Palm oil spills on the performance of non-palm plantations in Indonesia: an empirical analysis

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Abstract. Rapid development of oil palm plantations is predicted to cause various problems, one of which is the conversion of land and the shift of non-palm oil businesses to palm oil businesses. This research is aimed at analyzing the impacts of palm oil industry, through the price of palm oil in the international market, to the area and production of non-oil palm plantations (rubber, cacao, and coffee). The study employed time series data from 1991 to 2015. An econometric model was built to connect variables that affect the area and the production level of non-palm plantation and use multiple regression methods to determine its effect. The results showed that the price of palm oil had a positive effect on the expansion of rubber, cocoa, and coffee plantations. The effect of the price of palm oil on the production of non-palm plantations also shows a positive direction. Thus, the development of oil palm plantations does not have a negative impact on the development of non-palm plantations. The policy implications of the results of this study are the need to utilize the positive impacts of development of the palm oil industry for the development of plantations in the broadest sense.

1. Introduction
Palm oil is increasingly important in the international oil and fat market. The characteristics of palm oil that are suitable for various uses in the food and non-food industries make the demand for palm oil tend to increase from year to year. The dominance of palm oil in the international market is mainly due to the higher competitiveness of palm oil than other sources of vegetable oil. The role of palm oil in the oil and fat trade continue to increase with the growing use of palm oil for non-food industry needs, especially for increasing biofuel production, and surging demand for palm oil in China and India.

Crude oil prices in international markets are fluctuating and tend to increase, and coupled with the awareness to reduce greenhouse gas emissions has made the petroleum substitute industry sourced from renewable raw materials increasingly important. Palm oil is one of the raw materials for the biofuel industry whose use continues to increase. Increased use of palm oil for energy has led to debate about its impact on food security and land use change. The use of palm oil products for energy production leads to an increase in food prices. Increase in palm plantation due to the increase in palm oil price will ultimately reduce the area dedicated for non-oil plantations. If indeed the development of oil palm plantations reduces the area for other plantation crops, it can have a negative impact on export diversification that also means increasing the risk of long-term foreign exchange earnings.

The price increase of palm oil in the international market is one of the important factors in increasing the area of oil palm plantations in Indonesia. Based on data from the Central Statistics
Agency (BPS), in 1991 the area of oil palm was 0.77 million hectares and continued to increase to 11.91 million hectares in 2016. At the same time, the production of palm oil also increased from 0.55 million tons to 6.64 million tons. The rapid growth of the palm oil has made palm oil a very important role in the Indonesian economy. Palm oil exports tend to continue to increase and occupy the largest share of total non-oil and gas exports. Oil palm plantations and its derivative industries also make a significant contribution to poverty alleviation and provide employment opportunities as in [1].

With the Indonesian government's decision in 2018 requiring the use of 20 percent palm oil-based biofuel (B20), oil palm plantations expected to continue to increase in the future. Increasingly oil palm plantations have an impact on the emergence of various social, economic and environmental problems. The growth of oil palm areas considered to have neglected the interests of local communities, reduced income diversification in the regions, and reduced biodiversity and wildlife. Reference [2] indicated that increasingly limited land resources could cause oil palm expansion to replace land use for other uses. The wider area of oil palm can have an impact on forest encroachment, the use of peatland, or land conversion. Increasing palm oil prices and the area of oil palm plantations that continue to expand expected to have negative impacts on the area of non-palm plantations that also become a mainstay for Indonesian exports.

This research is aimed to find out how the influence of palm oil development, represented by the price of palm oil on the international market, the area and production of rubber plantations, cocoa, and coffee. Rubber, cocoa, and coffee selected as cases because they are considered that these 3 products do not have a direct relationship in their demand or consumption with oil palm. However, these 3 crops, namely rubber, cocoa, and coffee have a production relationship that competes for land use. This is different from coconut plantations that have links with oil palm, both in terms of demand or consumption and aspects of supply or production.

2. Literature review
Various studies conducted to determine the effect of the price of a commodity on the prices of other commodities. Reference [3] shows a close link between oil prices and commodity prices. Using pairwise Granger causation test, he found a direct relationship from the price of wheat and soybean to the price of ethanol. Reference [4] shows that there is a close relationship between the price of petroleum and the price of maize, and the price of maize has a spill impact on related agricultural products. Reference [5] using weekly data from 2003 to 2007 found a significant relationship between the price of petroleum and soybean prices. The relationship between these 2 prices changed from negative throughout 2003-2006 to be positive throughout 2007. However, with the same set of data in the same year [5] found no relationship between the price of petroleum and the price of corn. Previously, reference [6] using the Granger test and impulse response also failed to find a significant relationship between the price of petroleum and the price of edible oils. From these various studies concluded that the empirical closeness and direction of the relationship between energy prices and commodity prices vary between commodities and between periods.

