Does Trade Openess and Transportation Intensity Promote Enviromental Degradation in Indonesia?

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ABSTRACT

Transportation is one of the most important sectors in supporting all economic activities in order to support inclusive economic development. However, in its development, trade openness triggers high economic activity that triggers environmental pollution, one of which is the impact of the transportation sector. This study aims to estimate the effect of trade openness and transportation intensity as well as total factor productivity as a proxy for technological development on the growth of carbon emissions in Indonesia. The methods used in this research are Engle-Granger ECM and Granger Causality. The results show that in the long-term trade openness and transportation intensity have a significant positive effect, while the total productivity factor has a significant negative effect. In the short term with the same direction of influence, total productivity factors and transportation intensity have a significant effect, but trade openness does not have a significant effect. Furthermore, there is a unidirectional effect of fossil energy consumption on transportation intensity & trade oponess on transportation intensity. Last, transportation intensity and trade openness have been shown to have a bidirectional relationship.

Keywords: Lingkungan, Transportasi, Keterbukaan Perdagangan, *Total Factor Productivity*

ABSTRAK

Transportasi merupakan salah satu sektor terpenting dalam menunjang seluruh kegiatan perekonomian dalam rangka menunjang pembangunan perekonomian yang inklusif. Namun dalam perkembangannya keterbukaan perdagangan memicu tingginya aktifitas perekonomian yang memicu pencemaran lingkungan salah satunya sebagai dampak sektor transportasi. Penelitian ini bertujuan untuk menganalisis bagaimana pengaruh keterbukaan perdangan dan intensitas transportasi serta total faktor produktivity sebagai proxy technological development terhadap pertumbuhan emisi karbon di Indonesia. Metode yang digunakan dalam penelitian ini adalah Engle-Granger ECM dan Granger Causality. Hasil penelitian menunjukan bahwa dalam jangka panjang keterbukaan perdagangan dan intensitas transportasi memiliki pengaruh positif signifikan, sedangkan total faktor produktivitas memiliki pengaruh negatif sigifikan. Dalam jangka pendek dengan arah pengaruh yang sama total faktor produktivitas dan intensitas transportasi memiliki pengaruh signifikan, namun keterbukaan perdagangan tidak memiliki pengaruh signifikan. Lebih lanjut terdapat pengaruh unidirectional dari konsumsi energi fosil terhadap transportasi dan keterbukaan perdagangan terhadap

intensitas transportasi. Terakhir, intensitas transportasi dan keterbukaan perdagangan terbukti memiliki hubungan bidirectional.

Kata Kunci: *Environment, Transportation, Trade Opennes, Total Factor Productivity.*

INTRODUCTION

Nowadays, the development process is seen as a reform that is multidimensional in the environmental aspect, not only focusing on structural problems such as infrastructure provision, poverty alleviation, and job creation but also starting to expand on environmental mitigation. (Morin et al., 2018). The ideal development is one that includes problems that are multidimensional in nature, namely sustainable development. Sustainable development in question is that all economic activities must be able to run simultaneously with the environment to create an ecological balance. This is because development should have a welfare effect not only from the point of view of economic growth but also from another angle that is no less important, namely the quality of the environment which will affect the quality of life of the community (Morin et al., 2018). However, in reality, a lot of economic development that is carried out is often only in pursuit of income, without regard to environmental problems so environmental damage appears as a result.

One form of environmental pollution experienced by developing countries such as Indonesia for their economic activities is air pollution. The emergence of air pollution is usually marked by the emission of carbon dioxide (Co^2) gas. These emissions can come from industry, transportation, agriculture, and forestry. One of the important components of economic activity is the logistics and transportation sector, but on the other hand, transportation is also one of the sectors with the largest energy consumption after the industrial sector. According to (Holmberg & Erdemir, 2015) Transportation accounts for 63 percent of the total global oil consumption. The rest is used by industry, for raw materials and other uses. Within the transportation sector, road traffic is the largest user of energy 73 percent, followed by marine 10 percent, aviation 10 percent, and rail traffic 3 percent, and the rest are used in other. It means higher transportation intensity would be raises the energy consumption as well as increasing the potential of environmental degradation in the country. Pollution from transportation is a major health hazard. Rapid urbanization and increasing time spent in congested traffic mean that exposure is increasing even where pollution levels are falling. The greatest burden is in the mega-cities of developing countries (Woodcock et al., 2007).

