Panel Data Regression Analysis on Oil Palm Plantation Development and Community Welfare

Analisis Regresi Data Panel pada Pengembangan Perkebunan Kelapa Sawit dan Kesejahteraan Masyarakat

Zulkarnain Nasution[1*], Khairul Rizal[2], Nasir[3] dan Sri Wahyuni[4]

Abstract This research employs a green economy theory approach, which is rare in oil palm plantation studies. This study aims to analyze the impact of oil palm plantations on community welfare, using variables such as the proportion of oil palm plantations, productivity, and farmer-added value, alongside area control and Gross Fixed Capital Formation, with the dependent variable being the welfare level of the Human Development Index. Data from the Central Statistics Agency at the district and provincial levels consisting of 8 districts with a time span of 10 years. Utilizing panel data regression models. Results show plantation areas are less prosperous than non-plantation areas in North Sumatra's east coast. The results highlight the need for Local governments need to promote economic diversification, particularly through downstream agro-industries and MSME development, while prioritizing productivity improvements rather than land expansion.

Keywords*:* Farmers' Terms of Trade, Gross Fixed Capital Formation, Human Development Index, Productivity, Proportion of Oil Palm Plantations

Abstrak Penelitian ini menggunakan pendekatan teori ekonomi hijau, yang jarang ditemukan dalam studi perkebunan kelapa sawit. Penelitian ini bertujuan untuk menganalisis dampak perkebunan kelapa sawit terhadap kesejahteraan masyarakat, dengan menggunakan variabel seperti proporsi perkebunan kelapa sawit, produktivitas, dan nilai tambah petani, serta kontrol area dan Pembentukan Modal Tetap Bruto, dengan variabel dependen tingkat kesejahteraan berupa Indeks Pembangunan Manusia. Data dari Badan Pusat Statistik di tingkat distrik dan provinsi yang terdiri dari 8 kabupaten dengan rentang waktu 10 tahun. Penelitian ini menggunakan analisis data panel. Hasil penelitian menunjukkan bahwa kawasan perkebunan kurang sejahtera dibandingkan kawasan non-perkebunan di pesisir timur Sumatera Utara. Hasil penelitian ini menyoroti perlunya dukungan prioritas bagi petani kecil untuk meningkatkan efisiensi dan pendapatan.

Kata Kunci*:* Nilai Tukar Petani, Pembentukan Modal Tetap Bruto, Indeks Pembangunan Manusia, Produktivitas, Proporsi Perkebunan Kelapa Sawit

INTRODUCTION

The oil palm plantations contribute to the local economy and create job opportunities for the surrounding community (Barkah, 2024). With good infrastructure support and a favorable climate, North Sumatra has significant opportunities to develop this sector further (Aziz et al., 2024). However, it is essential to consider sustainability and environmental impacts when managing these plantations. The presence of oil palm in these regions has established it as a leading commodity, thanks to the strong competitive edge among these areas (Luke et al., 2020). Additionally, the development of the oil palm industry in North Sumatra contributes to the local economy by creating jobs and improving the welfare of the local community (Purba et al., 2023). This situation highlights the importance of the agricultural sector in supporting regional economic growth (Loizou et al., 2019).

Penulis yang tidak disertai dengan catatan kaki instansi adalah peneliti pada Pusat Penelitian Kelapa Sawit

Zulkarnain Nasution[1*] (✉)
[1,2]University of Labuhanbatu, North Sumatera
Email: zulkarnainnasution1974@ulb.ac.id

[3]Tridinanti University, South Sumatra
[4]Almuslim University, Aceh

Naskah masuk: 29/12/2025; Naskah diterima: 27/07/2026

In North Sumatra Province, the area of oil palm plantations continues to grow each year. The total area of oil palm plantations reached 1,357,230 hectares. Data from the Ministry of Agriculture/BPS (2022) recorded a total of 2,079,027 hectares, consisting of 31.99% Smallholder Plantations (PR) and 45.77% Large Private Plantations (PBS). Fresh Fruit Bunch (FFB) production reached 22,984,379 tons (2022) with a productivity of 21.23 tons/ha/year. North Sumatra's crude palm oil (CPO) production reached 7.45 million tons in 2021, while 2022 data showed CPO production from smallholder plantations alone reached 7.78 million tons. Notably, the land managed by farmers and state-owned companies has shown significant increases (Koizumi, 2022). This matter reflects the success in managing and developing the oil palm sector in the region. This growth contributes to the local economy and strengthens the position of oil palm as a leading commodity (Supriatna et al., 2024). Thus, the agricultural industry becomes a vital pillar in enhancing the community's welfare in this province (Syahza et al., 2020).