Increased crude oil prices and awareness of the need to prevent an increase in greenhouse gases have caused biofuel production to increase. Increased biofuels production can certainly affect commodity prices to be used as raw materials for biofuels that will indirectly cause land use changes. Various studies show that there is a significant relationship between biofuels production and changes in land use for commodities. Reference [7] using the CGE model shows how biofuels production becomes a driving force for land use change and deforestation. Reference [8] founds the need for corn plant expansion to meet increasing industrial demand for corn-based ethanol in the US. The expansion of the corn area will replace the soybean area and cause an increase in the price of wheat. The results of their study found the elasticity of the addition of area corn with an increase in wheat price of 1. The results of this study are in line with the research of [9] who examines the relationship between corn prices and the area of land reserved for production.

Changes in land use for the needs of various commodities expected to occur if there is a relative price change between them. Reference [10] documented a shift in land use between rangeland and
cropland in response to change in commodity prices in the US. Reference [11] examined the effect of biofuels on land use cash rent in Iowa. They examined the relationship between cash rental rates for cropped land (hay) and non-cropland (pastureland) use. The study found that the relationship between crop prices and the amount of cropland explained by the influence of product market prices on the share of cropland in the total farmland. Reference [11] analyzed using regression panel model with explanatory variables as expected corn price, soybean price, and feed for cattle prices. The results of their analysis show that increasing corn prices causes an increase in land conversion from non-cropland to corn production. Reference [12] also showed the impact of changes in agricultural commodity prices on deforestation. The results of various studies mentioned above implicate that changes in relative prices between commodities can affect land use and the level of production of various commodities.

This research is also based on the finding of [13] in his testimony for the US Senate Committee on Homeland Security, and Governmental Affairs stated that food prices and fuel prices are highly correlated. Thus, the corollary idea is that an increase in the area of oil palm estimated to affect the area of other plantations. Changes in land use from non-palm oil crops to oil palm plantations naturally occur because of the relative changes between the prices of palm oil and non-palm oil prices. Changes in relative prices not only affect the area of non-palm oil plantation but also expected to affect the level of production of non-oil palm.

3. Research methods

The non-palm plantations selected in this study are rubber, cocoa and coffee plantations. The selection of these 3 commodities is based on the consideration that the 3 commodities are also the mainstay of Indonesia's non-oil and gas exports. Indonesia is the largest palm oil producer in the world, and for rubber, cocoa and coffee commodities Indonesia rank second, third, and third in the world respectively. These 3 commodities are also important employment providers. The share of smallholders in the area of rubber, cocoa and coffee is the largest compared to the area owned by government own enterprises or large scale privately own enterprises. In 2015 the share of smallholder plantation areas from the total area for rubber, cacao and coffee was 84, 97 and 96 percent, respectively.

The performance of rubber, cocoa, and coffee plantations analyzed in this study is the area and production level of each commodity. The effect of palm oil on the performance of non-palm oil plantations is represented through changes in palm oil prices on the international market. The international palm oil price employed is the world price of crude palm oil (CPO) and the world price of palm kernel oil (PKO). While the price for each non-palm commodity will be represented with the price received at the exporter level. The price at the exporter level calculated from the value of exported commodity divided by the quantity exported. As a control for the influence of commodity price variables, the research model also included the variable wage rates for labour work in plantations and credit interest rates in Indonesia.

The models used in this study are as follows:

\[
\text{AREA}_{it} = \beta_0 + \beta_1 \text{WAGE}_t + \beta_2 \text{INTRATE}_t + \beta_3 \text{PWCPO}_t + \beta_4 \text{PWPKO}_t + \beta_5 \text{PEXP}_t + \mathcal{U}_t \tag{1}
\]

\[
\text{PROD}_{it} = \beta_0 + \beta_1 \text{WAGE}_t + \beta_2 \text{INTRATE}_t + \beta_3 \text{PWCPO}_t + \beta_4 \text{PWPKO}_t + \beta_5 \text{PEXP}_t + \mathcal{U}_t \tag{2}
\]

Where:
- \( \beta_0 \) = Intercept (constant)
- \( \beta_1 - \beta_5 \) = Coefficient regression of each variable
- \( \mathcal{U} \) = Error term
- \( i \) = Rubber, Cocoa, Coffee
- \( t \) = Time (year)
The description of the variables used in equation model and data sources can be looked at table 1. The data used in this study are time series data from 1991 to 2015. All data employed in this study are secondary data.

