Impact Of Transportation Sector Energy Consumption, Diesel Production, Crude Oil Imports On Carbon (Co2) Emissions In Indonesia

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Abstract. The problem in this study is the declining quality of the environment in Indonesia, such as increasing global temperatures and climate change which has caused natural disasters such as floods, land slides and other natural disasters which have had an impact on hampering the wheels of the economy and causing losses in the economy. The data analysis technique performed is first using the Error Correction Model . The findings indicate that there has been an increase in energy use in the transportation industry, which will short-term increase carbon emissions (CO2), there is an increase it will increase carbon emissions (CO2) in the long term. Diesel Production Variable, there is an increase it will not increase Short-term carbon emissions (CO2), the Diesel Production Variable there is an increase it will not increase carbon emissions (CO2) in the long term. Crude Oil Import Value Variable, there is a decrease it will reduce emissions of carbon in the near future, there is an increase (depreciation) in the Crude Oil Import variable, it will increase carbon emissions (CO2) in the long run.

Keywords : Energy Consumption Transportation Sector, Diesel Production, Crude Oil Imports, CO2 Emission

1 Introduction

Growing concentrations of greenhouse gases are causing worldwide warming plus climate change in the atmosphere in large quantities invited advanced industrial countries to create The United Nations Framework Convention on Climate Change (UNFCCC) [1]. As a concrete step in realizing the goals of the UNFCCC, in 1997 the Kyoto Protocol was produced. An agreement made at the United Nations Consultative Convention on the Climate Change (UNFCCC), known as the Kyoto Protocol accepted throughout the world regarding global warming. Countries that collaborate to implement this protocol in their respective countries

[1] ESDM Public Relations, 'CDM for the Future', *Ministry of Energy and Mineral Resources* , 2009 <https://www.esdm.go.id/id/media-center/arsip-berita/cdm-untuk-masa-depan-dunia #:~:text=As a concrete step in realizing lower emissions by 1990.> [accessed 19 March 2023].

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commit to reducing the release of carbon dioxide and five other greenhouse gases, or cooperate in trading gas release contracts if they maintain the amount or increase the release of these gases, which is the peak symptoms of global warming [2].

One of the nations that has accepted both the Kyoto Protocol and the UNFCCC is Indonesia, having done so by Law Number 6 of 1994 Number 17 of 2004 to participate in handling Changes in climate. Indonesia is a developing country that the Kyoto Protocol calls one of the non-Annex I countries that can implement the CDM (Clean Development Mechanism) scheme [3]. One of Indonesia's efforts is to implement a low carbon development policy which is one of the transition strategies towards a green economy and sustainable development. Low carbon development is also the backbone towards a green economy to achieve the vision of a developed Indonesia in 2045 and achieve zero emissions by 2060 [4].

Transforming the Indonesian economy into a green economy is one strategy for Indonesia to get out of the "middle income trap". A green economy and low carbon development will encourage economic growth and improve social welfare while maintaining environmental quality [5]. According to the Energy and Mining Regulation Minister No. 22 of 2019 Article 5 states that the source of carbon emissions comes from the energy industry, transportation, and energy consumption, both household and commercial [6].

The Environmental Kuznets Curve (EKC) which theoretically discusses the connection between accelerated economic expansion and environmental damage. The World Meteorological Organization (WMO) states that CO2 is the primary reason of global warming. CO2 emissions have increased sharply in the last century a result of human activity, especially the use of energy from fossil fuels including gas, oil, and coal, manufacturing activities, transportation, and consumption of goods and services that are directly related to economic growth. Thus, the Environmental Kuznet Curve (EKC) indicates a consistent link between environmental quality and economic growth which forms an inverted U-curve [7].

Deputy Minister of Finance (Wamenkeu) Suahasil Nazara explained that the transition to a green economy also includes not only developing EBT, but also reducing carbon dioxide (CO2) emitted [8]. The goal of the "green economy" is to increase the well-being and social

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[2] Tomaž Gerden, 'The Adoption of the Kyoto Protocol of t He United Nations Framework Convention on Climate Change', *Prispevki Za Novejso Zgodovino* , 58.2 (2018) <https://doi.org/10.51663/pnz.58.2.07>.

