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Impact Analysis of Energy Policy: Fuel Oil Subsidies and Global Warming Costs

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Abstract

Global warming has become an increasingly urgent issue to address, with the use of fossil fuels being the major contributor to CO2 in the atmosphere. This has encouraged governments in various countries to focus on reducing greenhouse gas emissions. The fuel oil subsidy policy will affect fuel consumption patterns, which in turn will affect the cost of global warming. This study aims to analyze the impact of energy policies related to fuel subsidies on global warming costs in lower- and upper-middle-income countries. This study uses panel data for both categories of countries from 2015 to 2022. The analysis employed fuel oil subsidy and global warming cost data, along with relevant economic factors. The estimation method uses a Fixed Effect model with Driscoll-Kraay standard errors to address cross-sectional dependency in the panel data analyzed. The analysis results show that fuel oil subsidies have a significant influence on increasing the cost of global warming in lower- and upper-middle-income countries. Therefore, it is necessary to consider reducing fuel subsidies and strengthening carbon emission regulations to address the increasing impact of global warming.

Keywords: CO_2; Driscoll-Kraay; Fixed Effect; fuel oil subsidies; global warming costs
JEL classification: O20; Q48; Q54

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1. INTRODUCTION

Global warming is one of the primary global concerns. Countries around the world are increasingly concerned about the buildup of greenhouse gases in the atmosphere, especially carbon dioxide (CO2), methane, nitrous oxide, ozone, and chlorofluorocarbons (CFCs), which can significantly contribute to surface warming (Churchill & Saunders, 1991). Emissions produced from human activities have been the main cause of climate change since pre-industrial times (Jones et al., 2023). From 1990 to 2020, the electricity and heat generation

sector became the main source of greenhouse gas (GHG) emissions, followed by the transportation sector (see Figure 1).

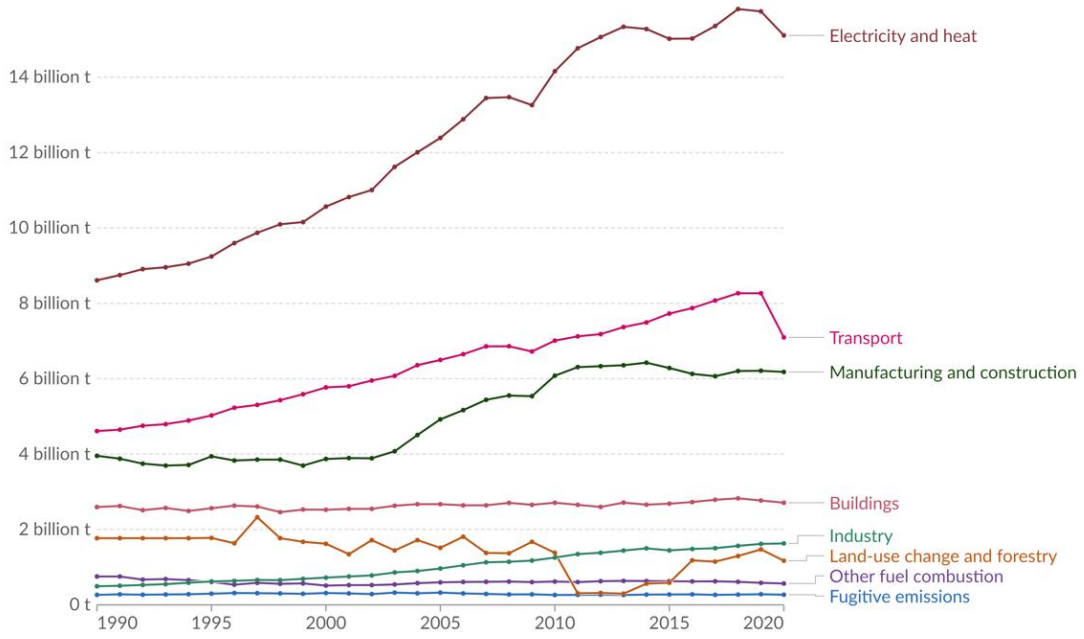

Figure 1. Greenhouse Gas Emissions by Sector, World
Source: ourworldindata.org (2024)

The increase in fossil fuel usage across various sectors—including energy, industry, transportation, waste management, and forestry—has led to higher atmospheric concentrations of carbon dioxide (CO2), methane (CH4), and nitrogen oxides (N2O). This has disrupted the energy balance on Earth. Since the pre-industrial era, emissions from human activities have been the primary drivers of climate change (Jones et al., 2023). Fossil fuels significantly contribute to environmental degradation and are the main source of CO2 emissions (Yoro & Daramola, 2020). According to Figure 1, between 1990 and 2020, the electricity and heat generation sector was the leading contributor to Greenhouse Gas (GHG) emissions, followed by the transportation sector.

