The Effects of Carbon Taxes on Firms' Carbon Emission: Simulation Model in Indonesia

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Abstract. This research examines the effect of taxes on carbon on firms' carbon emissions. To examine the effect, this research used a manufacturing firm-level dataset from 2012-2019. The data were secondary data collected by Indonesian Statistics. The research did not include 2020 and 2021 because Indonesian Statistics did not survey those years because of the Covid 19 pandemic. It did not include the data in 2016 either due to the unavailability of data. The research data includes the types and numbers of energy consumed by the firms to calculate the firms' carbon emission, investment, and value-added. By using the common effect approach, the study result indicates that increasing the marginal cost of carbon taxes increased firms' carbon emissions. Thus, this result did not provide empirical evidence that the IDR 30.00 tariff of a carbon tax is an effective carbon pricing policy. This might be because the carbon tax tariff of IDR 30.00 per kilogram of CO_2e is still low, so the tariff did not effectively push firms to consume fossil fuels more efficiently and adopt clean technology.

Keywords: Allowance, Carbon pricing, Carbon emissions, Carbon tax, Fossil fuels

1 Introduction

More investment in sustainable energy and energy efficiency measures is needed to reach the Paris Agreement goal of fewer than 1.5 degrees of global warming. The damages resulting from global warming have not been included in the price that communities bear the costs. These costs are called externalities [1]. Externalities such as pollution are market failures because pollution costs are not included in market prices and affect people other than emitters [2]. Carbon pricing, consisting of a tax carbon or carbon trading mechanism, incentivizes companies to be more energy-efficient and shift from fossil fuels to sustainable energy by swelling carbon emission costs [3]. However, even though there is an agreement on the vital of carbon pricing in dealing with global warming, thorough empirical tests employing data at the firm level are still rare.

Many studies on carbon pricing and competitiveness have been conducted. For example, Anger and Oberndorfer [4] found that allowable carbon allocation affects company income and employment in Germany but is not significant on firm competitiveness. Arlinghaus [5] concluded that most time-series econometric research shows that carbon pricing significantly impacted environmental effectiveness but could not find a

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significant effect on competitiveness. Based on the previous literature findings, Arlinghaus suggested that the explanation lies in the carbon costs directly passed on to consumers. Venmans et al. [6] studied carbon pricing and competitiveness concerning the decline in competitiveness because of implementing of carbon pricing. Flues and Lutz [7] examined the competitive impact of the electricity tax on German firms, employing a discontinuity regression analysis to compare the impact between firms paying the full tax rate and firms qualified for an 80% discount. They argue that the current tax exemption rules are unnecessary because granting tax exemptions does not affect the competitiveness of companies and suggest that tax exemptions should be phased out and the effect of these step-by-step eliminations should be evaluated. Jaraite et al. [3] find that the Swedish carbon tax significantly affects corporate environmental spending. However, they find no significant effect of this carbon tax on investment in carbon reductions. Meanwhile, in France, Dussaux [8] found that a 10% rise in energy prices (due to incorporating a carbon levy) leads to a decrease in fossil fuel use by 6.5%, greenhouse gas emissions at 9.2%, and 5.2% of energy intensity. Brännlund et al. [9] used company panel data from 1990-2004, and Martinsson and Strömberg [10] used a similar approach from 1990-2015. They found evidence that carbon taxes reduced emissions and production over that period. The intensity of carbon emissions decreases by 3.4%.

The existing research was conducted in the developed countries implementing the scheme, so the data is available. For Indonesia, carbon pricing has not been implemented yet. Unfortunately, what is already implemented in other countries cannot automatically be implemented in Indonesia due to different socio-economic and people welfare levels. Hence, another economic strategy is needed to analyze the impact of Indonesia's carbon tax on firm carbon emissions due to the lack of micro data for carbon taxes, considering that the carbon tax in Indonesia will take effect soon. This study, therefore, aims to examine the effect of a carbon tax on firms' carbon emissions. For that purpose, this study used past data, where the past data will be used. Each emission is calculated and subject to applicable tax rates for simulation modeling.

