Carbon Dioxide and Agricultural Economics in the Sphere of Sustainable Economic Development

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Abstract :
This study uses annual time series data with a time period of 1985 to 2020. The data consists of various sources. The data is secondary data collected from the Global Footprint Network, Penn World, and World Bank. This research utilized the following two time-series models for the period from 1985 to 2020 for the following variables. The dependent variable in this study is the ecological footprint and CO2 as an indicator of environmental damage. The independent variables in this study are the human capital index (HC), economic growth (EG), infrastructure (Gx), and natural resource depletion (NR) as indicators of economic activity and environmental changes as a result of economic activity. We found that Indonesia is a country with a large enough open green space, especially on islands outside Java, so it is very important to preserve Indonesia's nature as a supplier of world oxygen. On the other hand, infrastructure development is quite massive in 2019-2021 in Indonesia to encourage economic growth. Therefore, this study examines how Natural Resources Depletion (NR), human capital (HC), Economic Growth (EG), and Infrastructure Investment (GX) affect environmental degradation from the perspective of two important indicators, namely, Ecological footprint (EF) and CO2 from 1985 to 2020. The results of the analysis using the ARDL approach show that in the long term human capital and natural resources have a negative relationship with CO2, while Economic Growth and infrastructure development have a positive relationship with CO2. Based on the ARDL results, it can be concluded that the role of human capital is very important in preserving nature and infrastructure development needs to be carried out while preserving nature or trying to minimize environmental damage.

Keywords: Carbon Dioxide, Agricultural Economics,Sustainable Economic Development,Indonesia

JEL Classification: C10, N5, Q01,Q13

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Introduction

Human activities and investment in various economic fields in Indonesia have an impact on improving the Indonesian economy (Widarni & Bawono, 2021). Modern economic activities that operate various factories, machines, and vehicles result in environmental degradation which ultimately results in climate change. CO2 is indicated as a gas that has a long life cycle so it contributes greatly to the greenhouse effect and climate change in the long term.

Indonesia as a country that makes the agricultural sector an important sector and is an important country in supporting the world's oxygen supply needs to be preserved for its natural environment including maintaining low CO2 levels in Indonesia. Indonesia as one of the countries supporting the world's oxygen supply is experiencing air quality degradation with increasing CO2 levels in various big cities such as Jakarta. Economic activities such as transportation and the operation of production machines are significant contributors to carbon dioxide in the air.

Economic growth has an impact on environmental sustainability. The agricultural sector is one sector that is expected to be able to support a green economy that is environmentally friendly. However, the agricultural sector also requires electrical energy and oil energy in carrying out business in the agricultural sector. Of course, electricity and oil, directly and indirectly, contribute to carbon dioxide in the air.

Electrical energy with fossil fuels such as coal, of course, burns coal which results in an increase in CO2 levels in the air. Environmentally friendly electricity needs to be developed and efforts to reduce the use of fossil energy also need to be made.

Akbostanel and Türüt-Aşık et al. (2009) conducted a study related to income and CO2 emissions in Turkey with the conclusion that an increase in income has a relationship with an increase in CO2 emissions in Turkey. The relationship between economic activity and environmental degradation was also investigated by Li Guozhi and Li Zongzhi (2010) in China who found that growth in an economy driven by the agricultural sector contributed significantly to the increase in CO2 emissions in China's air. Sasongko et al (2021) explained that China has a fairly rapid economic growth which is supported by various economic sectors including the agricultural sector.

Research related to CO2 emissions and economic growth in Indonesia is still scarce and the purpose of this research is to complement the scientific literature related to CO2 emissions and economic growth in Indonesia.

Literature Review

Indonesia's natural preservation is very important for the world because Indonesia is one of the oxygen-producing countries for the world. However, Indonesia also needs to grow and develop economically as a nation (Cahyaningsih et al., 2021; Maxton-Lee, 2020). Sodri & Garniwa (2016) explained that sustainable environmental sustainability is very important and the reduction of environmental degradation needs to be done in economic development.

