

# Nexus analysis between CPO production, carbon emissions and GDP: A case study in Indonesia

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## Abstract

Indonesia is the world's largest CPO producer, which can positively impact its economic fundamentals. However, clearing new land for CPO farming will have an impact in the form of carbon emissions. The amount of carbon emissions can have an impact on the Indonesian economy as well. Thus, the study aims to predict the relationship between the amount of CPO production, carbon emissions, and GDP in Indonesia. The study uses the VAR method. The annual data starts from 1980 to 2020. PCPO and CO<sub>2</sub> are positively related, especially in the long term. PCPO and GDP also have a positive relationship, especially in the long term. The relationship between CO<sub>2</sub> emissions and GDP is also positive in the long term. In the short term, the three variables are related lucratively. The most significant relationship is between PCPO and CO<sub>2</sub> emissions.

## Public interest statement

Understanding the relationship between CPO production, carbon emissions, and GDP is necessary, considering that Indonesia is the largest CPO producer. As the largest CPO producer, it will impact the economy. It will also have an impact on the creation of carbon emissions. Therefore, it is necessary to understand how those variables are related.

**Keywords:** *Carbon Emissions, CPO, GDP and VAR*

**Paper type:** Case study

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## INTRODUCTION

Crude Palm Oil (CPO) has become an important fundamental for the Indonesian economy considering that CPO is the largest produced in this country (Gimni.org, 2018). CPO is also considered important because it is the main ingredient for producing cooking oil and it has become an important commodity for the people of Indonesia (Sundoro & Putlia, 2021). Thus, CPO is considered important for the Indonesian economy. CPO production requires land as a plantation area. Much of the opening of new land for palm oil plantations in Indonesia is carried out by deforesting and burning land (Mongabay.co.id, 2022). Thus, the more palm oil peat land that is cleared, the greater the opportunity for carbon emissions to increase. There is a contradiction when the more CPO production the better it should be for the Indonesian economy, but on the contrary the opening of new land for CPO production can actually cause carbon emissions.

The relationship between CPO production, carbon emissions and GDP has been discussed by several previous studies. The benchmark for the relationship between CPO production and economic growth in a country must be seen from the three largest CPO producing countries in the world, namely Indonesia, Malaysia and Nigeria. Research conducted by Abah *et al.* (2020) found that in the short and long term, increased CPO production will contribute to growing Nigeria's GDP. Likewise, research conducted in Indonesia and Malaysia by Qodri & Wahyudi (2021) and Ezechi & Muda (2019) found that there is a positive relationship between a country's economic conditions and CPO production, especially in the short term. However, there is a negative relationship between CPO production and GDP in Indonesia and Malaysia in the long term.

The finding of Qodri & Wahyudi (2021) also state that for every one hectare of land cleared for palm oil plantations in Indonesia, it will generate 174 tons of carbon emissions. Likewise, a finding by Ezechi & Muda (2019) in Malaysia also find the same thing. Increasing CPO production can sacrifice around 20 percent of forests in Malaysia, which creates carbon emissions. Several previous studies have found that carbon emissions and GDP in a country can have a relationship according to the Environmental Kuznet Curve (EKC) theory. Two Asian countries that are growing economically, namely India and China, have also been studied by Shahbaz *et al.* (2015) and Jian *et al.* (2019). The results of those research find that the EKC theory is in accordance with what happened in India and China where in the long run carbon emissions and GDP will be negatively related. Precisely the findings in Indonesia conducted by Azwar (2019) states that the EKC theory does not apply in Indonesia. The reason is that there is a positive relationship between carbon emissions, especially from the electricity and heat industry, and GDP in Indonesia.