2 Method

This research will develop a carbon pricing model through a carbon tax. A simulation of the carbon tax impact on carbon emissions is carried out (Table 1). The samples taken are manufacturing companies with data on fuel and electricity consumption which are used to calculate the carbon emissions produced by each company and regulations for quoting industrial fuel and carbon taxes. The data collected is used to estimate the carbon emissions produced by the company and calculate the company's carbon tax. This study also includes the firm's investments—time series data for 2012, 2013, 2014, 2015, 2017, 2018, and 2019. The research did not include data from 2016, 2020, and 2021 because Indonesian Statistics did not survey during those years. The data needed in the research is the company's consumption of fossil fuels and electricity, output, input, value-added, and company investment that all the data are available in

the Indonesian Statistics survey [11]. Furthermore, in determining the sample, the companies produced significant carbon emissions, which consume energy per output above the average of all companies included.

Table 1. Measurement of Research Variables

Variable	Information
	Dependent variables
Carbon emission [12]	Ln Carbon emission
	Independent Variable
Carbon tax [13]	$\left(\frac{\text{Marginal carbon emissions}}{\text{output}}\right) * \text{Carbon tax tariff}$ $\text{Marginal emission} = \frac{\text{Carbon emission}}{\text{output}} - \text{Allowance of carbon emission}$ $\text{The limit of carbon emission allowance} = \frac{\sum^{\frac{\text{carbon emission}}{\text{Output}}}}{\text{number of samples}}$
Fuel tax tariff	fuel tax tariff for industrial needs * fuel expenses of a firm in a year
	Control Variables
Investment [14]	Ln Investment
Value added [15]	Ln Value added
Firm's status	Dummy variable, score 1 for the carbon-intensive firm Carbon-intensive companies produce carbon above the cut-off percentile value of 90% of the total sample. Score 0 for companies not classified in group 1
Over/under the limit	$\frac{\text{Produced carbon emissions}}{\text{Output}} - \left(\frac{\sum \frac{\text{Carbon emission}}{\text{Output}}}{\text{Number of samples}}\right)$

2.1 Simulation model development

The common effect model is used to analyze the impact of a carbon tax on firms' carbon emissions. The common effects model's main advantage was the ability to deal with unobserved firm heterogeneity, focusing on variations within firms. Many factors can influence how companies respond to changes in fossil fuel and uncontrollable carbon taxes, making the common effect model the most suitable choice. Unobserved factors are assumed to be unchanged in the short run. This study uses the usual OLS regression model but does not control the unobserved factors. Previous studies have also used this common effect method [8-10].

This study takes a policy design in which the treatment is resolute by variables that take place continuously, not before and after approaches, because the before-after approach relies on differential analysis; meanwhile, the carbon tax has not taken place in Indonesia [16]. Accordingly, this study used Flues and Lutz's previous study [7] with a regression with the common effect model because tax rates from new policy research are enforced. The Flues and Lutz approach [7] can be implemented to develop a simulation model with the assumption that the carbon tax policy has been implemented in manufacturing companies in Indonesia. Due to the carbon tax implementation, the carbon tax and allowance data must be built based on the available data on each company's carbon emissions. Among them, the maximum allowable carbon emission limit equals the average carbon emission intensity of all manufacturing companies included in the

sample. Based on the presidential regulation, the carbon tax is set at Rp.30 per kg or Rp.30,000 per tonne on the company's carbon emissions [13]. This carbon tax is imposed on the excess carbon emissions produced.

To approximate the impacts of dissimilar groups, e.g., company status on carbon emissions generated or interaction requirements are needed. In the common effect model, two main assumptions must be met for the common effect model to be effective. First, the regressor should not be constant over time because the regressor being observed varies over time. The second assumption is a strict exogenous assumption, (ϵit |) = 0, which is necessary for the estimation to be consistent [17]. This refers to the absence of a correlation between the regressor and the firm's unobserved share varying over time. This postulation is expected to exist because the marginal tax rate is not impacted by the variance of the firm's time-specific factors. Certain companies may be able to produce high carbon emissions so that companies can develop policies on carbon. Using the company's carbon emission status dummy, this study can distinguish the relative importance of the factors between sectors. For example, rising fuel prices will affect the manufacturing sector more. Changes in fuel prices motivate companies to reduce their consumption of fossil fuels. This is because changes in fossil fuel prices are mostly exogenous to the company. It is also possible for the government to develop a carbon tax policy.