Therefore, urban planning is one of the issues that are of concern to many governments around the world in minimizing the impact of air pollution and environmental degradation. One of the most important instruments in realizing good urban planning in ensuring the health and welfare of the community is transportation infrastructure. According to (Giles-Corti et al., 2016) good urban planning can be done by minimizing the company and the production of private vehicles with fossil fuels, designing pedestrian and cycling friendly movement networks, reducing the distance to public transport, and enhancing the desirability of active travel modes (e.g. creating safe attractive neighborhoods and safe, affordable, and convenient public transport).

Transportation is one of the most important sectors in the economy, especially in the industrial and trade sectors. All trade activities that occur involve the transportation sector as a means of logistics for delivering goods to other places. The more often a country conducts trading activities is an indication that the country has a high level of trade openness. With the integration of the world economy, the trend of trade openness between countries has become more and more obvious, and the economy has developed more and more prosperous (D. Wang et al., 2011). However, trade openness is a double-edged sword. It not only brings benefits to a country's national economic development but also causes environmental and climate problems.

Furthermore, every transportation sector activity requires energy consumption to be able to generate. In line with the rapid development of transportation intensity that arises from trade, the activity could be triggered environmental issues. According to production and industrial energy consumption are major sources of environmental pollution, since increased energy consumption generally results in greater pollutant emissions. Another thing that we need to be aware of is that the increasing economic activity will lead to various inventions through the development of technology that can trigger productivity and minimize the impact on economic activity. One of the parameters used to explain the role of technology in triggering industrial productivity is total factor productivity (Alhassan, 2021). Kohli (2015), defined Total Factor Productivity (TFP) is the portion of output not explained by the amount of inputs used in production. Research conducted by (Hongshan et al., 2020) found evidence that environmental regulation has a positive effect on the total factor productivity. It means that more environmental regulation is given by the government. It will boost the TFP through technological development.

The EKC hypothesis states that there is an inverse U-shaped relationship between environmental quality, as measured by several indicators of environmental degradation and per capita income. This means that environmental degradation is initially low when per capita income is low, then increases with increasing per capita income, and finally decreases with further increases in per capita income (Priyagus, 2017). Empirically, an increase in per capita income can be created through high productivity in the industrial and economic sectors, but it should be realized that economic activity also requires synergies from various other aspects such as transportation and energy consumption so that in the end it can also have an impact on environmental quality. Furthermore, technological development can also affect the environment, Impact, Population, Affluence, Technology (IPAT Theory) which was developed by Ehrlich and Holdren (1972), explaining driving factors of environmental change from human activities. Ehrlich and Holdren in Wang & Lili (2021) also assume that each factor has a multiplier proportionally worth one. In addition, population and per capita income are assumed to be the main factors that can increase the environmental impact, which is then followed by the development of technology to balance the environmental impact value from the right side.

This study aims to fill the literature gap on environmental degradation in Indonesia, by using the addition of other aspects in the development process, namely Total Factor Productivity and transportation intensity. Total factor productivity is generally used as an explanatory variable for the productivity of the industrial sector and is closely related to the level of work participation and unemployment, but in this study it is used as a variable that is thought to affect environmental degradation. In addition, transportation intensity is also rarely considered as a factor that can trigger environmental degradation, it is because the previous study uses the transportation sector's contribution to the economy and energy consumption of the transportation sector to measure the role of transportation itself. This is what underlies the author to examine the effect of transportation intensity, energy consumption, trade openness, energy prices, and total factor productivity on carbon dioxide emissions in one of the developing countries, namely Indonesia.