If related to the previous researches (Azwar, 2019; Ezechi & Muda, 2019; Jian *et al.*, 2019; and Qodri & Tri Wahyudi, 2021), the novelty of this research is the incorporation of discussions about production CPO, carbon emissions and economic growth into one scope. Previous researches separate the study of all those variables not in one scope. Then, this research will use the VAR method which later the results of this study will show how much the relationship is by each variable both in the short and long term. Previous researches explain more about the relationship between the three variables, but do not explain how much the relationship between those variables. CPO production is considered to create carbon emissions. On the one hand, Indonesia expects CPO production to create increased economic growth. Therefore a study is needed to find out how the relationship between CPO production, carbon emissions and economic growth. As a result, this research is conducted with the aim of knowing how the relationship between CPO production, carbon emissions and GDP in Indonesia

## LITERATURE REVIEW

### Crude Palm Oil

Crude Palm Oil (CPO) comes from the fruit of the palm oil tree where the flesh of the processed palm fruit produces oil known as CPO. According to Gimni.org (2018), CPO has been used by most industries because palm oil can be used as a substitute for solar energy. In fact, CPO production is not only used for industrial purposes, data from BPS (2020) also shows that until mid-2020 CPO can make the biggest contribution to Indonesia's trade balance.

### Carbon Emissions

In general, it is known that carbon dioxide (CO<sub>2</sub>) emissions as a type of greenhouse gas that can cause global warming in the earth's atmosphere. It is also generally known that CO<sub>2</sub> emissions usually come from vehicle pollution and factory smoke pollution. However, carbon dioxide can also come from root respiration or respiration from the oxidation of soil organic matter (Sarmah *et al.*, 2015).

### Economic Growth (GDP)

Economic growth is the development of activities in the economy that causes goods and services produced in society to increase and people's prosperity increases in the long term (Untoro, 2010). From the statement, growth from the production side in a country can create economic growth for that country. According to BPS, one of the important indicators to determine the economic condition in a country in a certain period is the Gross Domestic Product (GDP) data.

### Theoretical Model Framework

The relationship between CPO production and economic growth in a country must be seen from the three largest CPO producing countries in the world, namely Indonesia, Malaysia and Nigeria. According to Abah *et al.* (2020), the increasing of CPO production will grow Nigeria's GDP either in the short or in the long term. Likewise researches, which are conducted in Indonesia and Malaysia by Qodri & Wahyudi (2021) and Ezechi & Muda (2019), find that there is a positive relationship between GDP and CPO production in the short term. However, there is a negative relationship between GDP and CPO production that happened in Indonesia and Malaysia especially in the long term.

**H1:** CPO production and GDP have a relationship in Indonesia

There are several previous studies which find that CPO production can have a negative impact where it can create carbon emissions. Qodri & Wahyudi (2021) states that for every land clearing for a palm oil plantation of one hectare, it will generate 174 tons of carbon emissions. A finding by Brown *et al.* (2021) also states that to produce CPO, land clearing for palm oil in Indonesia would be carried out by means of deforestation where this method could lead to an increase in carbon dioxide. Likewise, a finding by Ezechi & Muda (2019) in Malaysia finds the same thing. Increasing CPO production can sacrifice around 20 percent of forests in Malaysia, which creates carbon emissions.

**H2:** CPO production and carbon emissions have a relationship in Indonesia

Whereas several previous studies have found that carbon emissions and GDP in a country can have a relationship. Grossman dan Krueger in 1991 suggested the Environmental Kuznet Curve (EKC) theory. The EKC theory explains the relationship between carbon emissions and GDP in an inverted U. The meaning itself is that at the beginning carbon emissions will increase but GDP will be in a small amount and in the long run carbon emissions will decrease where GDP will increase in value. Two Asian countries whose economies are growing, namely India and China, have also been studied by Shahbaz *et al.* (2015) and Jian *et al.* (2019). The result finds that the EKC theory is in accordance with what happened in India and China where in the long run carbon emissions and GDP will be negatively related. On the contrary, a finding by Azwar (2019) in Indonesia shows that the EKC theory does not apply in Indonesia. The result shows a positive relationship between carbon emissions, especially from the electricity and heat industry, and GDP in Indonesia.

**H3:** Carbon emissions and GDP have a relationship in Indonesia

## METHODS

The research is a quantitative method. Secondary data is used in this research and in the form of an annual time series. The sampling technique is carried out by purposive sampling. The length of the research period is from 1980 to 2020. The research period starts from 1980 because that year is the first time the pattern of cooperation between farmers with government and companies, namely PTPN (PT Perkebunan Nusantara), through the intervention of the PIR (Perkebunan Inti Rakyat) policy (Gapki.id, 2018). Table 1 can show the data sources for each variable.