The proportion of added value from oil palm plantations provides information about regional progress (Parveez et al., 2024). The enhancement of regional economic development serves as a potential source for measuring increases in welfare. A greater proportion of added value from oil palm plantations significantly impacts the financial improvement of local communities (Baka et al., 2024). Regions with a high proportion of oil palm plantations tend to experience a strong multiplier effect (Xin et al., 2021). Therefore, it is undeniable that oil palm plantations make a significant contribution to the agricultural sector's Gross Regional Domestic Product (GRDP).

Research in oil palm plantations has developed, but the number of studies remains limited. Previous research indicates that factors influencing the level of welfare in oil palm plantation areas vary significantly. According to Otieno et al., (2016), and Santika *et al*., (2019), the primary factor is labor absorption. Other factors include productivity, farmers' perceptions, local income, poverty, and income distribution. Therefore, a more in-depth study is needed on the role of oil palm plantations in enhancing the economy and welfare of the people in the eastern coastal region of North Sumatra Province.

This study differs from previous research as it focuses on analyzing the impact of oil palm development in the eastern coastal region of North Sumatra Province on welfare levels, using HDI as a proxy. The method employed is descriptive quantitative, which also distinguishes it from the studies by, Bandyopadhyay et al., (2019), and Euler et al., (2017). Furthermore, the indicators used in this research differ from previous studies in that they incorporate the concept of a green economy (Giacovelli, 2018). This study included new variables such as the variable control Land Area and Gross Fixed Capital Formation (GFJF), which had not previously been included. This is because land area is a relevant structural factor, particularly in regional and MSME-based analyses, as it reflects the physical capacity for production activities, infrastructure expansion, and resource utilization. Furthermore, Gross Fixed Capital Formation (GFCF) represents investment in physical assets such as machinery, buildings, and infrastructure. In economic theory, particularly in growth models, capital accumulation is a key driver of productivity and output.

MATERIALS & METHODS

Clark et al., (2021) state that research variables carry information that connects individuals or objects being studied with the organization under investigation. Based on Figure 1, the oil palm plantation sector is one of the important economic sectors in the country. The proportion of oil palm plantations (percent) in region \(i\) in period \(t\) is the percentage of land area planted with oil palm compared to the total land area (or total plantation area) in that region in a given year. The proportion of oil palm plantations can influence income distribution, job opportunities, and economic growth in specific regions. The research design used is specific and detailed, implemented in a research framework conducted directly, following the methodology proposed by Bryman (2016).

Data were sourced from the Central Statistics Agency at the district and provincial levels. Estimating an economic model is necessary to understand the actual conditions of the studied object. In this research, the estimation model used can be formulated as follows:

$Y_{it} = \beta_0 + \beta_1 PRO_{it} + \beta_2 PROD_{it} + \beta_3 FER_{it} + \beta_4 LA_{it} + \beta_5 GFJF_{it} + \beta_6 D_1 + \beta_7 D_2 + e$ ..... (1)

When :

Y_{it} : Human Development Index in region i during period t

PRO_{it} : Proportion of Oil Palm Plantations (percent) in region i during period t