Padhan et al., (2020) explained that the process of burning non-renewable energy such as coal and other economic activities that produce carbon dioxide has an impact on deteriorating the environment and increasing global warming. Adedoyin and Zakari (2020) confirm the findings of Padhan et al. (2020) by finding that there is a process of energy consumption in economic activities increasing carbon dioxide in the air which has an impact on deteriorating environmental quality. Atil et al. (2020) explained the natural resources make a significant contribution to economic growth as well as to increase carbon dioxide. Danish et al.,(2019) explained that the exploitation of natural resources and economic activities affect the ecological footprint and has an impact on environmental quality degradation. The ecological footprint is a measure of impact. environmental pollution and energy consumption from economic activities.

Danish et al. (2019) explain that an increase in industrial activity in the economy increases the exploitation of natural resources which has an impact on the environment. Yao et al. (2020) explained that the development of human capital has an impact on environmental preservation as well as encouraging economic growth. Rusmingsih et al. (2021) explain that human capital can be developed through increased education and has an impact on human psychology to be more sensitive to the environment while improving the performance of human resources. Ahmed et al. (2020) explain that educated human resources are more aware of environmental sustainability. Mangone (2016) explains that Infrastructure in addition to acting as a driver of economic growth also has an impact on the environment.

Research Method

This study uses annual time series data with a time period of 1985 to 2020. The data consists of various sources. The data is secondary data collected from the Global Footprint Network, Penn World, and World Bank. This research utilized the following two time-series models for the period from 1985 to 2020 for the following variables. The dependent variable in this study is the ecological footprint and CO2 as an indicator of environmental damage. The independent variables in this study are the human capital index (HC), economic growth (EG), infrastructure (Gx), and natural resource depletion (NR) as indicators of economic activity and environmental changes as a result of economic activity.

$$EF_t = \beta_0 + \beta_1 HC_t + \beta_2 EG_t + \beta_3 Gx_t + \beta_4 NR_t + e_t$$

$$CO2_t = \beta_0 + \beta_1 HC_t + \beta_2 EG_t + \beta_3 Gx_t + \beta_4 NR_t + e_t$$

The long-term relationship between research variables was examined by cointegration test referring to the research of Pesaran et al. (2001) using the calculated F-statistical value as the basis for drawing conclusions whether or not there is cointegration between research variables. The conclusion of whether there is cointegration between the dependent and independent variables is based on the following two hypotheses:

$H0 : \beta1 = \beta2 = \beta3 = \beta4 = \beta5 = 0$

$H1 : \beta1 \neq \beta2 \neq \beta3 \neq \beta4 \neq \beta5 \neq 0$

If there is a cointegration relationship between the research variables based on the two hypotheses above, then a long-term and short-term relationship between the research variables is tested with the following equation:

$$\Delta EF_t = \beta_0 + \beta_1 EF_{t-1} + \beta_2 HC_{t-1} + \beta_3 EG_{t-1} + \beta_4 Gx_{t-1} + \beta_5 NR_{t-1} + \sum_{i=1}^{q} \beta_6 \Delta EF_{t-1} + \sum_{i=1}^{q} \beta_7 \Delta HC_{t-1} + \sum_{i=1}^{q} \beta_8 \Delta EG_{t-1} + \sum_{i=1}^{q} \beta_9 \Delta Gx_{t-1} + \sum_{i=1}^{q} \beta_{10} \Delta NR_{t-1} + e_t$$

$$\Delta CO2_t = \beta_0 + \beta_1 CO2_{t-1} + \beta_2 HC_{t-1} + \beta_3 EG_{t-1} + \beta_4 Gx_{t-1} + \beta_5 NR_{t-1} + \sum_{i=1}^{q} \beta_6 \Delta EF_{t-1} + \sum_{i=1}^{q} \beta_7 \Delta HC_{t-1} + \sum_{i=1}^{q} \beta_8 \Delta EG_{t-1} + \sum_{i=1}^{q} \beta_9 \Delta Gx_{t-1} + \sum_{i=1}^{q} \beta_{10} \Delta NR_{t-1} + e_t$$