**Table 1.**

*Data sources, symbol, units, and variable types*

No.	Variable Types	Symbol	Units	Data Sources
1.	CPO Production	PCPO	Million Tons	CEIC data
2.	Carbon Emissions	CO2	Ton/Capita	Country Economy
3.	GDP/Economic Growth	PDB	% Annual	World Bank

Sources: Combined Multiple Data, 2022

Table 1 shows that the units of measurement in the data for all variables in this research have differences. The research wants to equate the unit of measurement into percentage units. Therefore all variables that are still in the form of nominal units, the units of measurement will be converted into percentage units. To measure CPO production from 1980 to 2020, the research finds from CEIC data website. CPO production unit in million tons. To equate CPO production units with GDP in the form of percentage growth, CPO production data can be changed with the following formula:

$$\frac{\text{CPO production in the current year} - \text{CPO production in the previous year}}{\text{CPO production in the previous year}} \times 100\%$$

The amount of carbon dioxide emissions (CO2 emissions) can already be known by looking at reports from several credible institutions. To measure carbon dioxide emissions from 1980 to 2020, the research looks for from the Country Economy website. The unit of carbon dioxide

emission is still in tons per capita. To equate carbon emission units with GDP in the form of percentage growth, carbon emission data is converted into the following formula:

$$\frac{\text{Carbon emissions in the current year} - \text{Carbon emissions in the previous year}}{\text{Carbon emissions in the previous year}} \times 100\%$$

The type of GDP used in this research is real GDP using constant prices so that it can determine economic growth from year to year. Real GDP data in Indonesia on an annual basis from 1980 to 2020 can be seen on the World Bank website. For real GDP units, it is already in the form of percentage growth, so the data does not need to be changed its proxy.

To get the best VAR-VECM model, other statistical tests must be carried out. Stationarity test needs to be done first to show the data has a unit root or not. Data that has unit roots will create a spurious regression (Sundoro & Theovardo, 2019). Spurious regression will make a regression to be biased because statistically the regression is actually not significant. If one of all variables is not stationary or still have unit roots, then the cointegration test can be carried out. The VAR test is used if the data used is stationary and free from cointegration. On the contrary, the VECM test will be used if the data is still not stationary but has been cointegrated (Sihombing & Sundoro, 2017). The VAR-VECM model is suitable for use in time series data and moreover it can explain how big the relationship between variables in the research (Verbeek, 2017). The equation model that can be written in this research to predict the relationship between CPO production, carbon emissions and GDP is as follows:

$$PCPO_t = a_1 + \sum_{i=1}^P a_{1i} PCPO_{t-i} + \sum_{i=1}^P a_{1i} CO2_{t-i} + \sum_{i=1}^P a_{1i} PDB_{t-i} + \varepsilon_t$$

$$CO2_t = a_2 + \sum_{i=1}^P a_{2i} PCPO_{t-i} + \sum_{i=1}^P a_{2i} CO2_{t-i} + \sum_{i=1}^P a_{2i} PDB_{t-i} + \varepsilon_t$$

$$PDB_t = a_3 + \sum_{i=1}^P a_{3i} PCPO_{t-i} + \sum_{i=1}^P a_{3i} CO2_{t-i} + \sum_{i=1}^P a_{3i} PDB_{t-i} + \varepsilon_t$$

Where  $PCPO$  is CPO production;  $CO2$  is carbon emissions;  $PDB$  is economic growth;  $a_i$  is parameter matrix for each  $i = 1, 2, \dots, p$  and  $\varepsilon$  is residual vector.

## RESULTS AND DISCUSSION

### Unit Roots Test

Table 2 shows the results of the stationarity or unit root test using the Augmented Dickey-Fuller (ADF) method. All research variables are free from unit roots at level of significance with P-values below 0.05. Since all the research datas are stationary at the levels, the cointegration test in this study is not carried out.