METHODS

This study aims to determine the effect of trade and transportation variables on environmental degradation as indicated by the intensity of carbon emissions in Indonesia. In some previous literature, transportation is less considered as one of the contributors to environmental pollution in the world, but rather the service and processing industry sector. Whereas the transportation sector is also one of the important components supporting economic activity (Tánczos & Török, 2008)

The data used in this study is secondary data obtained from the Federal Reserve Bank, Worldbank, and British Petroleum through the observation method. The data used in this study is time series data from the country of Indonesia in the period 1990-2020. In explaining the effect of

transportation and trade on environmental degradation, this study uses two time-series data analyzes, namely: Engle-Granger Error Correction Model and Granger Causality.

To establish the relationship between transport and trade liberalization for Indonesian air pollution, this study uses econometric techniques Engle-Granger error correction model. The Engle-Granger error correction model is used in the analysis because the model provides complete information about the dynamic short-term and long-term connections between the cointegration variables(Enders, 1995). There are two model of eror correction model, the first is the basic model or called as long-run models:

$$\text{Log } EM_t = \beta_0 + \beta_1 TRAN_t + \beta_2 TOP_t + \beta_3 FOS_t + \beta_4 TFP_t + et \quad \text{..... (1)}$$

Next, the basic model is transformed into Error Correction Model form, or the short run model, as follow:

$$D(\text{LogEM})_t = \alpha_0 + \alpha_1 D(TRAN)_t + \alpha_2 D(TOP)_t + \alpha_3 D(FOS)_t \; \alpha_4 D(TFP)_t + et \quad \text{..... (2)}$$

Where Log represents the logarithm function, EM is CO2 emissions (metric tons per capita), TRAN is Transportation services (% of service exports, BoP) as the proxy of transportation intensity, TOP is Trade Openness (% of of GDross Domestic Product), FOS is fossil energy Consumptions (Kg of Oil Equivalent Percapita), TFP is total factor productivity as a proxy of technological surplus (Index), and ε is the residuals, t is the time. βo, β1, β2, β3 are the parameters for the long-run model, α0, α1, α2, α3, are the parameters for the ECM, D is the difference between the Nt observation and Nt-1 observation.

The conditions for E-G-ECM are as follows. (1) All variables are doesn't stationer at level I (0). (2) All variables are stationers at the first difference I (1). (3) All variables must be cointegrated (cointegration). The stationarity test is performed using the augmented Dickey-Fuller (ADF) unit root test, and the reconciliation test is performed using the residual (Gujarati. D. N., 2004) Engle-Granger cointegration test. The Engle and Granger reconciliation test is performed by running the basic model using OLS and using the ADF test to test whether the residue of the estimation equation is resting at that level. If the residuals are resting at the I (0) level, this means that the variables in the model are cointegrated, or that all the variables in the model are long-term relationships or long-term relationships between the variables. Indicates that you have a balanced relationship. model. Once these three conditions are met, error engle-granger correction model analysis can be used.

As described earlier, if there are two or more variables that are cointegrated, then these variables are said to have a long-term relationship. However, in the economy there are often shocks that can affect the relationship between variables to become unbalanced (equilibrium). In other words, in the short term, if there is a shock in the economy, it is likely that there will be an imbalance between the cointegrated variables. On this basis, the error correction model (ECM) is used to detect how big and fast is the short-term adjustment between cointegrated variables towards the initial equilibrium condition.

Granger Causality is a time series data analysis tool that can be used to determine the causal relationship between research variables, so that the results of the analysis given will be in the form of a two-way relationship. The causality relationship is an interesting phenomenon in the real world where most of the causality phenomena found are outside the research hypotheses and previous applicable theories (Gujarati. D. N., 2004).

Furthermore, according to (Bressler & Seth, 2010) the Granger Causality test can be used to determine the past effect of a variable on the condition of other variables in the present. Or, in other words, to find out which event occurred first which will result in another event occurring.