[3] Indonesia Environment Center, 'Training Clean Development Mechanism (CDM)', *Indonesia Environment Center* , 2016 <https://environment-indonesia.com/articles/training-clean-development-mechanism-cdm/> [accessed 19 March 2023] .

[4] ESDM, 'Getting to Know More About Green Economy Application Steps in Indonesia', *ESDM Human Resources Development Agency* , 2021 <https://ppsdmaparatur.esdm.go.id/seputar-ppsdma/mengenal-more-dalam-angkat-aplikasi- Ekonomi -green-in-indonesia> [accessed 21 January 2023].

[5] ESDM, 'Getting to know more about the steps to apply the green economy in Indonesia'.

[6] ESDM, 'Getting to know more about the steps to apply the green economy in Indonesia' .

[7] Fitri Kartiasih and Adi Setiawan, 'Application of Error Correction Mechanism in Analysis of the Impact of Economic Growth, Energy Consumption and International Trade on Co2 Emissions in Indonesia', Media *Statistics* , 13.1 (2020), 104–15 <https://doi.org/10.14710 /medstat.13.1.104-115>.

[8] Ministry of Finance, 'Pillars of Future Economic Growth: Green Economic Transition with EBT Development', *Ministry of Finance* (Jakarta, December 2022) <https://www.kemenkeu.go.id/information-publik/publikasi/berita-utama/lustrum- xiii-feb-unpad-%283%29>.

equality of society, while drastically lowering the possibility of harm to the environment. A market that is low carbon, or does not emit carbon dioxide into the atmosphere, conserves natural resources, and upholds social justice can also be considered a part of the green economy. A green economy, also known as a Low Carbon Economy (ERK), is an economic activity that produces low greenhouse gas emissions and supports adaptation activities for ecosystems as a mutually beneficial effort to build sustainable resilience [9].

This will impede the country's ability to thrive and flourish sustainably on the economic front. Changing environmental conditions can make sustainable economic development difficult, so everyone needs to pay attention. Environmental issues, especially increasing CO2 emissions, are influenced by economic growth. Economic growth and economic development can never be separated because economic growth will facilitate economic development while economic development will encourage economic growth [10].

Increasing energy consumption activities in the transportation sector, diesel production and crude oil imports have caused an increase in carbon emissions in Indonesia. Indonesia as one of the developing countries is trying to increase economic growth which is marked by the increasing number of domestic industries, energy consumption which is increasing day by day. According to data obtained from the International Energy Agency, total carbon emissions in Indonesia increased from 1990 to 2019, reaching 583.41 [11]Mt. The following is data on the increase in carbon emissions from 1990-2019

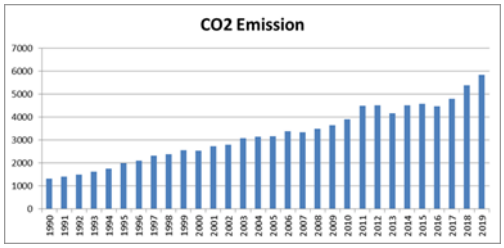

Fig. 1. Indonesian Carbon Emission Data 1990-2019

In the 2011-2015 period, the increase in carbon emissions tended to increase, however in 2013 CO2 carbon emissions in Indonesia decreased due to slowing economic growth, namely 5.8% compared to 2012, namely 6.2% and also an increase in subsidized fuel prices in in 2013 [12].

According to the Energy and Mineral Rights Regulation Minister No. 22 of 2019 Article 5 states that the source of carbon emissions comes from the energy industry, transportation, and energy consumption, both household and commercial (ESDM, 2012). 25% of the world's fuel

[9] ESDM, 'Increasing Oil and Gas Production and Reducing Carbon Emissions Must Be Maintained', *Ministry of Energy and Mineral Resources* , 2021 <https://www.esdm.go.id/id/media-center/arsip-berita/buka-ipa-ke -45-minister-of-ESDM-increasing-oil-and-gas-production-and-reducing-carbon-emissions-must-be-maintained> [accessed 26 January 2023].