2.2 Model specifications

The following model shows the common effects model [18]:

$$yist = \beta \boldsymbol{X} it + \varepsilon it \tag{1}$$

Y donates for the dependent variable of firm i in sector s at time t. X designates the vector of the regressors, diverging between entities and over time [18]. The dependent variable is used to determine the impact of the carbon tax on carbon emissions. The specification model will be used to analyze the regression:

$$\text{Ln (carbon emission)}_{ist} = c_i + \beta_1 * \ln(\text{Carbon tax})_{it} + \beta_2 * \ln(\text{fuel tax})_{it} + \beta_3 * \text{Value added}_{it} + \beta_4 * \text{Firm's status}_{it} + \beta_5 * \ln(\text{Investment})_{it} + \varepsilon_{it} \tag{2}$$

A log-linear specification is employed that enables to construe of the parameters. It is vital to highlight that this model solitary captures the immediate effects of carbon pricing. Moreover, it was previously found that carbon pricing affects energy intensity [9, 19]. Logic says a higher carbon tax can increase and decrease a company's carbon emissions. A carbon tax that is too low does not motivate companies to reduce company emissions because the company feels that the tax paid is still not worth it [20]. Carbon taxes can reduce carbon emissions if the taxes applied are high enough. Companies are trying to avoid the costs of paying significant taxes, so they will try to decrease their carbon emissions. To examine whether the tax impact is heterogeneous concerning carbon emissions. The model specification above is also estimated for the subsample with carbon-intensive companies (defined as companies that emit carbon above the 90%

percentile value of all companies) and non-carbon-intensive companies (below the 90% percentile value of all companies).

3 Result and Discussion

3.1 Descriptive Analysis

The amount of carbon a company uses depends on many factors, such as the type of fuel consumed, electricity consumed, production methods, and the technology used. These factors vary across industries and affect a firm's potential and costs to reduce emissions.

Table 2. The results of descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Ln CEmission	36,624	13.4358	2.221493	6.405096	23.95903
Ln_CarbonTax	36,624	2.09E-07	0.0002314	-0.0000824	0.0128764
Ln_FuelTax	36,624	0.0004415	0.0060648	8.47E-09	0.5306746
Value_Add	36,624	1.65E+10	1.28E+11	162	8.90E+12
Firm Status	36,624	0.0498853	0.217711	0	1
Ln_Invest	36,624	20.73516	2.713714	6.907755	32.96696

Source: calculated data

The results of descriptive statistics can be seen in Table 2. The total number of observations for eight years, namely 2012, 2013, 2013, 2014, 2015, 2017, 2018, and 2019 in Indonesia was 5232 companies. The company's carbon emissions are measured by Ln carbon emissions produced in kilograms of CO_2e. The average carbon emission produced is 13.4358 kg CO_2e. The average carbon tax rate is 0.000000209 per kg CO_2e. The minimum number is -0.0000824. The minus number means companies with a minus carbon tax rate can trade their carbon to companies over the limit (which produces carbon emissions above the allowable carbon emission limit). Fig. 2 shows changes in carbon emissions between 2012-2019. The figure also shows changes in carbon emissions, output, and investment.

Carbon emissions experienced a declining trend, but in 2019 there was an increase in carbon emissions again, although still lower than in 2012-2017. Investment is also relatively stable. Meanwhile, output has decreased in the last two years, namely 2018 and 2019.

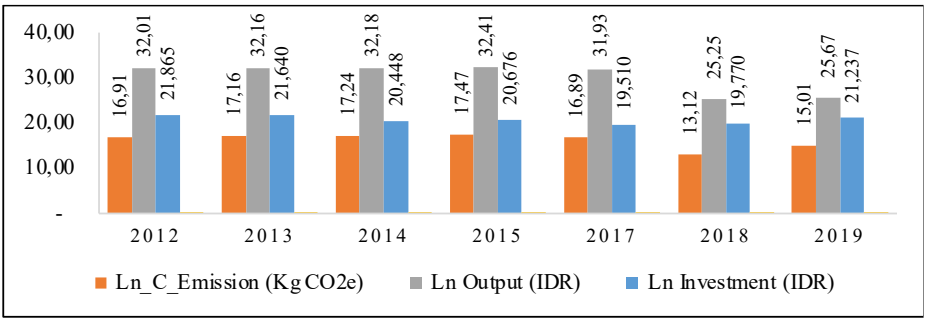

Fig. 1. Changes in firms' carbon emissions, output, and investment 2012-2019, excluding data from 2016