Thus, conceptually, this causality method has several components, namely: (i) only past values of X can cause Y; (ii) the necessary condition for X to be an exogenous variable of Y is that X fails to be a Granger-caused Y; and (iii) variables X and Y are said to be independent if both variables fail to be

Causal-Granger. Empirically the Granger Causality model from Bressler and Seth (2010) is formulated as follows:

$$\sum_{i=1}^{m} a_i X_{t-i} + \sum_{j=1}^{n} b_j Y_{t-j} + \mu_t \quad \text{.....(3)}$$

$$\sum_{i=1}^{r} C_i Y_{t-i} + \sum_{j=1}^{s} d_j X_{t-j} + v_t \quad \text{.....(4)}$$

Where u_t dan v_t represents error terms which in the model are assumed to contain serial correlation and m=n=r=s. In the Granger Causality method, determining the length of the short lag is one of the most difficult parts of modeling (Bressler & Seth, 2010). Various selection criteria to assess the length of the lag such as Akaike Information Criterion, Schwarz's Bayesian Hannan and Quinn Information and Final Prediction Error have been proposed in various econometric literature to overcome this difficulty (Bressler & Seth, 2010).

The results of the above two forms of regression analysis of the linear regression model show four possibilities for each regression coefficient value. First, there is a one-way causal relationship from variable x to variable y. Second, there is a one-way causal relationship from variable y to variable x. Third, there is no causal relationship between the variables x and y, and vice versa. Fourth, there is a mutual causal relationship between the variables x and y.

RESULTS AND DISCUSSIONS

In accordance with the purpose of this study, namely estimating the long-term and short-term effects between trade openness, transportation intensity, and total factor productivity as proxies for technological development, the Engle-Granger Error Correction Model analysis method was carried out using time series data from Indonesia in 1989-2020.

The first step of the Engle-Granger Error Correction Model analysis is to ensure that all variables are stationary at the first difference and not stationary at the level. To find out the stationarity of the variable, it can be done by going through the unit root test.

Table 1. Unit Root Test

Variables	Unit Root Test in I (0)	Unit Root Test in I (1)
EM	0.0906	0.0379
TRANS	0.6753	0.0004
TOP	0.1336	0.0000
FOS	0.0884	0.0000
TFP	0.7939	0.0012

Source: Data Processed, 2022

Based on the results of the unit root test, it is known that all variables are stationary at the first difference and not stationary at the level, so it can be concluded that this model has met the first requirement of the Engle-Granger Error Correction Model. Furthermore, to find out the model has a long-term relationship, a cointegration test is carried out as follows:

Table 2. Cointegration Test

		T-statistic	Prob.
ADF test statistic		-3.609409	0.0114
Test Critical Values	1% level	-3.661661	
	5% level	-2.960411	
	10% level	-2.619160	

Source: Data Processed, 2022.

Based on cointegration test shown in table 2 above, the test shows that the residuals are stationary at level, I(0). The test indicates that all variables in the model are cointegrated or which means that the model has a long-run relationship. The result suggests that the model fulfilled the third requirement of Engle-Granger Error Correction Model and we can proceed to Engle-Granger Error Correction Model.

Table 3. Longrun Engle-Granger Error Correction Model

Variable	Coefficient	Prob.
Constant	-3.717353	0.0000
TRANS	0.013034	0.0013
TOP	0.004845	0.0067
FOS	0.029698	0.0062
TFP	-4.223020	0.0001
Adjusted R^2	0.954483	
Prob F-Stat	0.000000	

Source: Data Processed, 2022

Based on the long-term estimation results in table 3, it is found that transportation intensity has a positive and significant effect on the growth of carbon emissions in Indonesia with a probability value of 0.0013. The value of the coefficient of transportation intensity is 0.013034, this means that assuming ceteris paribus, if there is an increase in transportation intensity of 1 percent, it will increase carbon emissions in Indonesia by 0.013 percent.

Furthermore, trade openness has a significance value of 0.0067 and is below the p-value, so it can be concluded that trade openness in the long term has a significant effect. The coefficient value of trade openness is 0.004845, meaning that in the long term, assuming ceteris paribus, an increase in trade openness of 1 percent will result in an increase in carbon emissions of 0.004 percent.