$PROD_{it}$: Oil Palm Productivity (ton/ha) in region i during period t

FER_{it} : Farmer Exchange Rate (percent) in region i during period t

LA_{it} : Land Area (ha) in region i during period t

$GFJF_{it}$: Gross Fixed Capital Formation (amount) in region i during period t

D_1 : Oil Palm Plantation Area < 20,000 ha

D_2 : Oil Palm Plantation Area > 20,000 ha

i : Cross Section

t : Time Series

β_0 : Constant

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$: Regression Coefficients

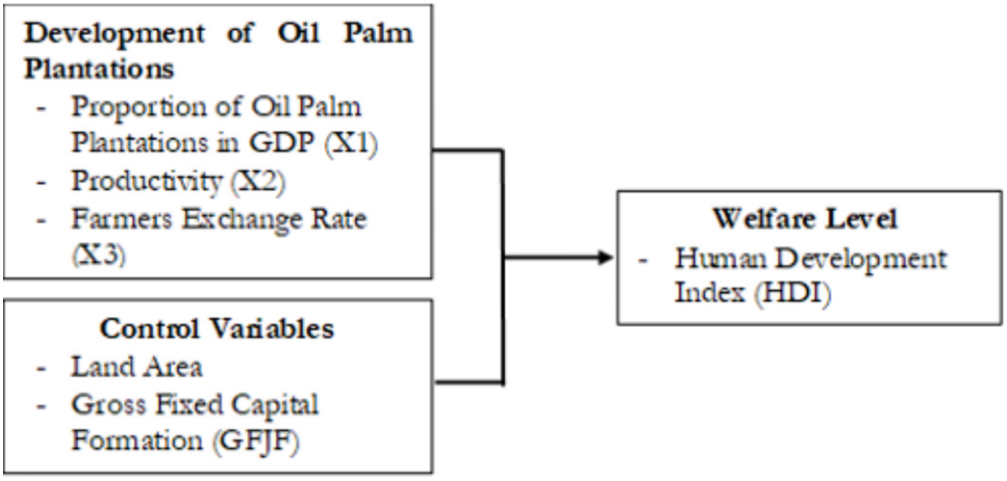

Figure 1. Research Conceptual Framework
Gambar 1. Kerangka Penelitian

RESULTS AND DISCUSSION

Panel Data Regression Model Testing

Common Effect Model (CEM) Significance Test

Below are the results of the panel data regression testing using the Common Effect model.

The estimation model CEM used can be formulated as follows:

$Y_{it} = 66.624 - 0.036PRO_{it} + 0.0009PROD_{it} - 0.119FER_{it} - 0.0001LA_{it} + 0.472GFJF_{it} + 1.539D_1 - 1.095D_2 + e$ ..... (2)

The Common Effects model panel data regression coefficients include (Ghozali, 2016). The results of the CEM can be explained as follows:

1. The independent variable, the proportion of oil palm plantations in GDP, does not have a significant effect on the dependent variable, the Human Development Index (HDI), in the eight districts of the eastern coastal region of North Sumatra, with a negative coefficient of -0.036 and a p-value (sig) of 0.144 > 0.05. This result means that a decreasing proportion leads to an increase in the HDI. Conversely, an increasing proportion results in a decrease in the HDI.
2. The independent variable, oil palm productivity, significantly affects the dependent variable, the HDI, in the same eight districts, with a positive coefficient of 0.0009 and a p-value (sig) of 0.011 < 0.05. This result indicates that an increase in oil palm productivity leads to an increase in the HDI, while a decrease in productivity results in a lower

HDI.

3. The independent variable, the farmer exchange rate for oil palm, significantly affects the HDI, with a negative coefficient of -0.119 and a p-value (sig) of 0.000 < 0.05. This result means that a decreasing exchange rate leads to an increase in the HDI, while an increasing exchange rate results in a decrease in the HDI.
4. The land area variable has a negative regression coefficient of -0.0001 with a p-value (sig) of 0.190 > 0.05. This result suggests that a decreasing land area leads to an increase in the HDI, while an increasing land area results in a decrease in the HDI.
5. The GFJF (Gross Fixed Capital Formation) variable has a positive regression coefficient of 0.472 with a p-value (sig) of 0.000 < 0.05. This result indicates that an increase in Gross Fixed Capital Formation (GFJF) leads to an increase in the HDI, while a decrease in GFJF results in a lower HDI.

Table 1. Results of Common Effect Model (CEM) Regression
Tabel 1. Hasil Regresi Common Effect Model (CEM)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	66.624	3.671	18.147	0.000
PRO	-0.036	0.024	-1.476	0.144
PROD	0.0009	0.0003	2.598	0.011
FER	-0.119	0.026	-4.569	0.000
LA	-0.0001	0.0001	-1.321	0.190
GFJF	0.472	0.064	7.371	0.000
DUMMY1	1.539	0.657	2.341	0.021
DUMMY2	-1.095	0.567	-1.929	0.057

(Source: Data processed using Eviews 10)
(Sumber: Data diolah dengan Eviews 10)

Fixed Effect Significance Test (FEM)

Using dummy variables, this approach is referred to as fixed effect or least squares dummy variable (LSDV).