The issue of global warming was first discussed internationally at the Earth Summit in Rio de Janeiro in 1992, which highlighted the concept of sustainable development (United Nations, 1993). Global discussions on global warming continued until the Paris Agreement in 2015, which included a commitment by all countries to reduce emissions and work together to improve adaptation to the impacts of climate change. Despite its negative environmental impact, energy is an essential engine for strong economic growth, affecting all dimensions of sustainable human development (United Nations ESCAP, 2007). Various sectors of life such as industry, transportation, communication, and households require adequate energy to function effectively.

In the dynamics of a country's development, energy consumption and economic growth are two inseparable elements. Any increase in economic activity, especially in critical sectors such as industry and infrastructure, demands greater energy supply to support smooth operations. The level of Gross Domestic Product (GDP) is an important indicator that reflects the quality of a country's economic growth, as GDP depicts the value of final goods and services produced in the economy during a given period (Blanchard, 2017). An increase in GDP is usually followed by an increase in energy consumption, as intensive economic activities require more energy resources.

In the current era of globalization, lower- and upper-middle-income countries play an important role in global economic dynamics. High population growth rates and rapid economic growth usually go hand in hand with high energy consumption, especially fuel oil. By 2022, the population of lower- and upper-middle-income countries (80 countries) will reach 3,681 million with an average annual increase in fuel consumption of 4-5% (IMF, 2023). To support economic growth and infrastructure development, the government must ensure that energy, as the primary driver of progress, is available to the community at affordable prices. To that end, the government provides support to the public through the provision of subsidies to ease the burden of energy costs. These subsidies are expected to maintain price stability and improve energy accessibility, as well as stimulate economic activity without placing an excessive burden on the community.

In promoting sustainable development, the government provides support to the community through the provision of subsidies to ease the burden of energy costs. Energy subsidies aim to ensure that all levels of society, especially low-income groups, can access energy at affordable prices. This measure not only helps reduce the economic burden on households but also encourages wider use of energy, which in turn can increase productivity. The subsidy is expected to maintain price stability and improve energy accessibility, as well as stimulate economic activity without placing an excessive burden on the community. In this context, the subsidy will reduce the selling price of fuel to the public, thereby encouraging increased fuel consumption in various sectors, including transportation, industry, and households.

Globally, fossil fuel subsidies in 2022 amounted to $7 trillion, or about 7.1% of GDP. This is an increase of $2 trillion compared to 2020 due to large government support for energy price spikes In many countries, fossil fuel subsidies are predominantly for petroleum products.

Figure 2 shows the comparison of fossil energy subsidies from various types of fuels. According to IMF data from 2015 to 2021, the largest fossil fuel subsidies are allocated to oil, which is prevalent in nearly all countries. Various sectors, including transportation, industry, and household economies, rely heavily on fuel oil. To fulfill this need, the government must ensure that fuel prices remain affordable so that economic sectors can operate efficiently.