Next is fossil energy consumption consider had probability value 0.0062 means that this variable has significance effect to emission growth. It also known that the coefficient value is0.029698, means that with the ceteris paribus assumption if the fossil energy consumption increases by 1 percent it will increase the emission growth in Indonesia by 0,02 percent.

Furthermore, total factor productivity has a probability value of 0.001, so it can be concluded that in the short-term total factor productivity has a significant effect on the growth of carbon emissions. It is known that the coefficient value of the total factor productivity is -4.223020, meaning that in the long term, through the ceteris paribus assumption, an increase in total factor productivity of 1 percent will reduce carbon emissions by 4.22 percent. The Engle Granger Error Correction Model can also estimate the short-term effect which is presented in table 4 below.

It is known that the probability f-stat value is 0.000 so it can be said that all variables in the model simultaneously affect carbon emissions. The R-square value is 0.954483, meaning that the research variable in the model has explained 95 percent of the variation in the influence of the dependent variable, and the rest is explained by variables outside the model.

Tabel 4. Shortrun Engle-Granger Error Correction Model

Variable	Coefficient	Prob.
Constant	0.030472	0.0384
TRANS	-0.001221	0.0187
TOP	-0.009357	0.3032
FOS	0.004781	0,6022
TFP	2.315394	0.0228
ECT_{t-1}	-0.438434	
Adjusted R^2	0.476687	

Source: Data Processed, 2022

Table 4 shows the results of the estimation of the short-term effect of the Engle-Granger Error Correction Model. In the short term, the intensity of transportation has a significant negative effect on the growth of carbon emissions. With a coefficient value of -0.001221, it means that in the short term a decrease in transportation intensity of 1 percent will increase carbon emissions by 0.21 percent. This is imply in the short run within the avalilable transoportation intensity still can handled the impact by the infrastructure provides by government, so the impact will be still positive.

Next is Fossil energy consumption is considering in short run has a positif insignificant effect to emission growth in indonesia, shows by the probability value is 0,6022. The coefficient value known is 0.004781, it means that in the short run the impact isn't significant so we can conclude that the fossil energy consumtion impact is indirect so it will be affectfull in longrun.

Furthermore, total factor productivity as a proxy for technological development has a significant negative effect on carbon emissions in Indonesia. With a coefficient value of -0.006190, it means that an increase in total factor productivity of 1 percent will reduce carbon emissions by 0.006 percent. While trade openness in the short term does not have a significant effect on carbon emissions, this may be due to the annual trade openness calculation, making it difficult to estimate the short-term effect and indicating an indirect impact of these variables on the growth of carbon emissions.

Considering the probability f-stat value is 0.004337 which is below the p-value so that it can be said that all variables in the model simultaneously affect the dependent variable. The R-square value is known to be 0.476687, meaning that all variables in the short-term model are able to explain 47 percent of the variation in the influence of the dependent variable and the rest are explained by variables outside the model.

As the last requirement of the Engle-Granger Error Correction Model, the ECTt-1 value must be negative and significant, in line with this, based on table 4, the ECTt-1 value is -0.438434with a probability of 0.0035, so it can be concluded that this model is said to be good because it has meet all the requirements of the Engle-Granger Error Correction Model.

After knowing the long-term and short-term relationship of the research model, a causality analysis was carried out to prove whether there was a two-way relationship between trade openness, transportation intensity, and technological development. The first step in analyzing Granger causality is determining the optimum lag length, table 5 shows the lag length selection test:

Table 5. Lags Length Selection Test

Lags	LogL	LR	FPE	AIC	SC	HQ
0	-173.8743	NA	0.243534	12.77673	13.01463	12.84946
1	-80.82956	146.2131	0.001951	7.916397	9.343759	8.352756
2	-64.56673	19.74772	0.004402	8.540481	11.15731	9.340472
3	-32.24649	27.70307	0.004564	8.017606	11.82390	9.181230
4	106.6621	69.45431*	5.68e-06*	-0.118724*	4.877043*	1.408532*