### Table 1. Description of the variables in the model, its unit value, and data sources

| No. | Symbol | Variable name | Unit value | Sources of data |
|-----|--------|---------------|------------|----------------|
| 1.  | AREA<sub>i</sub> | Area (rubber, cacao, coffee) | Hectare (Ha) | Directorate General of Estate Crops (DGEC) |
| 2.  | PROD<sub>i</sub> | Quantity of production (rubber, cacao, coffee) | Ton | DGEC |
| 3.  | WAGE  | Monthly wage of plantation worker | USD/month | BPS |
| 4.  | INTRATE | Credit interest rate | % | BPS |
| 5.  | PWCP0 | World price of crude palm oil | USD/ton | Oil World |
| 6.  | PWPKO | World price of palm kernel oil | USD/ton | Oil World |
| 7.  | PEXP<sub>i</sub> | Export price (rubber, cacao, coffee) | Rubber - USD/ton, Cacao – USD/ton, Coffee – USD/ton | DGEC |

Multiple regression method used to estimate the influence of predictor variables on variable area and variable production of each commodity. Multiple regression method employed to analyze the influence of several independent variables on a dependent variable. The use of multiple regression method can determine the relative influence of each independent variable on the dependent variable, based on a complex data set, the results of which can be wrong if the analysis conducted incorrectly. In this research the model for each commodity treated as a single equation and not analyzed simultaneously. That is why in the section of results and discussion also carried out separately for each commodity.

To ensure the goodness of fit of the model used in explaining the variations that occur in the area and production variables, the determination coefficient indicator ($R^2$) and $F$ test are used. The classic assumption test carried out to determine whether the coefficient obtained is truly unbiased and efficient. The Durbin Watson test used to see the existence of autocorrelations. In this study the Glejser test employed to detect the presence of heteroskedasticity, and VIF indicators to ensure the absence of multicollinearity. To be able to compare the ranking of the influence of each explanatory variable on the dependent variable (area and production area), then the standardization of the estimation result coefficient is done.

### 4. Results and discussion

#### 4.1. Rubber

After estimating the rubber area model, there is a high autocorrelation phenomenon with a Durbin Watson (DW) statistic of 0.617. To eliminate autocorrelation in the model, variable dummy crisis is added. Dummy crisis is rated 1 for the year of the 1997 financial crisis in Asia and the 2008 and 2009 world economic crisis. The new model can explain variations in the area of rubber with the coefficient of determination ($R^2$) of 0.517 and significant $F$ test values at 0.002. All variables have a VIF value below 10 that indicates that there is no serious multicollinearity. After the Glejser test, heteroskedasticity phenomenon was not found in the model. The Glejser test did not find explanatory or independent variables that significantly affected the error term $U$ with a significance level of less than 0.05.

The regression model for the quantity of rubber production also has an autocorrelation problem that is the same as the rubber area model with the DW value of 0.543. In the model of production level also was added variable dummy crisis. The result of the model has an $R^2$ value of 0.791 with a statistical $F$ test value of a significance level of 0.000. None of the VIF values for each explanatory variable is greater than 10, so there is no serious multicollinearity problem in the model. Likewise, after the Glejser test can be concluded the model does not have heteroskedasticity problems, because there are...
no explanatory variables that significantly affect the error term $U$ with a significance level smaller than 0.05. In summary, the estimation results in the area model and the number of rubber production model provided in Table 2.

CPO world price variables give positive and statistically significant effects on the level of error of less than 1 percent to the area of rubber plantation. Even the world price of oil palm has the greatest influence on the area of rubber compared to other variables. Wages have a significant negative effect on the area. Increasingly expensive labour can be an obstacle to efforts to increase the area of rubber plants. Likewise, the economic crisis can cause a decrease in the area of rubber. A declining world economy can cause the reduce need for rubber raw materials, and indirectly have a negative impact on rubber plantations.

Table 2. The results of estimation of factors affecting the area and production of rubber

| Explanatory variables | Var. dependent: $AREA_{rubber}$ | Var. dependent: $PROD_{rubber}$ |
|-----------------------|---------------------------------|---------------------------------|
|                       | Unstandardized coefficients     | Standardized coefficients       | Unstandardized coefficients | Standardized coefficients |
| 1. WAGE               | -207.201**                      | -0.510                          | -1046.068***                 | -0.464                     |
| 2. INTRATE            | -2715.382                       | 0.172                           | -17436.868                   | -0.199                     |
| 3. PWCPPO             | 662.697***                      | 1.105                           | 704.017                      | 0.211                      |
| 4. PWPKO              | 20.903                          | 0.051                           | -1.143                       | 0.000                      |
| 5. PEXP$_{rubber}$    | -88.044*                        | -0.734                          | 207.278*                     | 0.311                      |
| 6. DCRISS             | -67370.311*                     | -0.208                          | -64811.016                   | 0.036                      |
| 7. INTERCEPT          | 3134189.832***                  | -                                | 1906701.510***               | -                          |