The estimation model FE used can be formulated as follows:

$Y_{it} = 72.485+0.211PRO_{it} +0.002PROD_{it} - 0.146FER_{it} - 0.0005LA_{it} + 0.002GFJF_{it} + e$.....(3)

Based on Table 2, the estimation results using the fixed effect model are presented. This analysis focuses on the Human Development Index (HDI) in the eastern coastal region of North Sumatra. The regression coefficients from the fixed effect panel data model can be explained as follows:

1. The variable representing the proportion of oil palm plantations in GDP has a positive regression coefficient of 0.211 with a probability of 0.115 > 0.05. This result indicates that an increasing proportion leads to a higher HDI. Conversely, a decreasing proportion results in a lower HDI.
2. The variable for oil palm productivity has a positive

regression coefficient of 0.002 with a probability of 0.000 < 0.05. This result means increasing productivity results in a higher HDI, while decreasing productivity leads to a lower HDI.

3. The variable for the role of the Farmer Exchange Rate has a negative regression coefficient of -0.146 with a probability of 0.000 < 0.05. This result suggests that a decreasing exchange rate results in a higher HDI, while an increasing exchange rate leads to a lower HDI.
4. The land area variable has a negative regression coefficient of -0.0005 with a probability of 0.044 < 0.05. This result indicates that a decreasing land area leads to a higher HDI, while an increasing land area results in a lower HDI.
5. The Gross Fixed Capital Formation variable has a positive regression coefficient of 0.002 with a probability of 0.986 > 0.05. This result implies that an increase in gross fixed capital formation leads to a higher HDI, while a decrease results in a lower HDI.

Table 2. Results of Fixed Effect Model (FEM) Regression
Tabel 2. Hasil Regresi Fixed Effect Model (FEM)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	72.485	5.068	14.302	0.000
Pro	0.211	0.132	1.594	0.115
Prod	0.002	0.0003	7.066	0.000
FER	-0.146	0.020	-7.267	0.000
LA	-0.0005	0.0002	-2.046	0.044
GJFJ	0.002	0.120	0.017	0.986
	Effects Specification			
Cross-section fixed (dummy variables)				
R-squared	0.846	Mean dependent var		69.223
Adjusted R-squared	0.819	S.D. dependent var		2.445
S.E. of regression	1.039	Akaike info criterion		3.062
Sum squared resid	72.355	Schwarz criterion		3.449
Log likelihood	-109.497	Hannan-Quinn crister.		3.217
F-statistic	30.885	Durbin-Watson stat		1.355
Prob(F-statistic)	0.000000			

(Source: Data processed using Eviews 10)
(Sumber: Data Diolah dengan Eviews 10)

Random Effect Significance Test (REM)

The results of the panel data regression testing using the Random Effect Model through Eviews 10 are presented in Table 3.

Table 3. Results of Random Effect Model (REM) Regression
Tabel 3. Hasil Regresi Random Effect Model (REM)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	47.181	8.669	5.442	0.000
PRO	-0.132	0.025	-5.252	0.000
PROD	9.024	2.346	3.845	0.0003
FER	-0.115	0.018	-6.148	0.000
LA	-2.024	0.812	-2.491	0.015
GFJF	0.363	0.036	9.956	0.000
DUMMY1	3.136	0.508	6.173	0.000
DUMMY2	2.624	0.623	4.211	0.0001

(Source: Data processed using Eviews 10)
(Sumber: Data diolah dengan Evies 10)

The estimation model FE used can be formulated as follows:

Y_{it} = 47.181 - 0.132PRO_{it} + 9.024$PROD_{it}$ - 0.115FER_{it} - 2.024LA_{it}+ 0.363FJF_{it} +3.136D_1 + 2.624D_2 + e.....(4)

Based on Table 3, the estimation results using the Random Effect Model are presented. This analysis focuses on the Human Development Index (HDI) in the eastern coastal region of North Sumatra. The regression coefficients from the Random Effect panel data model can be explained as follows:

1. The variable representing the proportion of oil palm plantations in GDP has a negative regression coefficient of -0.132 with a probability of 0.000 < 0.05. This result indicates that a decreasing proportion of oil palm plantations leads to an increase in the HDI. Conversely, an increasing proportion results in a lower HDI.
2. The variable for oil palm productivity has a positive regression coefficient of 9.024 with a probability of 0.0003 < 0.05. This result means increasing productivity results in a higher HDI, while decreasing productivity leads to a lower HDI.
3. The variable for the Farmer Exchange Rate has a negative regression coefficient of -0.115 with a probability of 0.000 < 0.05. This result suggests that a decreasing exchange rate results in a higher HDI, while an increasing exchange rate leads to a lower HDI.
4. The land area variable has a positive regression coefficient of 2.024 with a probability of 0.015 < 0.05. This result indicates that an increasing land area leads to a higher HDI, while a decreasing land area results in a lower HDI.
5. The Gross Fixed Capital Formation (GFJF) variable has a positive regression coefficient of 0.363 with a probability of 0.000 < 0.05. This result implies that an increase in GFJF leads to a higher HDI, while a decrease in GFJF results in a lower HDI.