**Table 2.***Result of Stationarity Test*

Variable	Level	
	<i>P-value</i>	Annotation
PDB	0,0009	Stationary
PCPO	0,0000	Stationary
CO2	0,0226	Stationary

Source: E-views, processed data 2022

**Optimal Lag Test**

Furthermore, the research determines the appropriate lag length. Table 3 shows the determination of the length of the lag used by this study. Based on SC criteria, the recommended lag length is lag 0. Lag length 1 is suggested by HQ criteria. For the LR, FPE, and AIC criteria, the recommended lag length is lag 2. Then, the results of selecting the optimal lag will be selected with a lag length of 2 for this research.

**Table 3.***Result of Optimal Lag Test*

Lag	LogL	LR	FPE	AIC	SC	HQ
0	5,928953	NA	0,000172	-0,154155	-0,024872*	-0,108157
1	16,15537	18,29990	0,000162	-0,218704	0,298429	-0,034712*
2	21,57621	8,844528*	0,000197*	-0,030327*	0,874655	0,291659
3	26,77574	7,662470	0,000247	0,169698	1,462529	0,629677

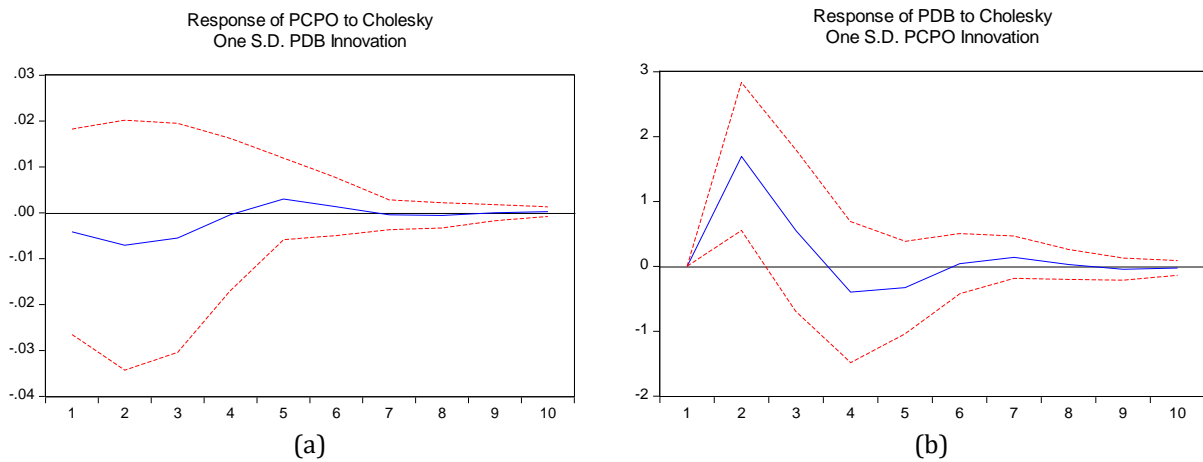
Source: E-views, processed data 2022

Based on previous statistical tests, this research is more suitable to use the VAR method with a lag length of 2. To analyze the VAR method, it will use Impulse Response Function (IRF) and Forecast Error Variance Decomposition (FEVD) analysis.

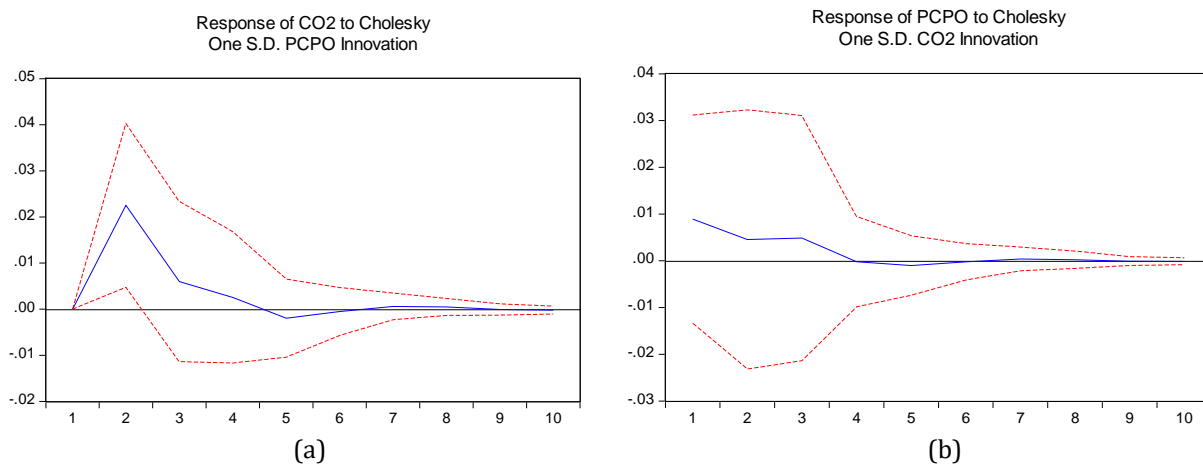
**Impulse Response Function (IRF) Analysis**