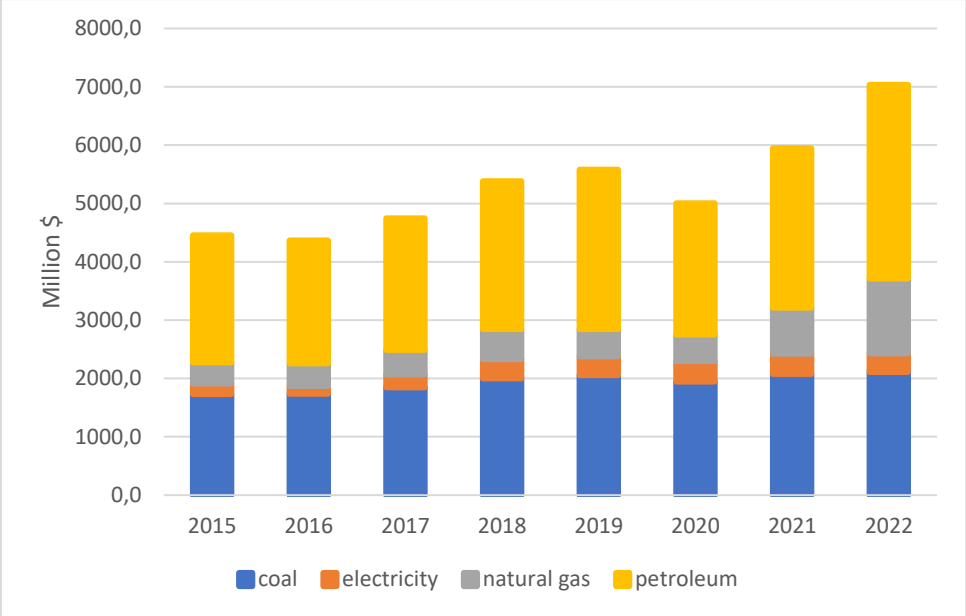

Figure 2. Comparison of Various Types of Global Fossil Energy Subsidies 2015-2022
Source: International Monetary Fund (2023)

Several studies have found that fossil fuel consumption is a major cause of environmental degradation including global warming (Fleurbaey et al., 2014; Omri, 2013; Yoro & Daramola, 2020). Additionally, air pollution from fuel combustion can cause health problems, such as cardiovascular and respiratory diseases, chronic bronchitis, and increased morbidity (Mukhopadhyay & Forssell, 2005).

When it comes to environmental impacts, fuel subsidy policy is a key factor influencing energy consumption patterns. Government subsidies on fuel prices can change market dynamics and encourage increased consumption. Increased fuel consumption can accelerate environmental degradation and exacerbate global warming issues. Setting appropriate fossil fuel prices is a top priority in economic policy to reduce greenhouse gas emissions (Larsen & Shah, 1992).

Figure 3. The Transmission Mechanism of Fuel Subsidies on Global Warming Costs

The transmission mechanism from fuel subsidies to environmental costs, particularly global warming (in Figure 3) can be explained as follows: the government subsidizes fuel to lower the selling price for consumers, which can include direct price reductions, other fiscal incentives, or external costs that should be accounted for in the fuel price. As a result, fuel

subsidies tend to increase fuel consumption among the public. Lower prices stimulate demand, leading to higher fossil fuel usage. The increased fuel consumption driven by these subsidies contributes to a rise in greenhouse gas emissions, such as carbon dioxide (CO2), as fuel combustion produces emissions that exacerbate global warming. This increase in greenhouse gas emissions contributes to climate change, causing environmental impacts such as rising temperatures, changing weather patterns, and rising sea levels. When these environmental losses are monetized, each liter of fuel consumed incurs associated global warming costs.

Since fuel subsidies tend to increase fossil fuel consumption, this study aims to examine the effects of fuel subsidies on global warming costs in lower-middle-income and upper-middle-income countries. By better understanding the relationship between fuel subsidies and global warming costs, more effective policy measures can be taken to reduce negative environmental impacts.

Most previous studies have focused on the relationship between fuel subsidies and carbon emissions, as conducted Solarin (2020), Arzaghi & Squalli (2023), Q. Wang & Li (2016), and Husaini et al. (2021). However, no study has specifically quantified the magnitude of global warming costs caused by fuel subsidy policies, especially those related to fuel oil. Thus, this study aims to provide new insights into the economic impact of fuel oil subsidy policies on global warming costs, an area that has not been explored much in previous research.

This study emphasizes global warming costs as a direct economic impact related to fuel subsidies, rather than focusing solely on carbon emissions. By highlighting this aspect, the study addresses a critical gap in the existing literature and aims to provide a new perspective for developing more effective and sustainable energy policies.

1.1 Fuel oil subsidies

In economic theory, the law of demand states that a decrease in the price of a good will increase the quantity demanded (Mankiw, 2021). This principle is used to look at consumption patterns because it illustrates how price changes can affect consumer behavior in consuming a good.

A subsidy is a form of payment intended to lower the price paid by the buyer, making it less than the seller's price. In other words, subsidies are also referred to as negative taxes (Pindyck & Rubinfeld, 2018). The government is considered to be subsidizing if the price paid by consumers is lower than the reference price (IEA).

Since the mid-20th century, crude oil has been a key indicator of global economic activity due to its vital role in meeting the world's energy needs (Ghalayini, 2011). There is an inverse relationship between oil prices and economic growth: as oil prices increase, economic growth tends to decrease (Difiglio, 2014; Sarwar et al., 2017).

Oil subsidies are calculated based on the difference between the market price of oil in 191 countries and the efficient price (considering economic, environmental, and health supply costs), multiplied by the amount of fuel consumed (Coady et al., 2019). The efficient price

includes infrastructure costs and external costs such as deaths, injuries, congestion, environmental impacts, and climate change (Moghaddam & Wirl, 2018).