MODEL SELECTION

Chow Test (Common Effect vs. Fixed Effect)

The Chow Test is used to ascertain whether the fixed effect method for panel data is more suitable. The Chow Test (Chow test) is conducted, and if the probability is > 0.05, the null hypothesis (H0) is accepted. Conversely, if the probability is < 0.05, the alternative hypothesis (H1) is accepted, indicating the fixed effect model is preferred. The results of the Chow Test calculations are presented in Table 4:

Table 4. Results of the Chow Test
Tabel 4. Hasil Uji Chow

Effects Test	Statistics	D.F.	Prob.
Cross-section F	11.527	(7,67)	0.0000
Cross-section Chi-square	63.235	7	0.0000

(Source: Data processed using Eviews 10)
(Sumber: Data diolah dengan Eviews 10)

The cross-section chi-square probability value obtained is 0.0000 based on the test results. This probability value is less than 5% (0.0000 < 0.05), leading to the rejection of the null hypothesis (H0). Therefore, the appropriate Chow Test indicates the selection of the fixed effect model.

Hausman Test (Fixed Effect vs. Random Effect)

The Hausman Test determines the best model between the random and fixed effect methods for panel data analysis (Kripfganz & Kiviet, 2021). The results of the Hausman Test calculations are presented in Table 5:

Table 5. Results of the Hausman Test
Tabel 5. Hasil Uji Hausman

Test Summary		Chi-Sq. Statistics	Chi-Sq. D.F.	Prob.
Cross-section random		28.311	7	0.432
Cross-section random effects test comparisons:				
Variable	Fixed	Random	Var(Diff.)	Prob.
PRO	0.212	-0.046	0.008	0.006
PROD	20.369	17.090	0.950	0.0008
FER	-0.151	-0.123	0.00005	0.0001
LA	-5.539	-0.974	4.663	0.0346
GFJF	0.024	0.290	0.010	0.0108
DUMMY1	-0.091	0.041	-2.200	0.0308
DUMMY2	0.102	0.089	0.0001	0.2728

(Source: Data processed using Eviews 10)
(Sumber: Data diolah dengan Eviews 10)

Based on the results of the Hausman Test estimation in Table 5, it can be explained that the significance probability value for the random cross-section is greater than the significance level (0.432 > 0.05). Therefore, it can be concluded that the random effect model is more appropriate than the fixed effect model.

PANEL DATA LINEAR REGRESSION ANALYSIS

Significance Test of the Common Effect Model (CEM)

Based on the model selection process using the Chow Test and the Hausman Test, the Random Effect Model (REM) is deemed the most suitable for depicting the relationships in the linear regression equation for the panel data. The regression analysis is conducted to understand the correlation between the dependent and independent variables. This study establishes the Human Development Index (HDI) as the dependent variable, while the independent variables include the proportion of plantations, palm oil productivity, and the farmer exchange rate. Control variables such as land area and gross fixed capital formation at the district level are also included.

Regression Results Using Control Variables

This research employs multiple regression analysis techniques with palm oil plantations as the independent variable (proportion of plantations), productivity, and the farmer exchange rate. At the same time, community welfare (HDI) is the dependent variable (Y). The land area and gross fixed capital formation are treated as control variables. The results of the multiple regression analysis are presented as follows:

Table 6. Regression Results with Control Variables
Tabel 6. Hasil Regresi dengan Variabel Kontrol

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	47.181	8.669	5.442	0.0000
PRO	-0.132	0.025	-5.252	0.0000
PROD	9.024	2.346	3.845	0.0003
FER	-0.115	0.018	-6.148	0.0000
LA	-2.024	0.812	-2.491	0.0150
GFJF	0.363	0.036	9.956	0.0000
DUMMY1	3.136	0.508	6.173	0.0000
DUMMY2	2.624	0.623	4.211	0.0001
	Effects Specification			
			S.D.	Rho
Cross-section random			0.453	0.160
Idiosyncratic random			1.039	0.83