Description: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Despite being positive, the CPO world price had no statistically significant effect on Indonesian rubber production. Rubber production is mainly influenced by the level of labour wages. The higher the wage level, the more rubber production will decrease. Rubber plantations are very intensive in using labour. The number of workers working on rubber plantations in 2016 reached 2.47 million people. Plantation smallholders contributed the largest workforce of 2.23 million people and followed by private companies amounting to 0.16 million people.

4.2. Cocoa

The coefficient of determination ($R^2$) is high, both for the area and production of cocoa models of 0.859 and 0.867, respectively, indicating the ability of the model to explain the variation in the area's of cocoa and the level of cocoa production. DW values are 1.457 and 1.591 indicate that there is no serious autocorrelation problem. The VIF value for each explanatory variable in the area model or level of production model is much smaller than 10, and even the largest VIF is only 3.889. In both models, no serious multicollinearity symptoms were found. Likewise, based on the results of the Glejser test, there was no problem with heteroskedasticity in the model, where no explanatory variables had a significant effect on the error term $U$ of the model. The results of the estimation of area and production models in summary are presented in Table 3.

Based on the estimation of the cocoa area model and cocoa production model, it can be seen that the CPO world price has a positive and statistically significant effect at the 10 percent level. However, for the PKO world price variable there is no significant effect on the area or the production level of cocoa. Price of cocoa at exporter level had a significant effect on the area but not on the level of production. Based on the size of the standardized coefficient, it can be seen that the influence of the CPO world price on the area and production level is lower than the effect of the wage and interest rate. However, the influence of world price of CPO to cocoa production level is greater than the exporter price of cocoa.
Table 3. The results of estimation of factors affecting the area and production of cocoa

| Explanatory variables | Var. dependent: \( \text{AREA}_{\text{cocoa}} \) | Var. dependent: \( \text{PROD}_{\text{cocoa}} \) |
|-----------------------|---------------------------------|---------------------------------|
|                       | Unstandardized coefficients | Standardized coefficients | Unstandardized coefficients | Standardized coefficients |
| 1. WAGE               | -553.376***                  | -0.339                         | -507.411***                  | -0.697                         |
| 2. INTRATE            | -16684.655***                | -0.263                         | -6966.369***                 | -0.246                         |
| 3. PWCP              | 324.136*                     | 0.135                          | 252.463*                     | 0.235                          |
| 4. PWPKO              | -137.336                     | -0.083                         | -32.088                      | -0.043                         |
| 5. PEXP\(_{\text{cocoa}}\) | 279.654***                 | 0.522                          | 1.343                        | 0.046                          |
| 6. INTERCEPT          | 846866.031***                | -                               | 646349.727***                | -                               |

Description: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

Variable amount of production is the amount of cacao production in the form of cacao bean. The \( PEXP_{\text{cocoa}} \) variable does not affect the level of production, possibly due to the use of cacao bean prices received by exporters as a substitute for prices received by cacao producers. The smallholders sell cocoa they produced in the form of unfermented or low quality of cacao bean to the traders or collectors, and by the collector, cocoa bean would be upgraded before being sold to exporters. Thus, the price of cocoa bean received by producers is likely not correlated or not influenced by the price at the level of exporters.

4.3. Coffee

Based on the test of the classic assumption of the regression model it can be concluded that the model employed does not have serious problems with autocorrelation, multicollinearity, and heteroskedasticity. \( DW \) values for the area model and production level model are 1.689 and 1.407, respectively. Likewise, no serious multicollinearity was found because the maximum \( VIF \) value of the explanatory variables for the model area and production model were 3.849 and 3.562. The model was also clean from heteroskedasticity problems because based on the Glejser test of both models, no explanatory variables were found that significantly level 5 percent of the error term \( U \) from the model. Based on \( R^2 \) value, area model and production model also have high goodness of fit because it can explain the variation of area variable and production variable of 0.722 and 0.833 respectively. The \( F \) test of the model also shows a high level of significance with a probability of error less than 1 percent.

The world price of CPO has no significant effect on the area of the coffee plantation, but has a positive effect at a 1 percent level of significance on the level of coffee production. The PKO world price has no significant statistical effect on the area and the level of coffee production. Price of coffee at exporter level significantly affects the area and also the level of coffee production. Area variables and production level variables are also negatively affected by plantation labour wages and interest rates.