Global Warming Costs

Externalities refer to the effects of production and consumption activities that are not directly reflected in the market (Pindyck & Rubinfeld, 2018). This means the impact or consequences of an economic activity that is not directly accounted for in market transactions or the price of a good or service. An example is the environmental impact of global warming resulting from the consumption of fossil fuels. Fossil fuels, including coal, oil, and gas, are the largest contributors to global climate change (accounting for more than 75% of global greenhouse gas emissions and almost 90% of total carbon dioxide emissions). When greenhouse gas emissions envelop the earth, the heat from the sun gets trapped, causing global warming and climate change.

Global warming refers to the long-term rise in Earth's temperature caused by human activities, particularly the combustion of fossil fuels, which elevates the concentration of greenhouse gases that trap heat in the atmosphere. The increase in atmospheric CO2 is widely recognized as a major contributor to global warming (Letcher, 2021). This phenomenon represents an environmental cost that should be incorporated into the price of fossil fuels, reflecting the external costs associated with their use. According to Coady (Coady et al., 2017), achieving economic efficiency involves setting energy prices that account for not only the costs of supply but also the environmental and health impacts, such as those from global warming and air pollution, in addition to consumption taxes.

Zhang (2014) characterizes the Emission Impact per Unit of Energy Consumption as the ratio of emission effects to the amount of energy consumed. A higher value of this indicator signifies a greater environmental impact from energy use. Meanwhile, Chen & Zhang (2021) defines the Environmental Cost per Unit of Energy Use as the total environmental costs divided by the total energy consumed over a year. Global warming costs refer to the environmental costs of greenhouse gas emissions from fossil fuel products (Black, 2023). Global warming costs are calculated based on the amount of carbon dioxide produced by each unit of energy burned. These calculations use estimates provided by the U.S. Energy Information Administration.

1.2 Empirical Study

Global warming is influenced by various factors, including population levels, GDP growth, primary energy consumption (Adekunle & Oseni, 2021; Solarin, 2020), and fuel prices (Husaini et al., 2021), which are affected by government subsidies. Fossil fuel combustion is a major contributor to CO2, and CO2 is a major contributor to global warming and climate change (Yoro & Daramola, 2020). Of all the fossil fuels, diesel and gasoline are the most polluting (Taghvaee et al., 2023).

Fossil fuel subsidies are believed to worsen climate change by reducing the cost of fossil fuels. By artificially lowering prices, these subsidies promote higher energy consumption, which leads to increased environmental pollution and congestion (Husaini et al., 2021;

Solarin, 2020). Since the majority of energy consumption relies on fossil fuels, this contributes significantly to greenhouse gas emissions and global warming (Pindyck & Rubinfeld, 2018). Additionally, Heshmati & Abolhosseini (2015) highlights that global CO2 emissions are positively correlated with fossil energy consumption.

Petroleum subsidies can cause major environmental and economic problems (Mundaca, 2017). The difference between the efficient fuel price and the actual fuel price is large, where the actual price does not take into account impacts such as pollution and health effects (Black, 2023). Pricing fossil fuels correctly is essential to ensure efficient resource allocation in the economy, given that the costs of using them are not only supply-side but also include environmental costs and other externalities such as air pollution and traffic congestion (Vernon et al., 2021). Pricing policy is also one of the alternative ways to manage fossil fuel demand in order to reduce greenhouse gas emissions (Taghvaee et al., 2023).

Impact of Fuel Subsidy Policies on Global Warming Costs

Global warming is influenced by various factors, including population levels, GDP growth, primary energy consumption (Adekunle & Oseni, 2021; Solarin, 2020), and fuel prices affected by government subsidies (Husaini et al., 2021). The combustion of fossil fuels is a major contributor to CO2 emissions, which is a significant factor in global warming and climate change (Yoro & Daramola, 2020). Taghvaee et al. (2023) states that diesel and gasoline have the largest environmental pollution impact compared to other fossil fuels.

Fossil fuel subsidies exacerbate climate change by artificially lowering fuel prices, which encourages excessive energy consumption and increases pollution and congestion (Husaini et al., 2021; Solarin, 2020). Since most energy consumption comes from fossil fuels, this contributes to greenhouse gas emissions and global warming (Heshmati & Abolhosseini, 2015; Pindyck & Rubinfeld, 2018).

