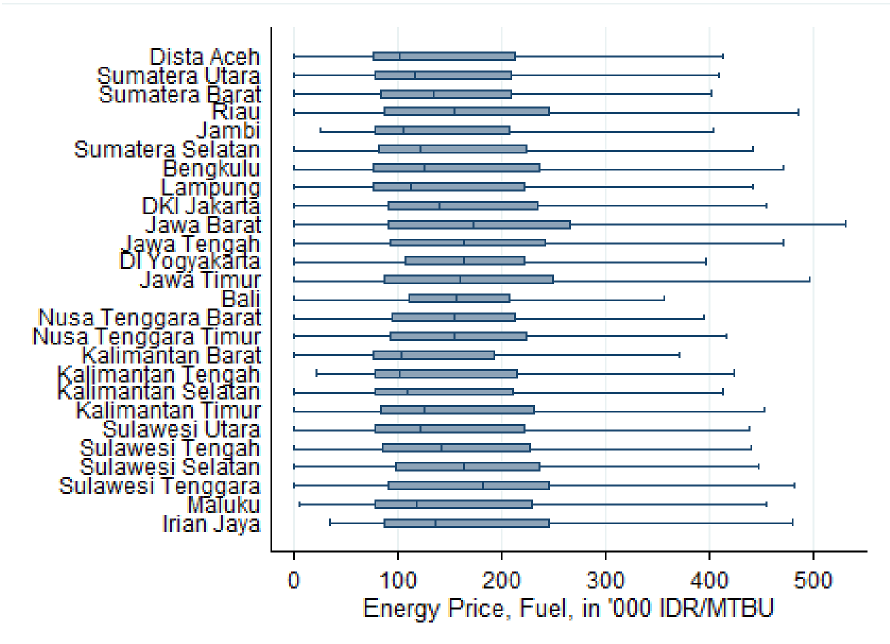
Variation in energy price index (FEPI) between provinces over time

Figure A. 1. Distribution of FEPI across provinces, Total, 1980-2015



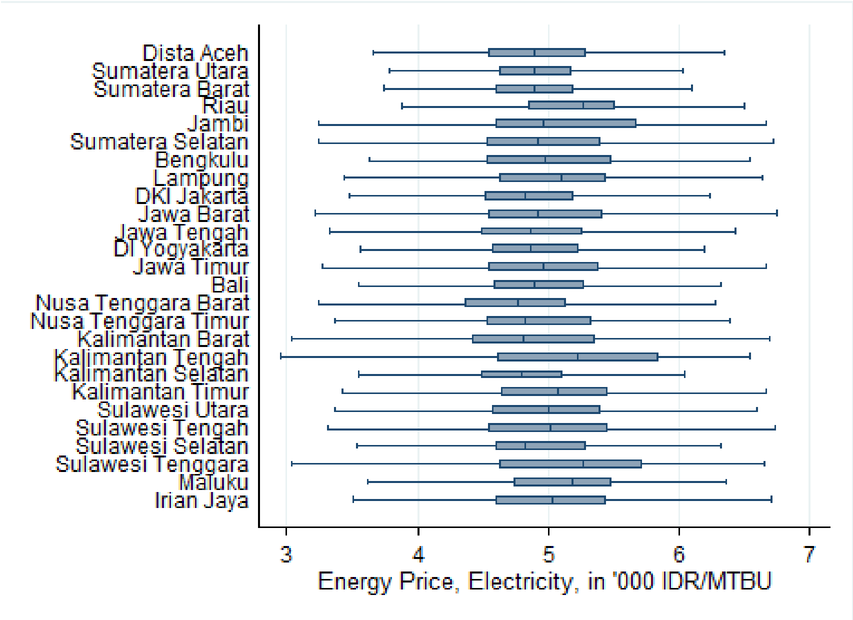
Note: The figure shows the 10th percentile, interquartile range, median and the 90th percentile.

