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Examination of rising oil prices on the logistic network and transportation greenhouse gas emission in the United States

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Abstract
Due to the logistic network and the rising price of crude oil, global crude-oil transportation is a substantial contributor to greenhouse gas (GHG). The primary objective of this study is to model greenhouse gas emissions with rising oil prices and crude oil transportation based on a logistic network. The secondary data was extracted from World Bank and US Energy Information Administration (EIA) respectively from 1990 to 2020. OLS regression model was applied and the result shows that there is a significant linear relationship between greenhouse gas emission, oil prices, and energy use (proxy to Crude oil transportation based on the logistic network) while controlling for Oil rents. More so, the coefficient estimates of the oil prices and energy use have a positive significant impact on greenhouse gas emissions, indicating that the rising oil prices and energy use will contribute to higher greenhouse gas emissions in the United States. Consequently, the use of energy and rising oil prices should be adequately regulated from time to time in line with the energy policy act to reduce greenhouse gas emissions to achieve a healthy and sustainable environment.

Keywords: Oil prices, energy use, greenhouse gas emission, OLS regression

1. Introduction

The improvement of the global economy and trade can be traced in significant part to maritime transportation. As a result of its affordability and security, it is regarded as one of the most practical options. Around 2% of the global anthropogenic greenhouse gas (GHG) emissions are caused by the shipping sector (International Energy Agency [IEA], 2021; International Maritime Organisation [IMO], 2020b; Wang *et al*., 2021) [11, 12, 21]. Global greenhouse gas (GHG) emissions from bunker fuel used in international shipping have more than doubled since 1990, and during the last three decades, their share of total global emissions has steadily increased from 1.9% to 2.5% (Climatewatch, 2021) [3]. This tendency is predicted to continue and total greenhouse gas emissions from international shipping will rise 2.5-fold between 2020 and 2050 under a business-as-usual emission scenario (IMO, 2014) [12]. Aiming to cut greenhouse gas (GHG) emissions by 90% with the use of third-generation biofuels (such as algae-based biofuel), 1–10% with voyage optimisation, 5–50% with fleet management and logistics changes, etc., the International Maritime Organisation (IMO) proposed a number of design and technical measures in 2018 (IMO, 2020a). The IMO has set short-, medium-, and long-term goals of 20%, 30%, and 50% reductions in ship carbon intensity by 2020, 2025, and 2050, in that order (Deloitte, 2020) [4]. Reports indicate that all supply chain participants must be involved and significant technological advancements and trade-route transformation must take place in order to accomplish these goals (Faber *et al*., 2020; Gossling & Humpe, 2020; Wan *et al*., 2018) [7, 8, 20].

The United Nations Conference on Trade and Development [UNCTAD], 2020 [19], reports that tanker vessels alone accounted for 30% of the total weight of the 11 billion metric tonnes of international maritime trade in 2018, despite their share of shipping having dropped from 55% in 1980. Crude oil, gas and chemicals are among the primary commodities handled by tanker vessels. Because of its major significance in international trade (crude oil tankers accounted for over 60% of all tanker vessels in 2018), crude oil transportation considerably contributes to the emissions from tanker vessels.

(Eriksen *et al*., 2021; UNCTAD, 2019) [6, 18]. According to UNCTAD 2019 [18] estimates, the world's crude oil production, totalling 1.9 billion metric tons, is traded across the sea (UNCTAD, 2019) [18]. The primary fuel used by tanker ships to transport crude is heavy fuel oil (HFO), which has a high carbon footprint and generates significant greenhouse gas emissions. Oil tankers alone produced 101 million metric tons, or 13%, of total maritime emissions in 2015, according to Olmer *et al*. (2017) [17]. Several variables, such as (1) the characteristics of tanker vessel design and operation and (2) the use of heavy fuels, have an impact on the emissions produced by the transportation of crude oil (e.g., HFO). The other major mode of transportation, pipelines, are responsible for approximately 5 million tons of the total emissions associated with shipping crude oil around the world; however, due to variations in the density, diameter, and flow of the crude oil, there may be significant changes in emissions from one country to the next (Choquette-Levy *et al*., 2018) [2].

In this study, the energy use was measured by the transportation of crude oil using a logistical network, the US oil prices, and the oil rents, which represent the value of crude oil production at regional prices less the entire expenses of production. As a result, the main goal of this research is to model greenhouse gas emissions in the context of growing oil prices and logistics-based crude oil transportation.