[10] Nindita and Y. Agus Bagus Budi N, 'Analysis of the Effect of Economic Growth, Number of Industries, Foreign Investment and Poverty on Co2 Emissions in Indonesia', *Journal of Accounting and Economics* , 22.22 (2022), 1–13 <https://doi. org/10.37859/jae.v12i2.4302>.

[11] IEA, 'Increasing Carbon Emissions', *International Energy Agency* , 2021 <https://www.iea.org/countries/indonesia>.

[12] Bank Indonesia, 'Domestic Economy', *Domestic Economy* , 2013.

is consumed by the transportation sector, which is also responsible for 23% of carbon emissions worldwide. [13].

Although the transportation industry is regarded as one of the top industries that contributes significantly to both the development of the nation and our everyday lives, it also consumes a significant amount of energy. The majority of the energy used in this industry is non-renewable, which negatively affects the environment. The need for transportation to fulfill the need to move people and goods as an economic activity has resulted in a high level of dependence on oil and fuel imports. This also has an environmental impact of increasing greenhouse gas emissions to reach 189 million tons -co2EQ (29.3% of GHG emissions in the energy sector). Without significant action to reduce the carbon intensity of the transportation sector, CO2 carbon emissions are expected to increase doubling in less than 10 years, and will greatly influence world climate change [14]. The following is energy consumption data in the Indonesian transportation sector from 1990-2019:

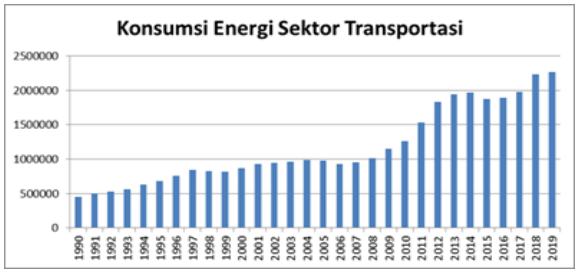

Fig. 2. Energy Consumption Data for the Indonesian Transportation Sector 1990-2019

According to organization for International Energy, energy consumption in the Indonesian transportation sector until 2019 reached 2,274,029 TJ (IEA, 2021). This is in line with the increasing number of motorized vehicles in Indonesia, reaching 133,617,012/unit until 2019 [15].

Syed Ali Raza, et al.'s research uses wavelet methods to investigate how economic development and energy use affect environmental deterioration in the United States. Monthly data from in order to see how factors relate to one another 1973 (January) to 2015 (July) was used. The research results show that energy use reduces carbon emissions over the short, medium, and long terms [16].

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[13] Muhammad Mohsin and others, 'Integrated Effect of Energy Consumption, Economic Development, and Population Growth on CO2 Based Environmental Degradation: A Case of Transport Sector', *Environmental Science and Pollution Research* , 26.32 (2019), 32824–35 <https:// doi.org/10.1007/s11356-019-06372-8>.

[14] ESDM Public Relations, 'Government Alternative Energy Policy for the Transportation Sector', *Ministry of Energy and Mineral Resources* , 2021, p. https://ebtke.esdm.go.id/ <https://ebtke.esdm.go.id/post/2021/01/08/2763/politik.energi.alternatif.bangun.untuk.sector.transportasi >.

[15] BPS, 'Increase in the Number of Motorized Vehicles', *Bps.Go.Id* , 2021, p. https://www.bps.go.id/.

[16] Syed Ali Raza, Nida Shah, and Arshian Sharif, 'Time Frequency Relationship between Energy Consumption, Economic Growth and Environmental Degradation in the United States: Evidence from Transportation Sector', Energy , 173 (2019), 706–20 <https *:* // doi.org/10.1016/j.energy.2019.01.077>.

Indonesia is committed to achieving the target by 2060, achieve net zero emissions. To support this achievement, Ministry of Mineral Resources and Energy has prepared a road map for the energy transition to carbon neutrality from 2021 to 2060. As a critical sector, the oil and gas industry is still a driver of the national economy and encourages the emergence of other economic activities [17].