Note: * indicates lag order selected by the criterion

Source: Data Processed, 2022

Table 5 shows the lag length selection test based on the lag criteria, based on the results above, (-4) is the optimal lag because the FPE, AIC, and HQ criteria are the best criteria. So that in carrying out the next analysis, namely Granger Causality, Lag (-4) is used as the optimum lag used in the model. Table 6 shows the results of the Granger Causality analysis:

Table 6. Granger Causality

Pairwise Granger Causality Tests
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
TOP does not Granger Cause EM	28	0.93249	0.4662
EM does not Granger Cause TOP		1.26638	0.3177
TRANS does not Granger Cause EM	28	0.15071	0.9604
EM does not Granger Cause TRANS		0.90042	0.4832
TFP does not Granger Cause EM	28	0.54460	0.7050
EM does not Granger Cause TFP		3.01922	0.0438
EC does not Granger Cause EM	28	0.11270	0.9765
EM does not Granger Cause EC		2.07239	0.1246
TRANS does not Granger Cause TOP	28	3.19631	0.0446*
TOP does not Granger Cause TRANS		5.96071	0.0028*
TFP does not Granger Cause TOP	28	0.91574	0.4750
TOP does not Granger Cause TFP		0.35993	0.8340
EC does not Granger Cause TOP	28	1.26102	0.3197
TOP does not Granger Cause EC		2.46770	0.0798
TFP does not Granger Cause TRANS	28	1.57885	0.2206
TRANS does not Granger Cause TFP		0.18335	0.9442
EC does not Granger Cause TRANS	28	4.23445	0.0129
TRANS does not Granger Cause EC		0.57442	0.6846
EC does not Granger Cause TFP	28	1.93582	0.1458
TFP does not Granger Cause EC		0.64555	0.6368

Source: Data Processed, 2022

Based on the results of the Granger Causality analysis above, it is known that there is a unidirectional effect of fossil energy consumption on transportation intensity & trade oponess on transportation intensity. Furthermore, this study also succeeded in proving the existence of a bidirectional causality relationship between transportation and trade openness, so that it can be said that the intensity of transportation and trade opennes has a two-way reciprocal causality relationship. While the other variables have no causality relationship at all. To provide more empirical results, figure 1 shows the Impulse Response Function (IRF) Analysis which is used to detect the response of each variable due to changes / surprises from others.

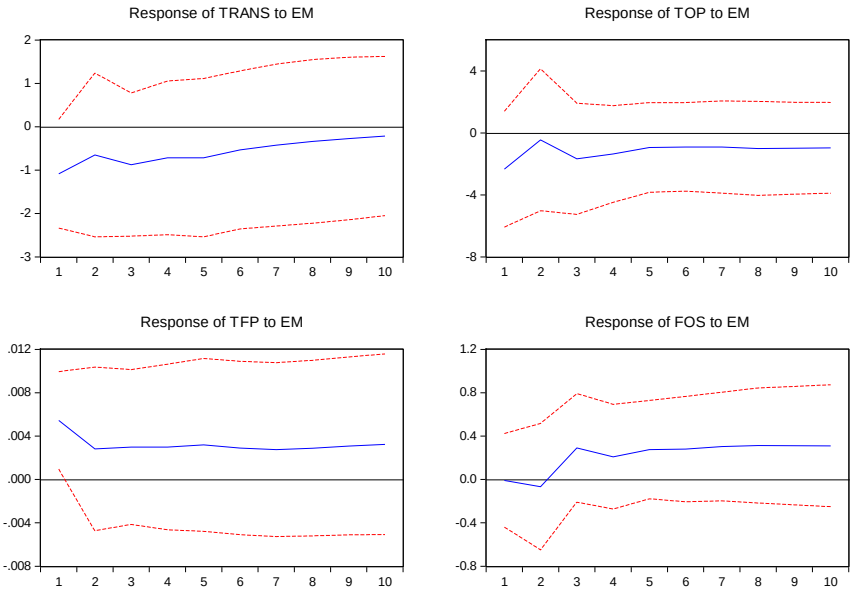

Figure 1. Impulse Response Function Estimation Result
Source: Data Processed, 2022