2. Literature review

The review of related literature works for this study shall be discussed under this section.

Several modelling techniques for GHG emissions from crude transportation have been put out in the literature. Greene *et al*. (2020) [9] devised a methodology to evaluate the carbon intensity associated with the transportation of marine crude oil along major trade routes, utilising data obtained from the Automatic Identification System (AIS). Based on the study's findings, which indicate that the assessment of emissions from marine crude-oil transportation is mostly influenced by distance, the authors suggest prioritising the local crude oil trade over enhancing the efficiency of vessels and tankers. According to the fourth IMO GHG assessment, the total greenhouse gas (GHG) emissions from shipping in 2018 amounted to 1056 million metric tonnes, representing a 9.3% rise compared to 2012. Faber *et al*. (2020) [7]. The estimation of shipping emissions was conducted using journey and vessel classification data, such as oil tankers, cargo, containers, etc., by the International Council on Clean Transportation (ICCT) and the International Maritime Organisation (IMO) in a "bottom-up" approach (IMF, 2014). In contrast, the International Energy Agency (IEA) utilised a "top-down" approach to determine emissions by utilising national surveys pertaining to fleet size and marine fuel demand, sometimes referred to as "fuel sales." Despite employing similar methodologies (ICCT, 2010; IMO, 2014) [10, 12], the energy consumption estimates differed. As an illustration, the ICCT and IMO documented a 13% and 19% increase in average fuel use compared to the IEA, respectively. The anticipated IEA energy consumption numbers are significantly lower than the "bottom-up" estimations due to disparities in methodology and assumptions. One more significant distinction lies in the delineation of international shipping. The ICCT and IMO regulations stipulate that larger vessel are deemed to make a significant contribution to global maritime transportation. However, the International Energy Agency (IEA) lacks the ability to distinguish between the fuel utilised for domestic and international shipping activities (IMO, 2020a). The extensive data coverage of both methodologies amplifies the level of uncertainty in estimating emissions. The assessment of greenhouse gas (GHG) emissions generated during the transportation of crude oil plays a crucial role in determining the accuracy of the calculated GHG emissions of crude oil from the extraction site to the national border.

Masnadi *et al*. (2018) [16] employed an engineering-based bottom-up model to determine that China's national volume-weighted average crude-oil upstream greenhouse gas (GHG) emissions vary between 1.5 and 46.9 g CO_2eq/MJ. These emissions are influenced by changes in field-level data, specifically the Oil Production, Gas, and Energy Efficiency (OPGEE) data. As reported by the California Air Resources Board, the mean carbon intensity of global oil in the year 2019 [1] was recorded at 12.52 g CO_2eq/MJ. In contrast, the carbon intensity of California crude oil varied between 1.59 and 48.3 g CO_2eq/MJ within the same year. In their study, El-Houjeiri *et al*. (2013) [5] employed a previous iteration of the OPGEE model to calculate emissions of crude oil output that are specific to each country. Variations in steam injection and gas flaring rates were the primary factor responsible for the emissions, which varied between 3 and 30 g CO_2eq/MJ. The ICCT (2010) reports that the carbon intensities of crude oil in Europe vary between 4 and 50 g CO_2eq/MJ. Although previous studies have examined greenhouse gas emissions during international oil transportation, their predictions were limited to typical distances for crude transportation and did not account for potential future improvements in fuel efficiency. A thorough analysis of the global transportation of petroleum among nations can help reduce the GHG emissions of crude oil from the well to the national gate from the perspectives of both crude production and crude consumption.

Li, Liang, Wang, and Zhang (2021) [21] assert that altering the number, position, and size of hubs within a logistics network can affect the network's transport routes. On the other hand, their analysis found a substantial positive connection between crude oil transportation based on the logistic networks and the C02 emissions.

3. Data and methodology

3.1 Data

This study adopts a quantitative research design in which secondary data was extracted from World Bank and US Energy Information Administration (EIA) respectively within a period of 1990 to 2020 based on data availability and purposive sampling technique.

3.2 Variables measurement

Crude oil transportation based on the logistic network is a proxy by Energy use (in kg of oil equivalent per capita).

C02 emission in millions Kiloton

Oil rents is a control variable in % of GDP.

Oil prices in US dollar.