Fossil fuel subsidies cause significant environmental and economic problems (Mundaca, 2017). Actual fuel prices often do not reflect the environmental and health costs arising from pollution (Black, 2023; IRENA, 2020). Setting the correct fossil fuel prices is crucial to ensure efficient resource allocation in the economy, given that fossil fuels have environmental costs and other externalities such as air pollution and traffic congestion (Vernon et al., 2021). Fossil fuel pricing policy can be an alternative to manage fuel demand in order to reduce greenhouse gas emissions (Taghvaee et al., 2023).

Previous studies have found that fossil fuel subsidies increase the ecological footprint in developing and emerging countries (Solarin, 2020). Research conducted by oghaddam & Wirl (2018) and Sasana & Aminata (2019) also found a positive relationship between energy subsidies and CO2 emissions, although it was not significant for the cases of Indonesia and oil and gas exporting countries. Meanwhile, Chepeliev's research (Chepeliev & van der Mensbrugghe, 2020) shows that removing fossil fuel consumption subsidies can be an effective mechanism to achieve greenhouse gas (GHG) emission reduction targets. According to Taghvaee's study (Taghvaee et al., 2023), energy pricing policies in Iran also affect fossil fuel consumption and reduce CO2 emissions.

Theoretically, reduced oil prices can lead to higher carbon emissions through three main pathways: an increase in total carbon emissions, a rise in carbon intensity (carbon emissions per unit of GDP), and a higher cost of reducing carbon emissions (Q. Wang & Li, 2016). Husaini's research (Husaini et al., 2021) in various Asian countries indicates that energy subsidies and oil prices significantly influence overall energy costs, which subsequently affects CO2 emissions linked to economic growth.

2. RESEARCH METHOD

2.1 Data

The data used is the period from 2015 to 2022, covering 80 countries: 40 lower-middle-income countries and 40 upper-middle-income countries.

In calculating the cost of global warming, the IMF uses a rational approach by determining the price of global CO2 emissions needed to achieve a certain temperature target. For example, for a temperature reduction target of 2°C, the price per ton of CO2 in 2022 is $60. The formula for calculating global warming damages is:

Global Warming Damages = CO2 Emissions × Carbon Price

Example: if the CO2 emission factor for diesel is 0.003 tons/liter, the environmental damage cost due to global warming per liter is 0.003 tons/liter × $60/ton = $0.18/liter. Thus, the total global warming cost (**glow**) is calculated by multiplying the environmental damage cost per liter of fuel consumed by the total fuel consumption (measured in millions of dollars). In this study, it is expected that the higher the fuel consumption (due to increased oil subsidies), the higher the global warming costs will be.

The total fuel subsidy (**subsidy**) is the difference between the required price (including supply costs, environmental costs, and other costs) and the retail price, multiplied by the fuel consumption volume. The subsidy in this study includes both explicit and implicit subsidies. This variable can affect global warming costs because fuel subsidies will influence the level of fuel consumption, which in turn contributes to the extent of global warming costs.

This study uses several control variables that aim to control the influence of other variables that might affect the relationship between fuel subsidies and global warming costs. These control variables are fuel consumption (**oilconsump**), GDP per capita (**gdpcap**), and population (**pop**).

Definitions and data sources for the dependent variable (global warming cost), the main independent variable (fuel subsidy), and control variables (fuel consumption, GDP per capita, population) used in this study are explained in Table 1. Descriptive statistics for each variable are provided in Table 2.

Table 1. Data and Data Source

Variable	Unit of Measure	Description	Source	Sign
glow	Million dollars	Environmental damage cost due to global warming caused by fuel consumption	IMF 2023	
subsidy	Million dollars	Financial support or incentives provided by the government to lower fuel prices	IMF 2023	+
oilconsump	Million dollars	Total fuel consumption in a country	IMF 2023, British Petroleum Statistical Review 2022	+
gdpcap	Dollars	Gross income of a country divided by its population	WDI 2023	+
pop	Million people	Total population of a country	IMF 2023	+

Table 2 Descriptive Statistics

Variable	Mean	Std. dev.	Min	Max
glow	3186.292	9341.173	2.863885	102969.5
subsidy	14895.67	41732.12	0.3360614	455534.3
oilconsump	19673.42	56664.37	18.80523	574119
gdpcap	5020.558	3194.941	608.3325	18199.47
pop	69.92585	218.742	0.116	1425.925

Notes: N = 640, n = 80

2.2 Model and Specifications

This study employs the Fixed Effect Model (FEM) approach with Driscoll-Kraay standard errors. This model is based on Arzaghi and Squalli's research (Arzaghi & Squalli, 2023), which explored the link between fuel subsidy policies and environmental emissions using FEM, and Shah's study (Shah et al., 2021), which applied the Driscoll-Kraay technique to analyze the impacts of renewable energy consumption, economic growth, population growth, foreign direct investment (FDI), and environmental degradation.