Table 4. The results of estimation of factors that affect the area and production of coffee

| Explanatory variables | Var. dependent: \( \text{AREA}_{\text{coffee}} \) | Var. dependent: \( \text{PROD}_{\text{coffee}} \) |
|-----------------------|---------------------------------|---------------------------------|
|                       | Unstandardized coefficients | Standardized coefficients | Unstandardized coefficients | Standardized coefficients |
| 1. WAGE               | -140.629***                   | -0.594                         | -276.503***                  | -0.800                         |
| 2. INTRATE            | -3312.855***                  | -0.360                         | -3523.744***                 | -0.262                         |
| 3. PWCP              | 74.163                        | 0.212                          | 187.955***                   | 0.368                          |
| 4. PWPKO             | -38.637                       | -0.160                         | -41.868                      | -0.119                         |
| 5. PEXP\(_{\text{coffee}}\) | -42972.539*                | 0.444                          | -3301.138**                  | 0.236                          |
| 6. INTERCEPT         | 1367490.055***               | -                               | 679672.637***                | -                               |

Description: *** significant at 1% level; ** significant at 5% level; * significant at 10% level
Coffee plantations in Indonesia are dominated by small-scale smallholders and using labour intensively. A large workforce is needed for the maintenance of plantation and harvesting. The green beans of coffee usually are harvested by farmers manually. Labour wages are an important factor in determining the amount of labour used by coffee farmers. In 2016 there were 1.79 million households operating coffee plantation. These small-scale farmers generally experience working capital limitations so that loan interest rates can negatively affect farmers' access to capital and ultimately have a negative effect on the level of production. On average the coffee farmers in Indonesia are only able to produce green coffee beans of 0.704 tons per hectare, far lower than in Brazil which amounted to 1.51 tons per hectare in 2016. Capital constraints are a factor that prevents Indonesian coffee farmers from being able to apply better coffee cultivation technology.

The rapidly growing palm oil industry expected to bring changes to physical, social and economic infrastructure. The expansion of oil palm plantations and its derivative industries is certainly accompanied by the construction of physical infrastructure for roads, warehouses and ports. Reference [14] indicated that palm oil development has a major influence on the infrastructure of the main growing regions of Indonesia that led to significant distortions in the transportation network of the islands on which it is grown. The development of the palm oil industry is also accompanied by institutional developments in the form of cooperation between the nucleus plantation and the plasma plantation. The palm market that penetrates to remote areas in Indonesia predicted to be able to improve the business capabilities of the community.

On the public policy side, the increasingly dominant role of palm oil in the economy has encouraged the government to provide support and greater attention to the palm oil industry. Various public policies such as the transmigration program, 20 percent oil palm biofuel obligations, and other marketing policies are directly and indirectly aimed at the growth of the palm oil industry as in [15]. Rubber plantations, cocoa, and coffee industries seem to get positive spill over effects from the growth of the palm oil industry. The growth of the palm oil industry also encourages the growth of land area and production of rubber, cocoa, and coffee. The expansion of oil palm land is allegedly not in the form of conversion of land for rubber, cocoa, or coffee plantations into palm plantation but instead there is a tendency to expand towards the reducing of forest areas, peatland, or land for other allotments. Reference [16] has found that the expansion of palm oil plantations in Papua and Kalimantan has caused deforestation and negative impacts such as water pollution, air pollution and soil erosion.

5. Conclusion

Based on the estimation results of the planting area model and production model of rubber, cocoa, and coffee concluded that in general, the world price of CPO has a positive influence on the harvested area and on the level of production. The results indicate that an increase in the area of oil palm due to the increasing competitiveness of oil palm will not cause a reducing area of rubber, cocoa and coffee.

The positive influence of world palm oil prices on area and production even tends to be greater than the influence of the own price of rubber, cocoa, or coffee. The effect of palm oil prices is only inferior to the influence of plantation labour wages in cocoa and coffee commodities models. Cocoa and coffee are industries that use labour intensively so that the increase in wages of labour will bring negative effects to the performance of the industry. In other words, the development and competitiveness of plantation in Indonesia still rely heavily on cheap labour.

The policy implications of the results of this study are the importance of making good use of the momentum created by the development of the palm oil industry to build other highly competitive plantation industries. Improvements in physical, social and economic infrastructure that are likely to accompany the growth of the palm oil industry can certainly also be used for the development of the rubber, cocoa and coffee industry. However, the results of this study indirectly warn of the need to take into account the negative impacts of the growth of the palm oil industry on land use change in forestland, peatland, and other land purposes.
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