Figure A. 2. Distribution of FEPI across provinces, Fuel, 1980-201



Note: The figure shows the 10th percentile, interquartile range, median and the 90th percentile.

Figure A. 3. Distribution of FEPI across provinces, Electricity, 1980-2015



Note: The figure shows the 10th percentile, interquartile range, median and the 90th percentile.

Robustness Checks

Table A. 3. Effect of energy price on environmental performance and economic performance, standard errors clustered at the province level

Variables	Energy use	CO_2 emission	Output	Employment
Log(energy price)	-0.523***	-0.577***	0.017	-0.020
	(0.033)	(0.050)	(0.030)	(0.015)
Kleibergen-Paap LM Statistic	6	6	6	6
	(0.015)	(0.015)	(0.01)	(0.015)
Kleibergen-Paap F-stat	472	472	472	472
Observations	485621	485663	485646	485672
Plant FE	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	Yes
Province Trend	Yes	Yes	Yes	Yes

Notes: Log (energy price) is instrumented by fixed energy price index (FEPI). Robust standard errors clustered at the province level are in parentheses. *, **, *** denote statistical significance at 10, 5 and 5 percent, respectively.

Other Tables and Figures

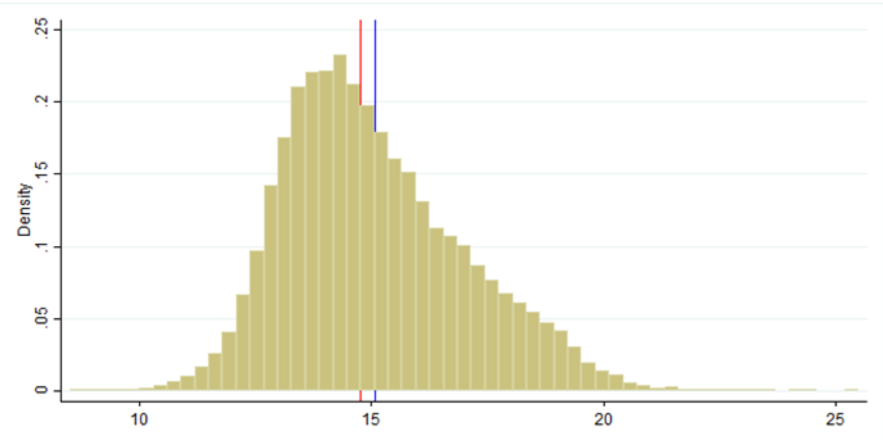
Table A. 4. The effect of energy prices on plant-level environmental and economic performance conditional on initial output and energy intensity

	Energy use	Energy intensity	CO_2 intensity	Employment	Capital	KL ratio
Log (energy price)	1.658***	-0.212***	2.213***	0.435***	1.055***	0.628***
	(0.090)	(0.075)	(0.115)	(0.041)	(0.158)	(0.154)
Initial output (t=1)	-0.139***	-0.021***	-0.178***	-0.029***	-0.070***	-0.042***
	(0.005)	(0.005)	(0.007)	(0.003)	(0.009)	(0.009)
Observations	466907	466882	466949	466953	243695	243695
K-P LM stat	6229	6229	6229	6229	3848	3848
	0.000	0.000	0.000	0.000	0.000	0.000
K-P F-stat	7721	7721	7722	7722	4498	4498
Log (energy price)	-1.283***	-1.698***	-1.827***	-0.064**	0.252**	0.304***
	(0.062)	(0.051)	(0.081)	(0.028)	(0.104)	(0.102)
Initial energy intensity (t=1)	-0.093***	-0.142***	-0.153***	-0.005*	0.037***	0.042***
	(0.007)	(0.006)	(0.009)	(0.003)	(0.011)	(0.011)
Observations	466899	466874	466941	466945	243692	243692
K-P LM stat	6145	6145	6145	6145	3827	3827
	0.000	0.000	0.000	0.000	0.000	0.000
K-P F-stat	7574	7573	7574	7574	4491	4491
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Province Trend	Yes	Yes	Yes	Yes	Yes	Yes