The Fixed Effect Model is used to address endogeneity issues (reduce selection bias), while the Driscoll-Kraay standard errors method is applied to resolve classical assumption issues such as heteroscedasticity, autocorrelation, and cross-sectional dependence that may arise in panel data processing. The equation model to be constructed is as follows:

$$\ln glow_{it} = \beta_0 + \beta_1 \ln subsidi_{it} + \beta_2 \ln oilconsump_{it} + \beta_3 \ln gdpcap_{it} + \beta_3 \ln pop_{it} + c_i + t_t + \mu_{it}$$

Where ln$glow_{it}$ represents the cost of global warming due to oil consumption (million $) for country i in year t in natural logarithm form, ln$subsidi_{it}$ is the subsidy provided for oil (million $) in country i in year t in natural logarithm form, ln$oilconsump_{it}$ represents oil consumption (million liters) in country i in year t in natural logarithm form, ln$gdpcap_{it}$ is GDP per capita ($) in country i in year t in natural logarithm form, lnpop_{it} is the total population (million people) in country i in year t in natural logarithm form, c_i represents unobserved heterogeneity in country i, t_t = time-specific effect, μ_{it} is the error term, i is the individual (country), and t is the time (year).

In this model, an error term (μ) is also added, which encompasses other factors affecting global warming costs not explained by the variables in the model.

The FEM approach was chosen considering that it can control unobserved factors that may affect the relationship between explanatory and response variables (Wooldridge, 2015). When the model encounters issues such as heteroskedasticity, autocorrelation, and cross-sectional dependency, robustness tests are conducted. One technique that can be used is the Driscoll-Kraay standard error (Hoechle, 2007). This technique is considered one of the best methods for addressing heteroskedasticity and spatial dependence in panel data (Acheampong et al., 2021; Baloch et al., 2019; Shah et al., 2021; Z. Wang et al., 2022), thus ensuring that the effect of all independent variables remains significant.

3. RESULTS AND DISCUSSION

According to IMF data (2023), there is a positive relationship between fuel subsidies and global warming costs. Figure 4 shows the relationship between fuel subsidies (X-axis) and global warming costs (Y-axis). Based on the pattern in the graph, there is a positive correlation between fuel subsidies and global warming costs. This means that the higher the fuel subsidy, the higher the resulting global warming costs.