3.3 Methodology

The method of data analysis that was explored for this study is descriptive statistics (using mean and standard deviation), the ordinary least square (OLS) regression model, and the graphical presentation for visual impression.

3.3.1 Model specification
The model for this study can be specified as follow.

Greenhouse gas emission = f (oil prices, Energy use, Oil rents).

3.4 OLS regression model
The regression model adopted in this study was used to model the Greenhouse gas emission which is a proxy by C02 using a predictor or independent variables such as oil prices and energy while controlling for Oil rents in the united states. The OLS regression can be expressed mathematically as follow.

$C02_t = \beta_0 + \beta_1 Oilprices_t + \beta_2 Energyuse_t + \beta_3 Oilrents_t + U_t$

Where β_0 is the constant term or intercept and β_1 to β_3 are the slopes or the coefficient estimates of the independent variables. C02 is the dependent variable used to measure the Greenhouse gas emission. The U_t is the stochastic random error that takes care of all under unaccounted factors in the model. The t is the period in years.

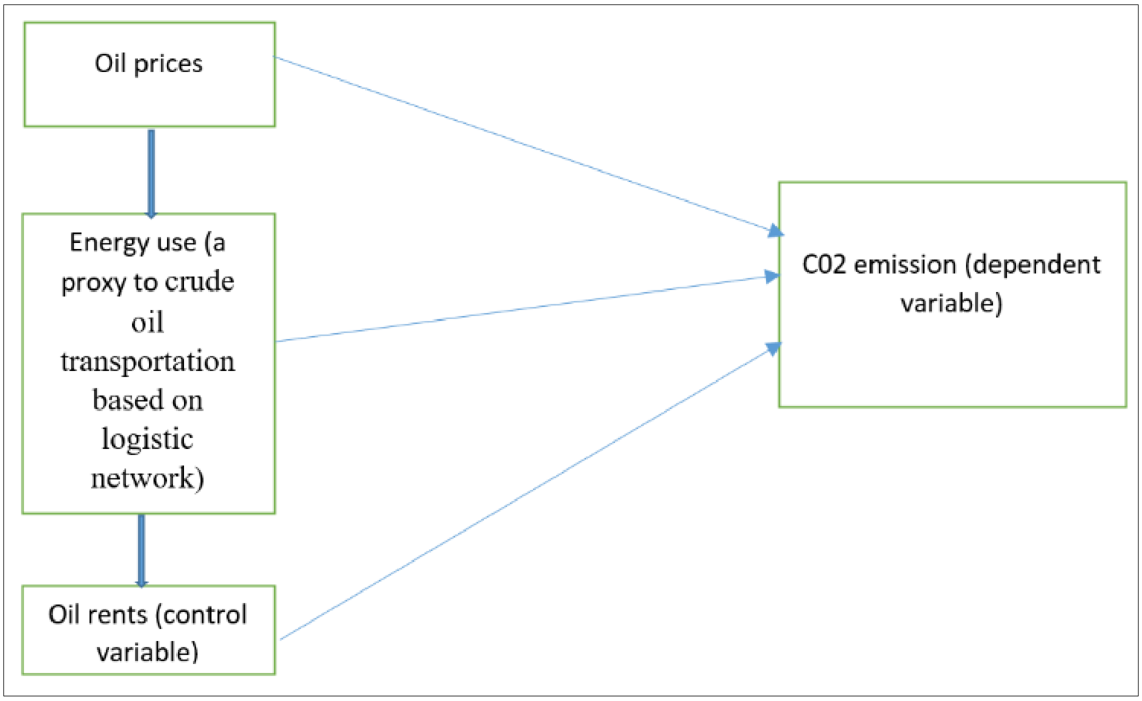

Fig 1: Model structure

4. Results and discussion

Table 1: Descriptive statistics

	N	Mean	Std. Deviation
CO_2	33	5.24	0.353
Oil Prices	33	44.06	27.645
Energy use	33	7.43	0.425
Oil rents	33	0.30	0.143
Valid N (listwise)	33		

Source: Author's Computation using SPSS software

Table 1 shows that carbon dioxide (C02) being a proxy to greenhouse gas emission has an average of about 5.2 million Kiloton with variability of about 0.4 million Kiloton during the period under review. The average oil prices is about 44 US dollars with variability of 28 US dollars. The average energy use is about 7.4 thousand kg per capita with variability of about 0.4 kg per capita while the average Oil rents is about 0.3 percent with variability of about 0.1 percent.