The result of IRF analysis in Figure 2 can answer the purpose of this research in knowing the relationship between CPO production and GDP in Indonesia. Figure 2 (a) shows the relationship between PCPO and PDB. From period 1 to 3, it can be seen that the relationship between the two variables occur negatively in the range of 0.007%. From period 4 and 5, PCPO and GDP are positively related in a smaller range at 0.003% before returning to equilibrium. Figure 2 (b) also show the same pattern between GDP and PCPO linkages. GDP and PCPO have a positive relationship with the largest range at 1.5% from period 1 to period 3. From period 4 to 5, there is a negative relationship. Then from period 7 to the equilibrium point, the relationship between GDP and PCPO occurs positively by 0.1%. Even though there is a positive relationship between PCPO and GDP, but the linkage is in a small range. The result of this research is similar to the findings of Qodri & Wahyudi (2021) in Indonesia and Ezechi & Muda (2019) in Malaysia. CPO production (PCPO) in the long term actually contributes less to GDP. Palm oil is considered to be able to provide degradation of soil quality for some time ahead (Tjahjaprijadi, 2014). The number of palm oil products will decrease, as a result, even though the operational costs and land area remain the same but the number of products decreases. Therefore, the results show that there is a positive relationship between CPO production and GDP in Indonesia but in small range. It can

reflect that in the long term CPO production only produces in the small number and only contributes in small amount for GDP in Indonesia.



**Figure 2.**  
*The Relationship between CPO Production and GDP in Indonesia*  
 Source: E-views, processed data 2022



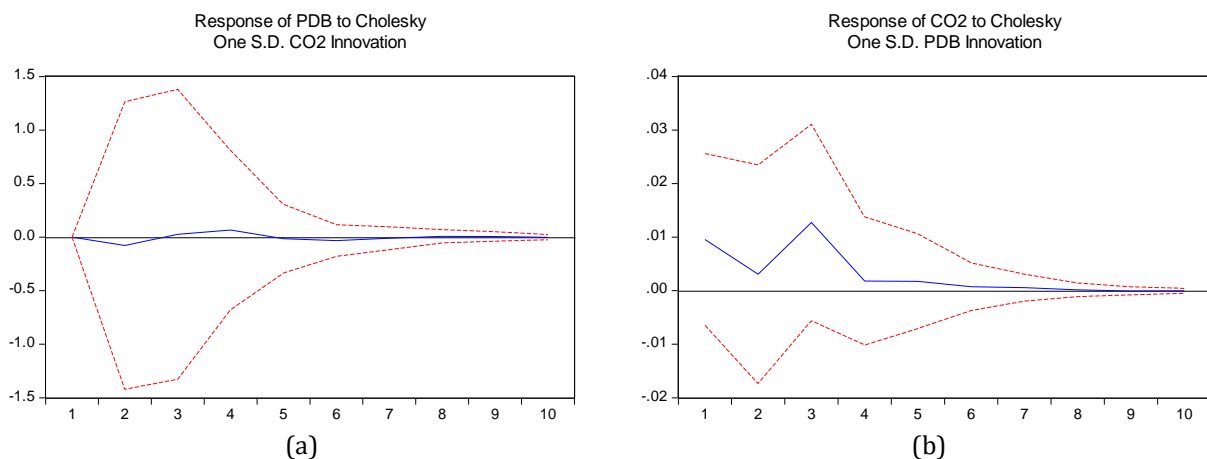
**Figure 3.**  
*The Relationship between CPO Production and Carbon Emissions in Indonesia*  
 Source: E-views, processed data 2022