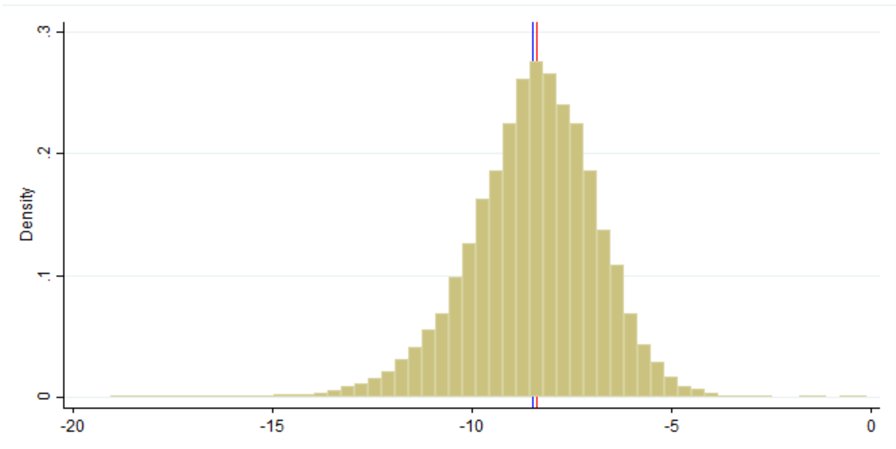
Notes: Log (energy price) is instrumented by fixed energy price index (FEPI). Robust standard errors clustered at the plant level and Chi-Sq. P value for the Kleibergen-Paap LM Stastistic are in parentheses. *, **, *** denote statistical significance at 10, 5 and 5 percent, respectively.

Figure A. 4. Distribution of initial output and energy intensity values, 1980-2015.