Dependent variable: C02

Table 2: OLS regression model

Variable	Coefficient	Std. Error	t-Statistic	Prob.	VIF
C	-1.844321	0.809586	-2.278105	0.0303	NA
OIL PRICES	0.007969	0.001585	5.026980	0.0000	1.896883
ENERGY USE	0.943514	0.103286	9.134972	0.0000	1.901717
OIL RENTS	-0.926184	0.224361	-4.128099	0.0003	1.029153
R-squared	0.764839	Mean dependent var		5.239697	
Adjusted R-squared	0.740512	S.D. dependent var		0.353337	
F-statistic	31.43985	Durbin-Watson stat		1.585469	
Prob(F-statistic)	0.000000				

Source: Author's Computation using EViews software

From table 2, we write out the OLS regression model as follows.

C02 = -1.844321 + 0.007969 Oil prices + 0.943514 Energy use – 0.926184 Oil rents

The regression model in table 2 shows that for 1 US dollar rise in oil prices, greenhouse gas emission will rise by about 8 million Kiloton. For 1 kg per capita rise in energy use (proxy to Crude oil transportation based on the logistic network), greenhouse gas emission will increase by about 9.4 million Kiloton and for 1 percent increase in Oil rents, the greenhouse gas emission will increase by about 9.2 million Kiloton.

Besides, the overall regression model (P = 0.000<0.05) indicate that the model is statistically significant and this reveal that there is a significant linear relationship between greenhouse gas emission, oil prices, energy use (proxy to Crude oil transportation based on the logistic network) while controlling for Oil rents. More so, the coefficient estimates of the oil prices and energy use have positive significant impact on greenhouse gas emission which indicate that the rising oil prices and energy use will contribute to higher greenhouse gas emission in the United States.

Meanwhile, the oil rents has negative significant impact on the greenhouse gas emission which suggest that the higher the oil rents, the lower will be the greenhouse gas emission. The coefficient of determination (R-squared = 0.76) indicate that about 76% variation in greenhouse gas emission can be attributed to oil prices, energy use and oil rents. Since the R-squared is relatively high and the overall regression model is statistically significant, this suggest that the fitted regression model is a good adequate and a good fit for the data and can be used for the future prediction of Greenhouse gas emission in the United States. Additionally, the variance inflation factor (VIF) for all the independent variables are less than 5 which means that the fitted OLS regression model does not suffer from the problem of multicollinearity and this makes the model reliable. The Durbin Watson statistic = 1.585 falls within the two critical values of 1.5 and 2.5 respectively which suggest that the regression model does not suffer from the problem of serial correlation which satisfy the OLS assumption.

Fig 2: Graph of C02 emission (Proxy to Greenhouse gas emission)

Figure 2 shows that the Greenhouse gas emission rises to the year 2000 and then demonstrate fluctuating pattern from 2000 to 2022.

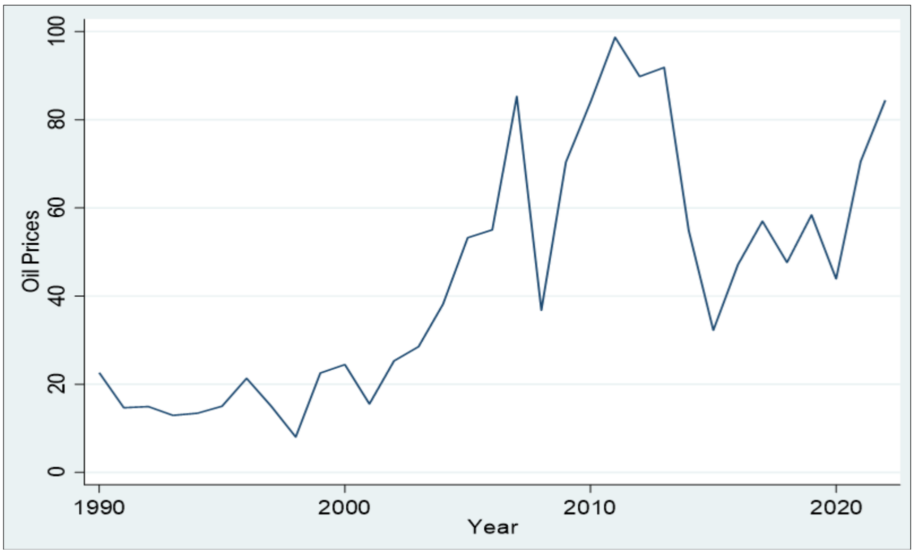

Fig 3: Graph of Oil prices

Figure 3 shows the oil prices display a fluctuating pattern from 1990 to 2019 but also reveal a sharp rise from 2020 to 2022 which can be attributed to supply shift created by the Russia-Ukraine war.