Figure 3 answers the hypothesis 2 for this research that there is a relationship between CPO production and carbon emissions in Indonesia. The relationship between CO2 and PCPO can be seen in Figure 3 (a). From the initial period to the 4th period, the two variables are positively related to each other with the greatest correlation in the 2nd period of 0.023%. In the period 5, CO2 and PCPO are negatively related to each other by 0.002% before returning to the equilibrium point. Figure 3 (b) can also show the relationship between PCPO and CO2 which shows the same pattern. From the initial period to the 4th period, PCPO and CO2 are positively related to each other with the greatest correlation in the 1st period of 0.009%. In the period 5, PCPO and CO2 are negatively related to each other with a small value of 0.001% before returning to the equilibrium. The result of the research is in accordance with the findings by Qodri & Wahyudi (2021) and Brown *et al.* (2021) in Indonesia and Ezechi & Muda (2019) in Malaysia which state that there is a positive relationship between CO2 and PCPO. Especially in the short term a positive relationship between CO2 and CPO production related in the large range. It means that every time new land is



cleared for palm oil production, it can create carbon emissions. In the long term eventhough there is a negative relationship between CPO production and emissions carbon, but it only happens in the small range.

Hypthesis 3 of this research can be answered by the result of IRF in figure 4. From figure 4, the relationship between carbon emissions and GDP in Indonesia is discussed. Figure 4 (a) shows the relationship between GDP and carbon emissions. In the second period, it can be seen that there is a negative relationship between GDP and carbon emissions (CO<sub>2</sub>) in the amount of 0.08%. From period 3 to period 4, there is a positive relationship between GDP and CO<sub>2</sub> with a range of 0.07% before finally returning to the equilibrium. The relationship between CO<sub>2</sub> and GDP can be seen in Figure 2 (d). From the initial period to the 7th period, there is a positive relationship between CO<sub>2</sub> and GDP before returning to the equilibrium point. The largest positive response between CO<sub>2</sub> and GDP is in the 3rd period with a response of 0.013%. The closer to period 7 before turning to the equilibrium, the positive relationship between CO<sub>2</sub> and GDP is getting smaller. The result of this research is not in accordance with the Environmental Kuznet Curve (EKC) theoretical concept which states that in the long term CO<sub>2</sub> has a negative relationship with GDP as happened in China (Jian *et al.*, 2019). This research actually shows a positive relationship between CO<sub>2</sub> and GDP in the long term which is in accordance with the finding of Azwar (2019). The increase in carbon emissions is indicated by an increase in economic activity so that GDP also increases.



**Figure 4.**  
*The Relationship between Carbon Emissions and GDP in Indonesia*  
Source: E-views, processed data 2022

### Forecast Error Variance Decomposition (FEVD) Analysis

The research also aims to show how big the relationship is by each variable both in the short term and in the long term. The result of FEVD in table 4 can be used to determine the magnitude of the relationship between PCPO, CO<sub>2</sub> and GDP both in the short term and in the long term.

From the initial period to the period 4, GDP has the greatest linkage with PCPO compared to CO<sub>2</sub> emissions with a range of above 20%. From the 5th period onwards, it can be seen that GDP is more related to PCPO at more than 23% compared to CO<sub>2</sub> emissions in the range of 0.08%. CO<sub>2</sub> is more related to PCPO than GDP. In the early period, CO<sub>2</sub> is more related to GDP at around 3.59% compared to PCPO without any linkage at all. However starting from the second period onwards, CO<sub>2</sub> is more related to PCPO in the range of more than 16%. PCPO is more related to



CO2 than GDP. Starting from the 6th period onwards, PCPO and CO2 consistently have a linkage at around 2.09% which is greater than the linkage between PCPO and GDP at around 1.82%.