Based on the impulse response function in figure 1, it is known that all research variables namely trade openness, transportation intensity, fossil energy consumption, and total factor productivity are able to provide a significant shock to carbon emissions. Trade openness in the short term will shock the increase in carbon emissions and then decline and be stable in the long term. Transportation intensity in the short term will also provide a shock that can increase carbon emissions and then decrease and continue to increase again in the long term. Meanwhile, total factor productivity in the short term will provide a significant reduction in carbon emissions, and in the long term, it will reduce carbon emissions with less significant changes. Finally, fossil energy consumption in the long term will shock the increase in carbon emissions and will continue to increase slowly in the long term.

The results of the research above show that trade openness has a significant positive effect on the growth of carbon emissions in Indonesia, the same result was also found by (Demirel, 2008), besides that in his research, it is also recommended to develop more efficient transportation infrastructure to minimize land use, especially in developing countries. Furthermore (Abdulai & Ramcke, 2009) also confirmed the inconsistency of the hypothesis of the relationship between trade and environmental degradation, it was found that the trade openness of a country, especially a developing country, would significantly promote environmental degradation. This result is also supported by findings from (Le et al., 2016)which state that trade openness can impact the environment through two major channels: economies of scale and constitutive effects. Economies of scale refer to the impact of trade on the level of economic activity. In particular, greater openness leads to greater economic activity, such as the production and consumption of more transportation services, and more generally more goods and services. Since these activities are inherently environmentally costly, we can conclude that the increase in economic activity stimulated by the opening of a business reduces the quality of the environment.

Through Granger Causality analysis, it was also found that there is a bidirectional relationship between trade openness and environmental degradation. This implies that trade openness can increase the intensity of transportation through its role as a logistics sector in the economy. Likewise, the higher intensity of transportation will represent the high mobility in a country that is able to encourage foreign parties to conduct transactions in Indonesia which in the end will also increase trade openness during the period. So that in the end for developing countries, trade openness will reduce the quality of the environment due to limitations in developing resources and efficiency of

output, therefore the role of technological development becomes very important in minimizing the impact of trade to the environment (Antweiler et al., 1998).

Based on the estimation results in the previous section, transportation has a significant positive effect on the intensity of transportation on environmental degradation which is represented by the amount of carbon emissions in Indonesia. According to (Banister, 2011) transportation plays a crucial role in the economy so that the impact given on the intensity of its activity depends on the type of transportation input used. When the state still uses fossil fuel transportation modes, of course it will have a negative impact on the environment, generally occurs in developing countries, one of which is Indonesia. In minimizing the impact of transportation, the government needs to implement green infrastructure development policies and enhance the use of environmentally friendly fuels, so that the intensity of transportation will not have a significant impact on the environment (Tánczos & Török, 2008).

Considering that trade openness has a unidirectional relationship to total factor productivity, it means that the higher trade openness, basically, can also trigger the growth of total factor productivity. This is evidenced by a study conducted by (Li et al., 2021) which found that in China and Korea, trade and foreign investment had a significant effect on increasing total factor productivity. Furthermore, through its significant effect on reducing carbon emissions in the long term, total factor productivity is able to confirm the Environmental Kuznet Curve, that initially the economy will increase environmental degradation, but in the long term it will decline and form a U-Shape Curve based on technological development adjustments that are represented total factor productivity.

Fossil energy consumption is known to have a significant positive effect in the long term on the growth of carbon emissions in Indonesia. This is in line with the results of research from (Yingfei et al., 2022), which states that high transportation activities will require more energy, in developing countries fossil fuels tend to be a top priority even though they have a negative impact on the environment. This result implies the importance of developing a good transportation system that is supported by the use of environmentally friendly and sustainable fuels.