Fig 4: Graph of Energy use (Proxy to Crude oil transportation based on the logistic network)

Figure 4 shows that the Energy use (proxy to Crude oil transportation based on the logistic network) reveal a downward trend pattern during the period under review.

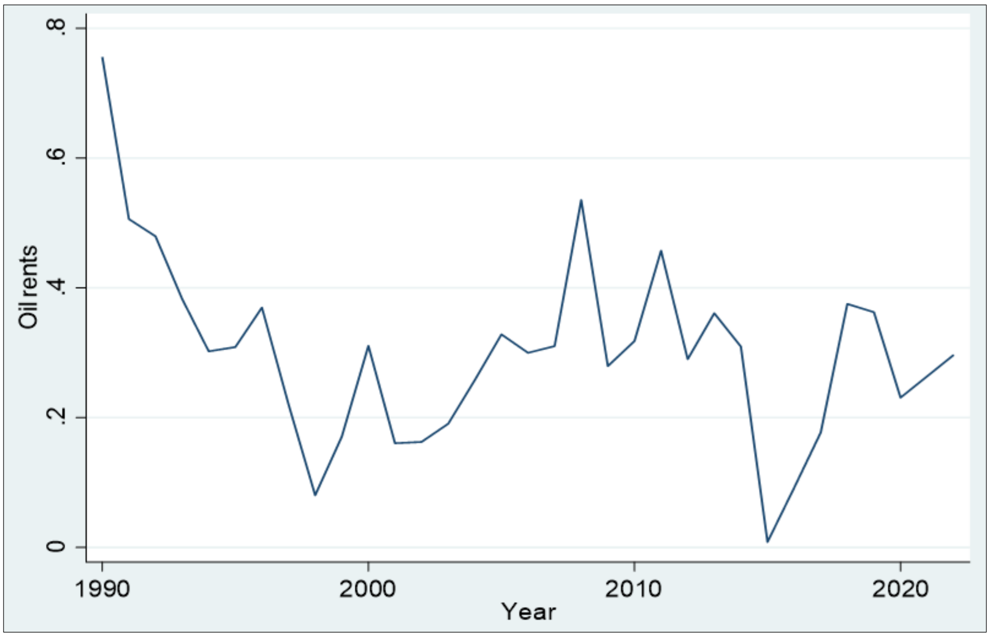

Fig 5: Graph of Oil rents (control variable)

Figure 5 shows that oil rents demonstrated a fluctuating pattern from 1990 to 2022 being a period under review.