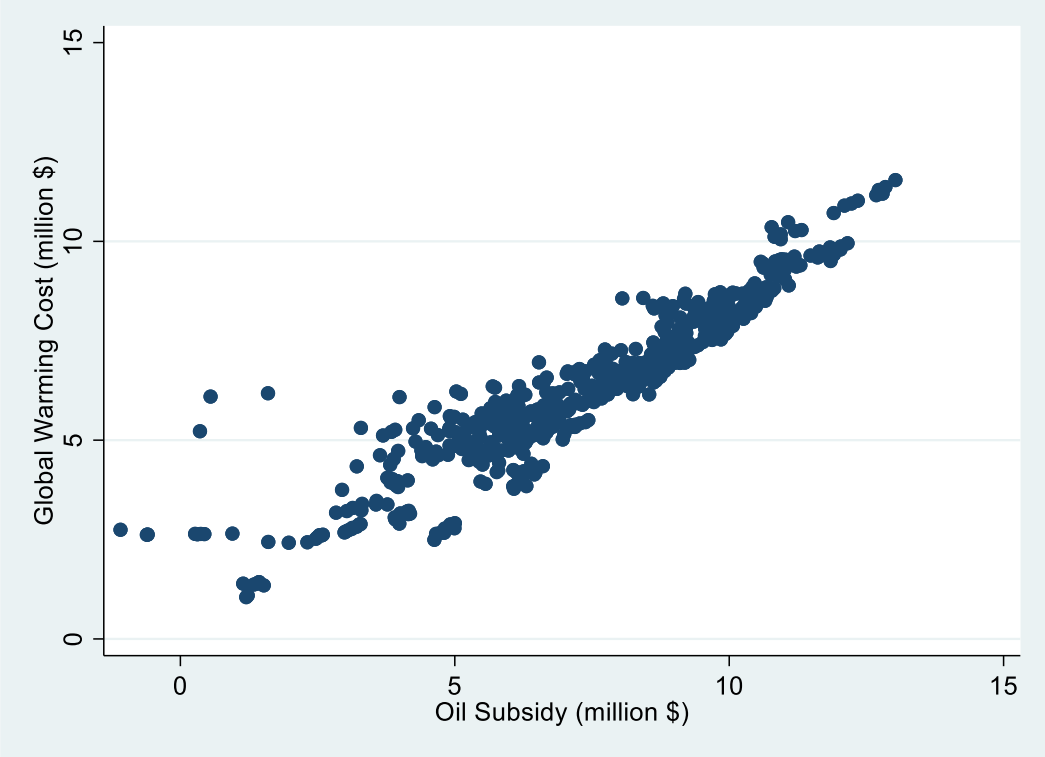

Figure 4. Scatter Plot of Fuel Subsidies and Global Warming Costs

The graph shows that when fuel subsidy values are low, global warming costs tend to be lower. However, as fuel subsidies increase, global warming costs also rise in a fairly consistent pattern. This positive correlation indicates that high fuel subsidy policies can encourage greater fossil fuel consumption, thereby increasing greenhouse gas emissions and contributing to higher global warming costs. This graph supports the hypothesis that fuel subsidies are correlated with global warming costs and strengthens the argument that reducing subsidies could be a strategy to control the environmental impact of global warming.

In processing panel data, there are several commonly used regression methods including the Random Effect Model (REM) and the Fixed Effect Model (FEM). The results of regression estimation through these two approaches are presented in Table 3.

Table 3 Estimation Results of REM and FEM Regression

Variable	*Random Effect*		*Fixed Effect*	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
lnglow (dependent variable)				
lnsubsidy	0.03650***	0.0057	0.0200***	0.0052
lnoilconsump	0.9511**	0.0105	1.024**	0.0186
lngdpcap	0.0010**	0.0120	0.1240**	0.0136

Variable	*Random Effect*		*Fixed Effect*	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
lnpop	0.0006***	0.0100	1.5687*	0.0572
_cons	-1.7667*	0.0787	-7.0820	0.2048
Number of obs	640	640		
Number of groups	80	80		
r2	0.7861	0.9160		

Notes: *** p<0.01, ** p<0.05, * p<0.10

Based on the regression results in Table 3, it is evident that the coefficients of all independent variables have positive values in both methods, meaning that fuel subsidies, fuel consumption, GDP per capita, and population have a positive influence on the cost of global warming. This is in line with research conducted by Solarin (2020), Husaini et al. (2021), and Adekunle & Oseni (2021) which states that fossil energy subsidies and consumption have a positive effect on the level of CO2 emissions. The variables "GDP per capita" and "population" also have positive values have negative values, consistent with the studies conducted by Omri (2013), Adekunle & Oseni (2021), Sasana & Aminata (2019), and Solarin (2020), which indicate that economic growth (GDP) and population drive an increase in CO2 emissions.

Based on the estimation results in Table 3, the R-squared value in FEM is much higher than in REM. However, to ensure the best model selection, Hausman test is required. Table 4 shows a p-value < 0.05, indicating that based on the Hausman test, the Fixed Effect model is better than the Random Effect model. Next, heteroscedasticity and cross-sectional dependence tests were conducted.

Table 4 Hausman Test Results

H_0: Difference in coefficients not systematic		
Chi^2	**Chi^2 df**	**Probability**
1095.06	4	0.0000

The results in Table 5 show a p-value <0.05, thus it can be concluded that there is a heteroscedasticity problem in the model. Based on the cross-sectional dependence test in Table 6, testing with Pesaran CD and Friedman has a p-value <0.05, indicating cross-sectional correlations in the model. To overcome this problem, the Driscoll-Kraay standard errors technique can be used.

Table 5 Heteroskedasticity Test Results

Modified Wald test for groupwise heteroskedasticity		
Chi²	**Chi² df**	**Probability**
73476.75	80	0.0000

Table 6. Cross-sectional Dependence Test

H0: *cross-sectional independence*		
Test	**Statistic**	**Probability**
Pesaran CD	53.885	0.0000
Friedman	182.617	0.0000
Frees	29.828	0.4325

Table 7 shows the estimation results of the variables studied using the Driscoll-Kraay Fixed Effect model. Fuel subsidies have a positive and significant impact on global warming costs, meaning that when the amount of fuel subsidies increases, the global warming costs also increase. Similarly, fuel consumption and GDP per capita have positive and significant impacts on global warming costs. Meanwhile, the population has a positive but not significant impact on global warming costs.