**Table 4.**

*The Result of Forecast Error*

Variance Decomposition of PDB:				
Period	S.E.	PDB	CO2	PCPO
1	3,188594	100,0000	0,000000	0,000000
2	3,773231	79,80219	0,043579	20,15424
3	3,823766	78,27188	0,047226	21,68090
4	3,845167	77,41478	0,075866	22,50935
5	3,859137	76,85531	0,076799	23,06789
6	3,860025	76,84821	0,083702	23,06809
7	3,862719	76,74826	0,084353	23,16738
8	3,862849	76,74375	0,084724	23,17152
9	3,863146	76,73361	0,084934	23,18146
10	3,863237	76,72999	0,084940	23,18507
Variance Decomposition of CO2:				
Period	S.E.	PDB	CO2	PCPO
1	0,050501	3,591972	96,40803	0,000000
2	0,055478	3,284294	80,24107	16,47463
3	0,057495	7,962115	75,61127	16,42662
4	0,057580	8,036165	75,39066	16,57317
5	0,057642	8,111063	75,23528	16,65365
6	0,057650	8,125329	75,21700	16,65767
7	0,057656	8,133123	75,20225	16,66462
8	0,057658	8,133193	75,19670	16,67011
9	0,057658	8,133233	75,19656	16,67021
10	0,057658	8,133164	75,19557	16,67127
Variance Decomposition of PCPO:				
Period	S.E.	PDB	CO2	PCPO
1	0,069999	0,351577	1,618731	98,02969
2	0,073280	1,249019	1,863919	96,88706
3	0,075889	1,683627	2,146391	96,16998
4	0,076770	1,647588	2,097952	96,25446
5	0,076909	1,795638	2,108088	96,09627
6	0,077153	1,814456	2,095696	96,08985
7	0,077158	1,817331	2,097981	96,08469
8	0,077187	1,821452	2,097245	96,08130
9	0,077193	1,821187	2,097025	96,08179
10	0,077195	1,822117	2,097134	96,08075

Source: E-views, processed data 2022

According to FEVD results, GDP has the greatest linkage with CPO production. Based on previous IRF test results, there is a positive relationship between GDP and CPO production. Thus to increase

GDP in Indonesia, one of the ways is to increase CPO production. This finding is accordance to Abah *et al.* (2020) in Nigeria and Ezechi & Muda (2019) in Malaysia. They find that the increasing of CPO production can contribute to a country's economic. Meanwhile, Indonesia government must to pay attention to the carbon emissions. CPO production has the greatest association with carbon emissions if according to FEVD results in table 4. Some previous studies that is done by Brown *et al.*, (2021) and Qodri & Tri Wahyudi (2021) find that the increasing of CPO production can sacrifice some forests which then it creates carbon emissions. Therefore, Indonesia government must to overcome how to manage in opening the new land for palm oil plantations. However the increasing of CPO production is needed in order to make the increasing of GDP but the reduction of CO<sub>2</sub> emission is needed as well in order to keep the environment.

## CONCLUSION

During the research period, PCPO, CO<sub>2</sub> and GDP are interrelated both in the short term and in the long term. Especially in the long run the relationship between PCPO, CO<sub>2</sub> emissions and GDP are more positive. The relationship between PCPO and GDP in the long term, although positively related, is in a small range. PCPO has the greatest association with CO<sub>2</sub> emissions compared to GDP. The government also seems unable to optimize the economic results of increasing CO<sub>2</sub> emissions in the short term because in the long term CO<sub>2</sub> emissions still have a positive relationship with GDP.

## Implication

CPO production does not provide benefits for the Indonesian economy in the long term but instead is more effective in creating CO<sub>2</sub> carbon emissions. The government should be more focus on overcoming any new land clearing for palm oil by accelerating a sustainable economy. Burning land and determining the appropriate spatial layout for new palm oil lands can be carried out immediately. Likewise, in the short term, the government should also be able to optimize economic results from increased CO<sub>2</sub> emissions. The government can provide a budget for technological progress so that it can support sustainable economic programs. In the long term, it is hoped that increased economic growth will reduce CO<sub>2</sub> emissions.

## Limitation and suggestion

The research starts the period at the beginning of the applied of the PIR (Nucleus Plantation) policy intervention in 1980 and this research is carried out on an annual basis. Therefore, the research has a data span that is not too long in the VAR method, which is 41. For further research, it is suggested that the research with related topics can be carried out with data over a longer time span.

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