3.2 Effects of carbon taxes and fuel taxes on corporate carbon emissions

The study results are shown in Table 3. The model is a common effect model, meaning that the research does not consider important events that occur in different years. Model (1) tests the hypothesis that the carbon tax affects the company's emissions. Each pair of models includes the main explanatory variables, namely carbon tax and fuel tax, and control variables, namely value-added, investment, and dummy variable dirty firm. Before performing regression analysis, this study conducted a series of classical assumption tests: normality, multicollinearity, and heteroscedasticity [17].

Table 3. Common effect regression uses the full sample with carbon emissions as the dependent variable

Variables	Ln Carbon Emission
Carbon_tax	403.7836***
Fuel_Tax	3.0327***
Value_Added	-2.66E-14
LN_Investment	0.1886***
C_Intensive_Firm	4.6036***
Constant	9.294 ***
Observations	36,624
No. firms	5,232
Adj. R^2	**0.2850**

The output presented in this table is the common effect regression from equations [1] and [2], with Ln carbon emission as the dependent variable. The *** indicates statistical significance at the 1% level.
Source: calculated data

The common effect regression output is shown in Table 2, representing that the carbon tax and fossil fuel tax positively and significantly affect carbon emissions. Every one percent increase in carbon tax causes an increase of 403.7836 kg of carbon emissions, assuming all other variables remain constant. These results contradict the hypothesis that carbon taxes negatively affect corporate carbon emissions. Furthermore, the fuel

tax positively and significantly affects the company's carbon emissions. Every 1% increase in the carbon tax rate will cause an increase in carbon emissions of 3,0327 kg, assuming all other variables remain constant. These results do not confirm the hypothesis that carbon levies negatively affect firms' carbon emissions.

The influence of the company's value-added has a negative but insignificant effect on the company's carbon emissions. The higher the value added produced by the company, the lower the carbon emissions produced by the company. However, the effect is not significant. The effect of the company's investment on carbon emissions is positive and significant. These results indicate that every one percent increase in investment impacts an increase in carbon emissions of 0.1886 percent. Meanwhile, the companies that produce high carbon emissions (dirty firms) have higher carbon emissions with a difference of 4,6036 kg CO2e than those grouped into less carbon-intensive firms (clean firms), which is significant.

The static of common effect model results shows that the fuel tax does not affect carbon emissions. This result aligns with previous literature, which has no significant or small effect [6]. These results cannot rule out that the fuel tax that applies in Indonesia is very small at 0.25%, and this fuel tax rate has never changed from 2011 until now. Moreover, a carbon levy has a significant impact on carbon emissions. The direction of influence that was previously expected was a negative influence. The results of this study gave the opposite result, which was supposed to be a positive effect. The expectation of the negative impact of the carbon levy on carbon emissions is that companies want to avoid paying taxes, so to avoid paying taxes, companies are trying to reduce fuel consumption. The results of the study provide evidence to the contrary. The higher the carbon tax rate, the higher the carbon emissions produced by the company.

4 Conclusion

In this study, we simulate the effect of carbon taxes on carbon emissions, using panel data covering 5,232 companies from 2012-2018 (missing data in 2016). As a result, with the common effects approach, a positive effect exists between a carbon tax and carbon emissions. The magnitude of the estimate shows that a 1% rise in marginal tax causes carbon emission increases by 403.7836%, keeping other factors constant. These results do not support the theory of tax avoidance. So, it can be said that the carbon tax policy with a tariff of IDR 30.00 per kilogram of CO2e is ineffective in reducing carbon emissions. Future research can test it with a common-effect approach to see the development of the specific impact every year. Testing the manufacturing industry sub-sector is necessary to see which sectors will significantly contribute to reducing carbon emissions.

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