According to the IEA, until 2020 Indonesia's energy production will reach 19695.1259 Tj (Terajoule). One of the energy and gas production sectors is diesel production (IEA, 2021). The following is data on Indonesian diesel production 1990-2019:

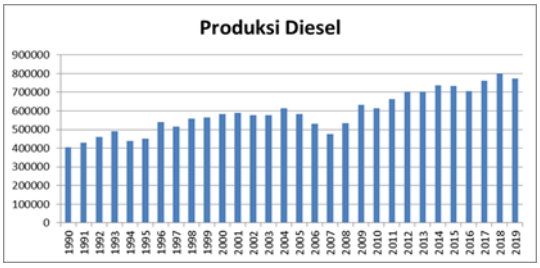

Fig. 3. Indonesian Diesel Production 1990-2019

In the 2007-2008 period there was a decline in diesel production due to the realization of oil lifting which did not reach the target in the APBN where in the 2008 APBN the target of 1.034 million barrels per day was revised to 0.910 million barrels per day (DPR.go.id, 2008).). However, after that there was an increase in production in 2012 until its peak in 2018 which was due to the price of diesel oil decreasing to IDR. 5,150/liter (ESDM, 2021b).

Research by Power-to-fuel is the key to a viable transportation system: An analysis of diesel was published by Schemme Steffen et al fuel and renewable electricity on CO2 in Germany shows that diesel fuel increases CO2 carbon emissions [18].

Previous research conducted by Hanif (2017) entitled The Americas and the Caribbean's Nexus of Economics, Energy, and Environment found that fuel oil imports contributed to increasing carbon emissions [19].

From the aforementioned studies, it can be inferred that international trade activities such as imports will have an impact on increasing CO2 carbon emissions in Indonesia, the following is data on Indonesian crude oil imports from 1990-2019:

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[17] ESDM, 'Increasing Oil and Gas Production and Reducing Carbon Emissions Must Be Maintained'.

[18] Steffen Schemme and others, 'Power-to-Fuel as a Key to Sustainable Transport Systems – An Analysis of Diesel Fuels Produced from CO2 and Renewable Electricity', *Fuel* , 205 (2017), 198–221 < https://doi.org /10.1016/j.fuel.2017.05.061>.

[19] Imran Hanif, 'Economics-Energy-Environment Nexus in Latin America and the Caribbean', *Energy* , 141 (2017), 170–78 <https://doi.org/10.1016/j.energy.2017.09.054>.

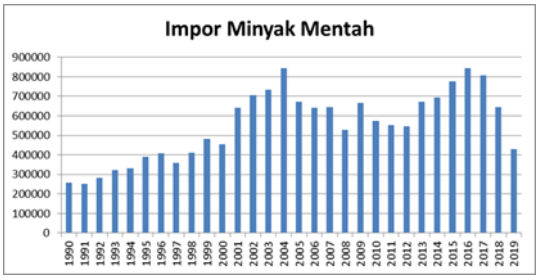

Fig. 4. Data on Indonesian Crude Oil Imports 1990-2019

In the period 2008-2016, Indonesia's crude oil imports experienced fluctuations. The lowest point occurred in 2008 as a result of an increase in domestic oil production of up to 100 thousand barrels as a result of oil exploration activities carried out by the government [20].

Based on the things stated above, namely the different results from several previous studies, the author is interested in analyzing "The Impact of Energy Consumption in the Transportation Sector, Diesel Production, Indonesia's Imports of Crude Oil Are Raising CO2 Emissions".

2 Researc Methods

This study's data analysis method estimates both in the near and long terms associations between the elements within the Error Correction Model (ECM) equations model the variables of Transportation Sector Energy Consumption, Diesel Production, Imports of Crude Oil and Indonesia's CO2 Emissions from 1990-2019 .

The ECM model used will go using a degree of integration examination and a stationarity test and Engle Granger (EG) test, cointegration and is free from any issues that these tests, so that the ECM model used is suitable for use and analysis. One way to identify relationships between The use of non-stationary variables in error correction modeling. With the condition that in a group of non-stationary variables there is cointegration, then The modeling for mistake correction is sound. The representative of Engle Granger states this need theorem (1987). The purpose of the Error Correction Model (ECM) is to make long-term corrections to the equation for regression between non-stationary variables such that they eventually revert to their equilibrium values.