In the above equations, β1 to β10 are the elements to be examined based on F statistical calculations. If there is cointegration in the research variables, then proceed with short-term and long-term dynamic ARDL simulation models. This study adopted the Dynamic ARDL model. Khan et al. (2020). The adoption of the ARDL model in this study aims to examine, simulate and predict the graph of shocks that occur in the independent variables. Jordan and Philips (2018) explain that the dynamic ARDL simulation model can be used if there is a cointegration relationship between research variables. The following ARDL model we use:

$\Delta EF_t = ųEF_{t-1} + \beta_1 HC_t + ų_1\Delta HCt_{-1} + \beta_2 EG_{t-1} + ų_2\Delta EG_{t-1} + \beta_3 Gx_{t-1} + ų_3\Delta Gx_{t-1} + \beta_4 NR_{t-1} + ų_4\Delta NR_{t-1} + ųDx_{t-1} + e_t$

$\Delta CO2_t = ųCO2_{t-1} + \beta_1 HC_t + ų_1\Delta HCt_{-1} + \beta_2 EG_{t-1} + ų_2\Delta EG_{t-1} + \beta_3 Gx_{t-1} + ų_3\Delta Gx_{t-1} + \beta_4 NR_{t-1} + ų_4\Delta NR_{t-1} + ųDx_{t-1} + e_t$

The two equations above are dynamic ARDL simulation models where β is the long-term coefficient and ų is the short-term coefficient, et is the error correction. Dx is applied to check the speed of adjustment of the imbalance.

Result and Discussion

Descriptive statistics related to Indonesia for the variables of the study are presented in Table 1.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std.Dev	Min	Max
EF	36	0.391	0.068	0.316	0.496
CO2	36	10.923	2.033	7.112	15.941
HC	36	1.59	0.188	1.229	1.769
EG	36	4.314	1.816	1.009	6.926
GX	36	23.559	16.787	3.278	60.115
NR	36	1.226	0.441	0.63	2.081

The results of the descriptive statistics are expressed in the minimum value (Min), the average value (mean), and the maximum value (Max). EF Min 0.316, EF Mean 0.391, EF Max 0.496, CO2 Min 7.112, CO2 Mean 10.923, CO2 Max 15.941, HC Min 1.229, HC Mean 1.59, HC Max 1.769, EG Min 1.009, EG Mean 4.314, EG Max 6.926, Gx Min 3.278, GX Mean 23.559, GX Max 60.115, and NR Min 0.63, NR Mean 1.226, NR Max 2.081. EF is Indonesia's ecological footprint, CO2 is Indonesia's carbon dioxide emissions, HC is Indonesia's human capital index, EG is Indonesia's gross domestic product, GX is Indonesian government investment in infrastructure, and NR is natural resource depletion.

Table 2 shows the results of the VAR lag order selection criteria.

Lag	logL	LR	FPE	AIC	SC	HQ
0	-111.8567	NA	0.021125	7.888612	8.271573	8.151154
1	-12.45817	172.1816	0.000213	2.233371	3.151156	3.336751
2	11.18725	36.81213	0.0000446	1.381762	3.031113	2.131322

Most lag selection criteria suggest a lag length of 2.

Table 3. The Phillip-Perron (PP) and Augmented Dickey-Fuller (ADF) Unit Root Tests

Unit root test table (PP)						
at level with constant	EF	CO2	EG	GX	HC	NR
t-Statistic	-1.468	-1.1228	-2.5131	-4.7362	-1.1124	-1.8215
Prob.	0.3667	0.5363	0.0214	0.0059	0.5519	0.2014
At first difference with constant	d(EF)	d(CO2)	d(EG)	d(GX)	d(HC)	d(NR)
t-Statistic	-3.9114	-4.9513	-12.3716	-14.1757	-6.1268	-4.1256

Prob.	0.0005	0.0000	0.000	0.0000	0.0000	0.0002
Unit root test table (ADF)						
at level with constant	EF	CO2	EG	GX	HC	NR
t-Statistic	-1.2152	3.3321	2.5737	-2.7531	-2.3112	-1.1532
Prob.	0.4432	0.2326	0.0127	0.0043	0.4481	0.1487
At first difference with constant	d(EF)	d(CO2)	d(EG)	d(GX)	d(HC)	d(NR)
t-Statistic	-2.2253	-4.8513	-8.1165	-6.1136	-6.2813	-4.1723
Prob.	0.0114	0.0000	0.000	0.0000	0.0005	0.0003