(A) Output=1

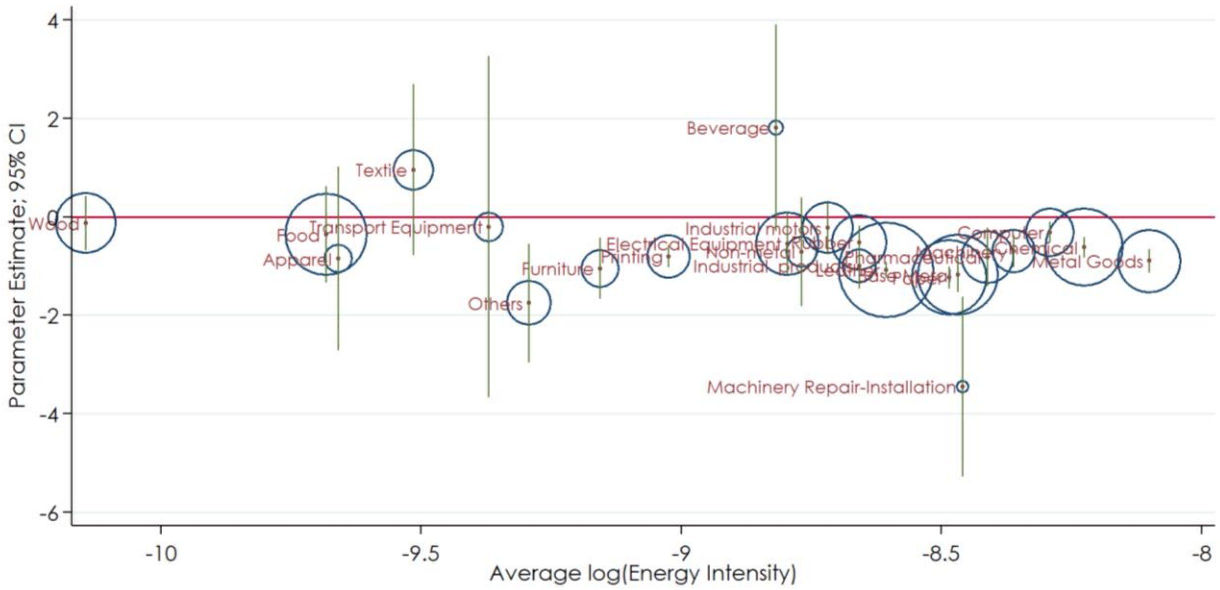


Energy intensity=1



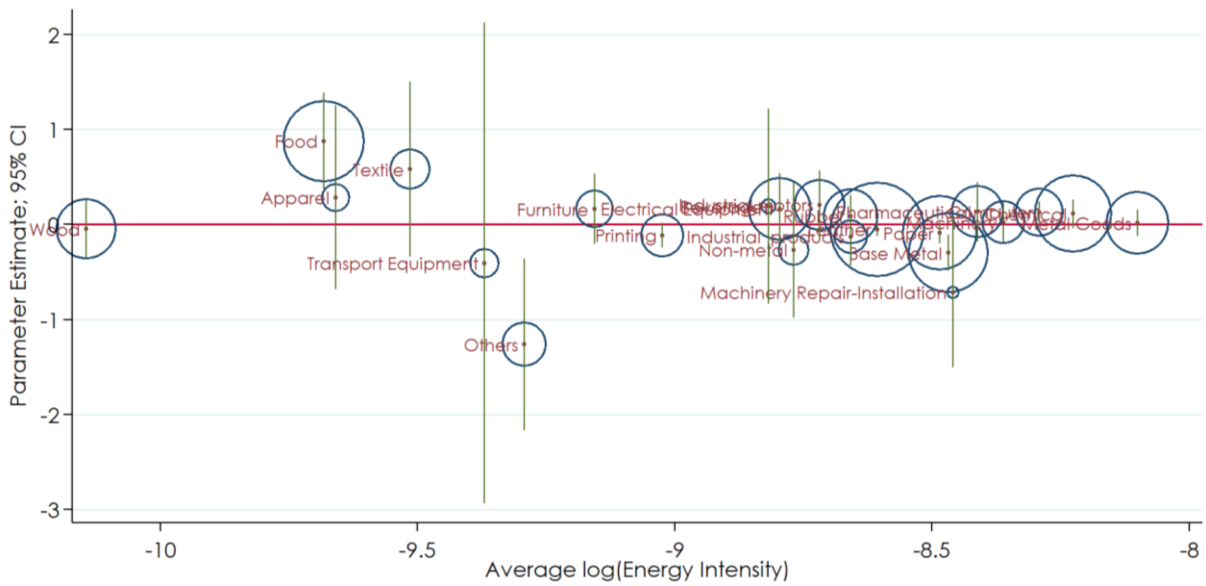
Source: Authors' calculations.

Figure A. 5. Results of IV regressions at the 2-digit ISIC sector level; Dependent variable = log CO_2 emission.



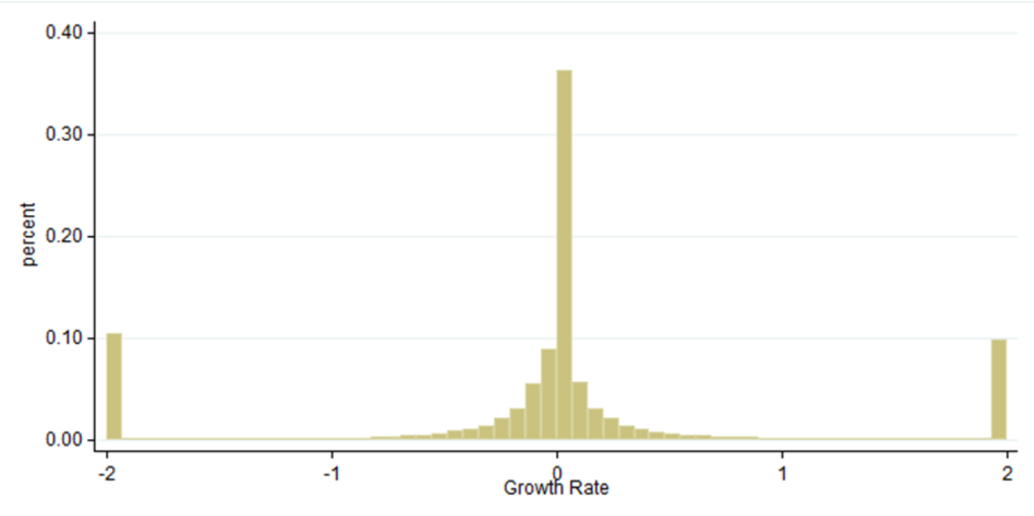
Notes: The figure presents the parameter estimates from regressing the log-transformed CO_2 emission ($KgCO_2$) on the instrumented log-transformed energy price at the 2-digit sector level. Each point is weighted by the sum of total output (in ‘000 IDR) to reflect relative contribution to the entire industry. Sector 12 (Tobacco manufacturing) has been dropped to get better illustration.