The Error Correction Model (ECM) methodology, a method for reversing temporary imbalances and achieving long haul balance, is being used in this time series data analysis. The equations that will be prepared in this research are as follows:

COt = f (ECt, Pt, Mt)……..[3.1]

Furthermore, if the formula, which takes the shape of an Error Correction Model (ECM), becomes:

[20] Esdm, 'In 2008, Oil Production Increased by 100 Thousand Barrels', *Ministry of Energy and Mineral Resources* , 2008 <https://migas.esdm.go.id/post/read/ Tahun-2008,-Proproduk-Oli-Increasing- 100-Thousand-Barrels> [accessed 19 February 2023].

D 〖 CO 〗 _t=y_0+y_1 D 〖 EC 〗 _t+y_2 DP_t+y_3 DM_t+y_4 B 〖 EC 〗 _t+y_5 BP_t+y_6 BM_t+y_7 ECT+∑i …… ..[3.2]

Where :

COt = CO2 Carbon Emissions

ECt = Energy Consumption

Pt = Diesel Production

Mt = Crude Oil Imports

DCOt = Change in CO2 Carbon Emissions in the long term

DECt = Change in Energy Consumption in the Transportation Sector in the long term

DPt = Change in Diesel Production in the long term

DMt = Change in Crude Oil Imports in the long term

ECT = Error Correction Term

B = Backward Lag Operator

Coefficient y0 = Intercept

Coefficients y1, y2, y3 = Long-term elasticity coefficients

Coefficients y4, y5, y6 = Short-term elasticity coefficients

Coefficient y7 = Imbalance correction coefficient (speed of adjustment)

3 Result and Discussion

3.1 Stationarity Test Results

The unit root or data stationary test can be conducted in order to determine whether or not the data is steady. The enhanced Dickey Fuller examine (ADF), created by Dikey Fuller, is a technique that econometricians frequently employ to examine data stationarity issues. The data is not stationary if the calculated DF value is higher than the critical threshold (Mackinon Critical Values) or if the likelihood is below or equal to the critical value, and if the calculated ADF value is less than the essential value (Mackinon Critical Values) or the likelihood is bigger than the critical value of 0.05 (5%) of 0.05, then the data is stationary

Variabel	ADF T-Statistik	Nilai Kritis			Prob.	Kesimpulan
		1%	5%	10%		
Konsumsi Energi Sektor Transportasi (X1)	-4.376248	-3.689194	-2.971853	-2.625121	0.0019	Stasioner
Produksi Diesel (X2)	-6.903975	-3.699871	-2.976263	-2.627420	0.0000	Stasioner
Impor Minyak Mentah (X3)	-6.882187	-3.699871	-2.976263	-2.627420	0.0000	Stasioner
CO2 Emission (Y)	-6.120664	-3.769597	-3.004861	-2.642242	0.0001	Stasioner

Fig 5. Root Test Results Using the Second Difference Method

Source: data processed by Eviews 10

Based on table 1, it shows that the data is stationary at the second difference level. So this research can be continued in Error Correction Model (ECM) analysis research.

3.2 Cointegration Test Results

Null Hypothesis: D(ECT) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.200350	0.0002
Test critical values:	1% level	-3.679322	
	5% level	-2.967767	
	10% level	-2.622989	

*MacKinnon (1996) one-sided p-values.

Fig. 6. Cointegration Test Results

Source: Processed Data, Eviews 10

Based on table 2, it shows the ADF value (-5.200350) with a critical value of 2.042272 with a probability ECT value of 0.0002 < 0.05. The value that remains of the formula is stable at zero degrees (0) or levels level since the ECT level is stable at level level. Thus, it may be said that the variable that is independent and the variable that is dependent have a substantial long-term link (cointegration).