The Phillip-Perron (PP) and Augmented Dickey-Fuller (ADF) unit root tests show the stationarity of all variables in the first difference. Pesaran et al. (2001) explained that in Dynamic ARDL cointegration testing is important to do using the ARDL bounds test. Table 4 shows the results of the ARDL bounds test for EF, and carbon dioxide (CO2) emissions.

Table 4. ARDL bounds test

CO2		EF		
Test Statistic	Value	Test Statistic	Value	K
F-Statistic	4,693	F-Statistic	10,5517	4
Critical Value Bounds				
Significance	10 bound		11 bound	
10%	2.45		3.52	
5%	2.86		4.01	
2.5%	3.25		4.49	
1%	3.74		5.06	

At the 5% significance level, the estimated F statistical values for both indicators are outside the upper limit.

The dynamic ARDL findings are as presented in Table 9.

	CO2	EF
ECT	0.212	0.239
	1.81	1.91
HC	-2.616	0.0131
	-3.15	2.11
HC t-1	4.616	0.212
	1.96	1.92
EG	0.321	0.228
	2.59	1.88
EG t-1	0.399	1.897
	2.85	2.16
GX	1.312	0.439
	0.87	1.91
GX t-1	4.838	1.86
	1.89	3.26
NR	-0.397	-0.121
	-2.16	-3.81
NR t-1	-1.379	-0.0115
	-1.81	-1.98

N	35	35
R square	0.7939	0.7626

In this study, that error correction speed, is denoted by the term ECT. Based on the dynamic ARDL results, it was shown that ECT was significant in both cases. The ECT values were 0.212 for carbon dioxide emissions and 0.239 for EF, respectively. Since the value lies between 0 and 1, it can be concluded that the equilibrium shock is adjusted in one year for both environmental degradation variables.

Based on the results of dynamic ARDL, HC in the long term has a significant negative impact on CO2 with a coefficient value of 2.616 but has a significant positive impact on EF with a coefficient value of 0.0131. In the short-term HC relationship, it has a positive direction towards CO2 with a coefficient value of 4.616 each and EF with a coefficient value of 0.212 each.

Based on ARDL results both in the short term and long term on both indicators of environmental damage, it was found to be significantly positive for economic growth (EG), namely 0.321 for CO2 and 0.228 for EF. In the short term, the coefficient values are 0.399 for CO2 and 1.897 for EF.

Based on ARDL results in both the short and long term, both indicators of environmental damage were found to be significantly positive for the Indonesian government's investment in infrastructure (GX), namely 1.312 for CO2 and 0.439 for EF. In the short term, the coefficient values are 4.838 for CO2 and 1.86 for EF. In the long run, the NR coefficient for CO2 is 0.397 and the EF is 0.121. In the short term, the coefficient of CO2 is 1.379, and for EF the coefficient is 0.0115. The overall explanatory power was higher for the CO2 model with an r-value of 79% compared to 76% for the EF model.

Conclusion

Indonesia is a country with a large enough open green space, especially on islands outside Java, so it is very important to preserve Indonesia's nature as a supplier of world oxygen. On the other hand, infrastructure development is quite massive in 2019-2021 in Indonesia to encourage economic growth. Therefore, this study examines how Natural Resources Depletion (NR), human capital (HC), Economic Growth (EG), and Infrastructure Investment (GX) affect environmental degradation from the perspective of two important indicators, namely, Ecological footprint (EF) and CO2 from 1985 to 2020. The results of the analysis using the ARDL approach show that in the long term human capital and natural resources have a negative relationship with CO2, while Economic Growth and infrastructure development have a positive relationship with CO2. Based on the ARDL results, it can be concluded that the role of human capital is very important in preserving nature and infrastructure development needs to be carried out while preserving nature or trying to minimize environmental damage.

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