Figure A. 6. Results of IV regressions at the 2-digit ISIC sector level; Dependent variable = log real output.



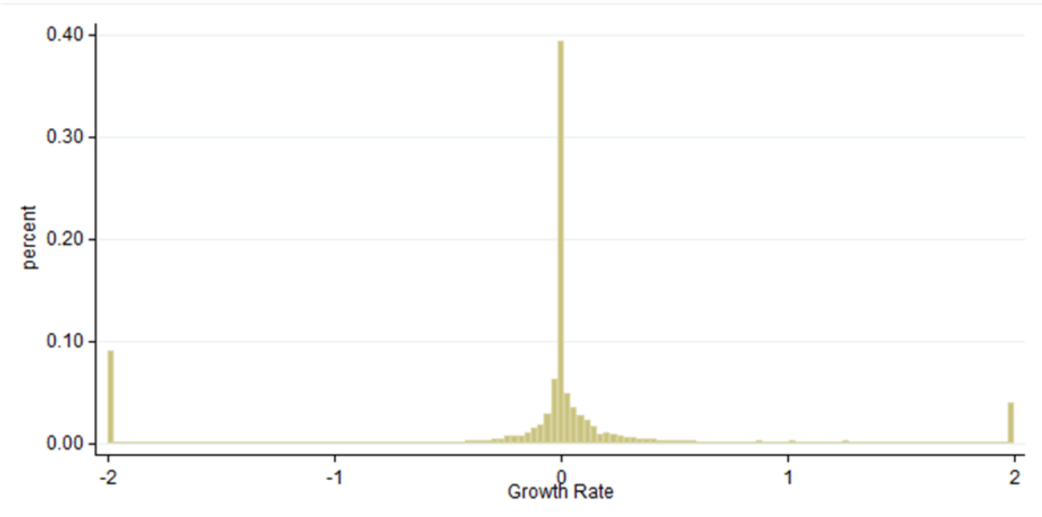
Notes: The figure presents the parameter estimates from regressing the log-transformed output (in ‘000IDR) on the instrumented log-transformed energy price at the 2-digit sector level. Each point is weighted by the sum of total output (in ‘000 IDR) to reflect relative contribution to the entire industry. Sector 12 (Tobacco manufacturing) has been dropped to get better illustration.

Figure A. 7. Unweighted employment growth rate distribution.



Note: The figure shows the empirical density of the 620,000 year-establishment observations between 1980 and 2014. The density is somewhat assymetric with central peaks in the interval [-2.2] with exit and entry corresponding to the endpoints.
Source: BPS-IBS, 1980-2015 (rates are authors' calculations)

Figure A. 8. Distribution of employment growth rate weighted by real output.



Notes: The Figure depicts the shape of the empirical density of observations over output-weighted observations on the 620,000 year-establishment observations between 1980 and 2014. The density is somewhat assymetric with central peaks in the interval [-2.2] with exit and entry corresponding to the endpoints.
Source: BPS-IBS, 1980-2015 (rates are authors' calculations)