3.3 Error Correction Model (ECM)

Dependent Variable: D(Y)
Method: Least Squares
Date: 04/11/23 Time: 13:01
Sample (adjusted): 1991 2020
Included observations: 30 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.026874	0.010711	2.508934	0.0190
D(X1)	0.398871	0.144986	2.751101	0.0109
D(X2)	0.007263	0.135385	0.053649	0.9576
D(X3)	-0.060324	0.056192	-1.073525	0.2933
ECT(-1)	-0.225310	0.099436	-2.265868	0.0324

R-squared	0.386508	Mean dependent var	0.046651
Adjusted R-squared	0.288349	S.D. dependent var	0.054360
S.E. of regression	0.045858	Akaike info criterion	-3.175519
Sum squared resid	0.052574	Schwarz criterion	-2.941986
Log likelihood	52.63279	Hannan-Quinn criter.	-3.100810
F-statistic	3.937578	Durbin-Watson stat	2.131577
Prob(F-statistic)	0.012983		

Fig. 7. Short Term Equation

Source: Processed Data, Eviews 10

Based on table 3, showing ECT (Error Correction Time), the estimation results utilizing the Error Correction Model (ECM), is achieved with an important and beneficial sign at a = 0.05% for CO2 estimation, so the above model is valid for use. In brief, the error correction model (ECM) is as follows:

$$D(DCOt = 0.026874 + 0.398871DECt + 0.007263DPt – 0.060324DMt + \sum 1$$

Based on the ECM results above, it indicates that temporary changes in the Energy Consumption variable in the transportation energy sector have a favorable impact on carbon emissions (CO2). Meanwhile, Diesel Production and Crude Oil Imports have an adverse effect on emissions of carbon (CO2), ceteris paribus.

Dependent Variable: Y
Method: Least Squares
Date: 04/11/23 Time: 13:26
Sample: 1990 2020
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.977295	2.468685	-0.800951	0.4302
X1	0.890862	0.119716	7.441488	0.0000
X2	-0.398797	0.306548	-1.300928	0.2043
X3	0.222259	0.066838	3.325363	0.0026

R-squared	0.955656	Mean dependent var	8.022873
Adjusted R-squared	0.950729	S.D. dependent var	0.420802
S.E. of regression	0.093406	Akaike info criterion	-1.783809
Sum squared resid	0.235566	Schwarz criterion	-1.598778
Log likelihood	31.64904	Hannan-Quinn criter.	-1.723494
F-statistic	193.9582	Durbin-Watson stat	0.592937
Prob(F-statistic)	0.000000		

Fig. 8. Long Term Equations

Source: Processed Data, Eviews 10

$$DCOt = -1.977295 + 0.890862DECt + 0.398797DPt – 0.022259DMt + \sum 2$$

Based on the ECM results above, it indicates that sustained alterations in the Transportation Energy Sector Energy consumption variable and the Crude Oil Import variable has a favorable and noteworthy impact on Carbon Emissions (CO2). Meanwhile, Diesel Production has an adverse effect on emissions of carbon (CO2), ceteris paribus.

4 Conclusion

4.1 Conclusion

Based on tests using the error correction model, of several independent variables that were tried and included in the carbon (CO2) emissions equation in Indonesia, namely consumption in the transportation sector had has adverse effects on emissions of carbon (CO2) emisssions in Indonesia, while the variables were diesel production and crude oil imports. The effects of carbon emissions are nonexistent. (CO2) in the short term. It can be concluded that consumption in the distributed transportation sector in the short term can determine an increase in carbon emissions which can have a negative impact on the economy and environmental quality in Indonesia.

Meanwhile, in the long term, there is a positive influence between transportation sector consumption and Indonesia's carbon (CO2) emissions from the purchase of crude oil. Meanwhile, diesel production has no influence on carbon emissions (CO2) in Indonesia.

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[16] Raza, Syed Ali, Nida Shah, and Arshian Sharif, 'Time Frequency Relationship between Energy Consumption, Economic Growth and Environmental Degradation in the United States: Evidence from Transportation Sector', Energy , 173 (2019), 706–20 < https://doi.org/10.1016/j.energy.2019.01.077>

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