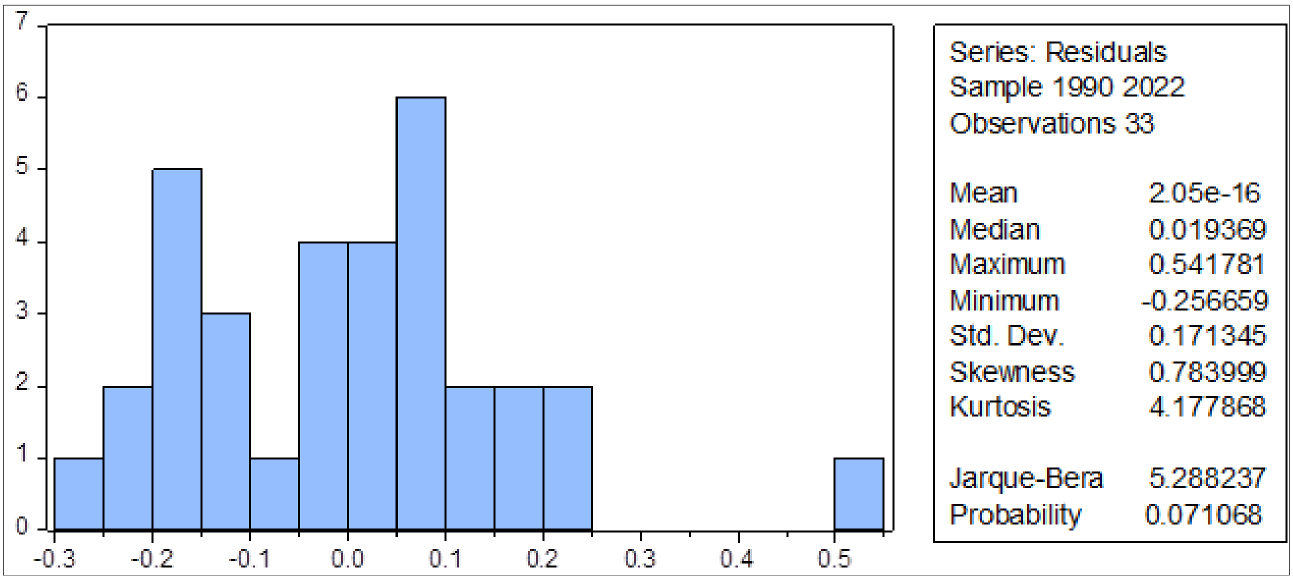

Fig 6: Normality test using Jarque-Bera test

Hypothesis for normality test
Ho: Residual is normally distributed

Ha: Residual is not normally distributed
Figure 6 shows that the P = 0.071 is greater than 0.05 significant level and this suggest that we do not regression the null hypothesis and this suggest that the residual error is normally distributed which also support the ordinary least square (OLS) regression assumption.

4.1 Discussion of findings
Based on the results of the analysis conducted in this study, the following is a discussion of the notable findings.
Table 1 shows that carbon dioxide (C02) being a proxy for greenhouse gas emission has an average of about 5.2 million Kiloton with variability of about 0.4 million Kiloton during the period under review. The average oil price is about 44 US dollars with a variability of 28 US dollars. The average energy use is about 7.4 thousand kg per capita with a variability of about 0.4 kg per capita while the average Oil rent is about 0.3 per cent with a variability of about 0.1 per cent.
The regression model in table 2 shows that for a 1 US dollar rise in oil prices, greenhouse gas emissions will rise by about 8 million Kiloton. For a 1 kg per capita rise in energy use (proxy to Crude oil transportation based on the logistic network), greenhouse gas emission will increase by about 9.4 million Kiloton and for a 1 per cent increase in Oil rents, the greenhouse gas emission will increase by about 9.2 million Kiloton.
Furthermore, the regression model is statistically significant and this reveals that there is a significant linear relationship between greenhouse gas emission, oil prices, and energy use (proxy to Crude oil transportation based on the logistic network) while controlling for Oil rents. More so, the coefficient estimates of the oil prices and energy use have a positive significant impact on greenhouse gas emission which indicate that the rising oil prices and energy use will contribute to higher greenhouse gas emission in the United States which is very consistence with the work of Li, Liang, Wang and Zhang (2021) [21].
Meanwhile, the oil rents have a negative significant impact on greenhouse gas emission which suggest that the higher the oil rents, the lower will be the greenhouse gas emission. The coefficient of determination (R-squared = 0.76) indicates that about 76% of the variation in greenhouse gas emission can be attributed to oil prices, energy use and oil rents. Since the R-squared is relatively high and the overall regression model is statistically significant, this suggests that the fitted regression model is a good adequate and a good fit for the data and can be used for the future prediction of Greenhouse gas emissions in the United States.
Besides, Figure 3 shows that oil prices display a fluctuating pattern from 1990 to 2019 but also reveal a sharp rise from 2020 to 2022 which can be attributed to the supply shift created by the Russia-Ukraine war. Figure 4 shows that the Energy use (proxy to Crude oil transportation based on the logistic network) reveals a downward trend pattern during the period under review.

5. Conclusion and policy implication.
The network of transportation for crude oil and changes in oil prices are major contributors to greenhouse gas emissions. This study's main objective is to simulate greenhouse gas emissions in the context of rising oil prices and logistics-based crude oil transportation. The regression model was used, and the results show that the coefficient estimates for energy use and oil prices have a positive, significant impact on greenhouse gas emissions. This suggests that as energy use and oil prices rise (a proxy for crude oil transportation based on the logistic network), greenhouse gas emissions in the United States will also rise. As a result, periodic regulation of energy use and rising oil prices in accordance with the Energy Policy Act is necessary to reduce greenhouse gas emissions and create a sustainable and healthy environment.

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