Total factor productivity has a negative effect on environmental degradation, this result implies that through technological development of firms and industries can reduce environmental degradation significantly. These results are in accordance with research conducted by (Wu et al., 2017) in his research in China, the growth of total factor productivity enterprises provides an increasing trend also in environmental quality. Furthermore (Rusiawan et al., 2015) added that the Indonesian government needs to increase green Total Factor Productivity to create sustainable industrial productivity growth, as well as an effort to minimize environmental externalities on economic activities.

Based on the analysis of several research variables in the previous section, it is known that the transportation sector has a large role as one of the main contributors to carbon emissions in Indonesia. It is known that the transportation sector is the second largest contributor to carbon emissions after the industrial sector in Indonesia. According to data from Energy and Natural Resources Emissions, the transportation sector utilizes 26.46% of Indonesia's carbon with an average annual increase of 7.17%. Thus, the transportation sector's mitigation policy in reducing carbon emissions in Indonesia is very important. The following is a policies brief compiled based on the results of the research above:

First, Development of Transit Oriented Development Areas, especially in Urban Areas. As previously known, the high intensity of transportation directly implies an increase in carbon emissions in Indonesia. A government-led carbon reduction policy can be achieved through the development of Transit Oriented Development (TOD) zones in urban areas. This concept will create an integrated transportation ecosystem and can develop a community of pedestrians and cyclists, thereby meeting people's need for a healthier life.

Second, Optimization of Sustainable Technology and Energy to Support the Performance of Economic Sectors, particularly the Transportation and Industrial Sectors. In realizing an

environmentally friendly sector, innovation through research and development is needed in order to reduce fossil energy consumption. Through the B20 and B30 Programs based on the Regulation of the Minister of Energy and Mineral Resources (ESDM) Number 12 of 2015 concerning the Provision, Utilization, and Trading System of Biofuels as Other Fuels. The use of alternative environmentally friendly fuels can help reduce carbon emissions in Indonesia. In addition, the carbon tax policy will also be very effectively implemented to reduce the number of carbon emissions in various economic sectors in Indonesia.

Third, Development of Supporting Infrastructure for Sustainable Energy Transportation. To support the implementation of other policies, a supporting policy is needed to assist the realization and successful implementation of the policies drawn up. In supporting the transmission of fuel use and environmentally friendly transportation, the government must also build more fuel stations and other supporting infrastructure for transportation based on electricity, biofuel, and other environmentally friendly energy.

Last, environmental-based fiscal policies and international trade policies need to be tightened in their implementation in Indonesia. This can be realized by the government through the implementation of a carbon tax, especially in the transportation sector which still uses fossil fuels. Then the revocation of fossil fuel subsidies for companies and the allocation of subsidies for sustainable fuels. In terms of international trade policy, it can be applied regarding increasing domestic and foreign trade taxes to be allocated to environmental protection.

CONCLUSIONS

Based on the results of the analysis of the Engle-Granger Error Correction Model, it was found that in the long-term trade openness and transportation intensity had a significant positive effect, while the total productivity factor had a significant negative effect. In the short term, the intensity of transportation has a positive and significant impact on the growth of carbon emissions in Indonesia. Meanwhile, total factor productivity has a negative and significant effect in the short term on the growth of carbon emissions in Indonesia. However, trade openness has an insignificant effect in the short term on the growth of carbon emissions in Indonesia

Furthermore, through Granger Causality analysis, it is found that there is a unidirectional effect of fossil energy consumption on transportation intensity & trade oponess on transportation intensity. Last, transportation intensity and trade openness have been shown to have a bidirectional relationship. The results describe that transportation plays an important role in improving environmental conditions. This study indicates that an increase in transport activities contributes to a reduction in environmental degradation. However, stable transport intensity is prioritized by the Indonesian Ministry of Transport. Therefore, this study has important policy implications for the Indonesian economy. Along with reducing emissions from transport and trade activities, the government should develop more transport-oriented development areas, improve green transport infrastructure and optimize traffic tax policy. communication and commerce in Indonesia to reduce the environmental impact of emissions.

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