Table 7. Estimation Results of the Fixed Effect Driscoll-Kraay model

Variable	Coefficient	Standard Error	Probability
lnglow (dependent variable)			
lnsubsidy	0.0200***	0.0048	0.0000
lnoilconsump	1.0244**	0.0252	0.0000
lngdpcap	0.1239**	0.0300	0.0000
lnpop	1.5687	0.1119	0.0000
_cons	-7.0820	0.4615	0.0000

Notes: *** p<0.01, ** p<0.05, * p<0.10

Heterogeneity Analysis

Heterogeneity analysis was conducted by dividing the sample into sub-samples based on country income level (lower-middle and upper-middle) and period (2015 - 2018 and 2019 - 2020). This approach will help determine whether the impact of fuel subsidies on global warming costs differs between the two groups of countries and across the two time periods.

The results of heterogeneity testing by dividing countries by income level in Table 8 show that the effect of fuel subsidies on global warming costs varies between the two groups of countries. The effect of fuel subsidies on global warming costs in upper-middle-income countries is larger than that in lower-middle-income countries.

Table 8. Heterogeneity Test Results Based on Income Level

Variable	Lower-Middle Income Countries		Upper-Middle Income Countries	
	Coefficient	Standard Error	Coefficient	Standard Error
lnsubsidy	0.0085***	0.0042	0.0587***	0.0078
lnoilconsump	1.0150**	0.0328	1.0089**	0.0336
lngdpcap	0.1150**	0.0256	0.1151**	0.0476
lnpop	1.5500*	0.0806	1.5837	0.1433
_cons	-7.0181	0.4687	-7.0128	0.6538
Number of obs	320		320	
Number of groups	40		40	
R2	0.9352		0.9059	
Prob F-stat	7022.93		3400.47	

Notes: *** p<0.01, ** p<0.05, * p<0.10

The results of the heterogeneity analysis by dividing countries by income level in Table 8 show that the effect of fuel subsidies on global warming costs in upper-middle-income countries is greater than that in lower-middle-income countries. Meanwhile, the heterogeneity analysis in Table 9 shows that the effect of fuel subsidies on global warming costs in the 2015-2018 period is greater than that in the 2019-2022 period. This is likely due to the influence of the COVID-19 pandemic in the 2019-2022 period where large-scale social restrictions have an impact on fuel consumption patterns and ultimately affect fuel subsidy policies.

Table 9. Heterogeneity Test Results Based on Research Period

Variable	Year 2015 - 2018		Year 2019 - 2022	
	Coefficient	Standard Error	Coefficient	Standard Error
lnsubsidy	0.0154***	0.0051	0.0016***	0.0009
lnoilconsump	1.0957**	0.0194	0.9836**	0.0144
lngdpcap	0.1038**	0.0118	0.0623**	0.0122
lnpop	1.7397**	0.0357	1.1636*	0.0815
_cons	-7.9070	0.2797	-5.0503*	0.0829
Number of obs	320		320	
Number of groups	40		40	
R2	0.9297		0.9768	
Prob F-stat	4476.83		2.77E+12	

Notes: *** p<0.01, ** p<0.05, * p<0.10

4. CONCLUSION

Climate change resulting from global warming is driven, in part, by the use of fossil fuels, which are major contributors to CO2 emissions in the atmosphere. Any policies enacted by the government, particularly those related to energy, will affect the consumption patterns of fossil fuels, ultimately impacting the level of carbon emissions. Energy policies related to fuel subsidies have a significant impact on global warming costs in both lower-middle-income and upper-middle-income countries. Panel data analysis from 2015 to 2022 shows a strong dependency between fuel subsidies and global warming costs. The results indicate that fuel subsidies are positively correlated with global warming costs.

In addition to fuel subsidies, other factors also influence global warming costs, such as fuel consumption, GDP per capita, and population. These factors as a whole show a positive and significant relationship with global warming costs.

Recommendations

Fuel subsidies aim to keep fuel prices lower for consumers, but their role in increasing global warming costs is becoming more significant. Given the findings of a positive relationship between fuel subsidies and global warming costs, governments should consider future policies to reduce fuel subsidies through more targeted allocation (focused on the underprivileged) and price adjustments as part of a strategy to reduce carbon emissions and global warming costs. If subsidy reduction policies cannot be implemented, other measures to control carbon emissions should be considered, such as energy efficiency, promoting the use of more environmentally friendly energy, developing clean energy technologies, and implementing strict regulatory policies related to carbon emissions, including emission limits for countries, industries, vehicles, and other major emission-contributing sectors.

Since fuel consumption has a positive effect on global warming costs, the government could diversify energy sources by utilizing renewable energy such as wind, solar, biomass, and geothermal as environmentally friendly and sustainable energy alternatives.

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