(*continued*)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
	Weighted Statistics			
R-squared	0.613	Mean dependent var		40.608
Adjusted R-squared	0.582	S.D. dependent var		1.941
S.E. of regression	1.255	Sum squared resid		114.99
F-statistic	19.347	Durbin-Watson stat		0.547
Prob(F-statistic)	0.000			
	Unweighted Statistics			
R-squared	0.658	Mean dependent var		69.223
Sum squared resid	161.250	Durbin-Watson stat		0.390

Source: Data processed using Eviews 9
Sumber: Data diolah dengan Eviews 9

Further discussion regarding the regression results for each variable is presented as follows:

Proportion of Palm Oil Plantations in GDP

The regression analysis on the proportion of palm oil plantations indicates its predictive effect on the Human Development Index (HDI). The estimation results show a score of -0.132, with a significance level of 0.0000, indicating that the proportion of palm oil plantations has a negative and significant impact. In countries with high per capita income, the levels of education and health tend to be higher. Wealthy individuals and governments will likely allocate more funds to the education and health sectors. The better the levels of health and education, the higher the productivity and income generated. Investment in health and education brings various benefits. Educated individuals contribute positively to their surroundings through reading or generating innovations.

Variable: Productivity

The regression analysis on the productivity of palm oil plantations aims to predict the proxy for the HDI. The estimation results show a score of 9.024, with a significance level of 0.0000, indicating that the productivity of palm oil plantations has a significant impact. The plantation subsector, being labor-intensive, involves production activities that heavily rely on human labor. An increase in labor productivity is expected to positively contribute to production increases, affecting Gross Domestic Product (GDP) growth. Several studies have shown that better health in individuals is associated with higher income levels (Chrisendo et al., 2022); (Bandyopadhyay et al., 2019).

Variable: Farmer Exchange Rate

Based on the regression results for the farmer exchange rate variable, how it affects the HDI can be predicted. The estimation results show a score of -

0.115, with a significance level of 0.0003. This result indicates that the farmer exchange rate for palm oil significantly impacts the HDI. This means that every time the exchange rate increases, farmers are not immediately able to increase the HDI. Generally, most plantation lands are worked by individuals who are palm oil farmers. It is important to note that not all palm oil plantations are owned by local communities or private companies. Although production has increased, it has not significantly improved the welfare of farmers, particularly regarding their purchasing power (Runtunuwu, 2020).

Control Variable: Land Area

The control variable involving land area is used in the regression analysis to predict the HDI. The estimation results show a score of -2.024, with a significance level of 0.0150. These findings indicate that this control variable negatively and significantly impacts the HDI. It serves as a tool to measure the impact of development performance in a region, encompassing a broad range of dimensions. As a concrete action, optimizing areas with economic potential can enhance the financial levels of a region (Pramesti & Indrasetianingsih, 2020). However, it is essential to note that development always involves land use, which can ultimately lead to problems due to human land usage.

Control Variable: Gross Fixed Capital Formation (GFJF)

The control variable, GFJF, is used to predict the level of community welfare. The estimation results show a score of 0.363, with a significance level of 0.0000. These findings indicate that the GFJF control variable positively and significantly impacts the HDI. Capital investment has a direct impact on improving the HDI, which in turn can enhance economic growth. The investment component in the Regional Gross Domestic Product, represented by physical investment, is an indicator in the HDI (Amutabi, 2023). GFJF occurs through investment activities in capital goods and production inventories.

Coefficient of Determination Test

The coefficient of determination reflects the ability of the independent variables to explain the dependent variable. To measure the model's explanatory power, the adjusted R^2 value is used. The analysis shows an adjusted R-squared value of 0.613 (61.3%), indicating that 61.3% of the variation in the level of community welfare can be explained by the independent variables included in the model. Meanwhile, the remaining 38.6% is influenced by other factors not included in this study. The test results indicate an adjusted R^2 value of 0.582 (58.2%), demonstrating how well the independent variables—proportion of palm oil plantations, productivity, and farmer exchange rate—explain the variation in community welfare as measured by the proxy of the HDI in the eastern region of North Sumatra Province.

Based on the research findings, a descriptive statistical analysis was conducted to illustrate the characteristics of the related data. The data used in this study consists of time series covering the period from 2011 to 2020. The data sources were obtained from the Central Bureau of Statistics (BPS) and the Ministry of Agriculture through literature references and other relevant sources. The statistical calculations indicate that among the three variables in the model, one variable has a positive effect, while two have adverse effects. Additionally, the control variables of land area and Gross Fixed Capital Formation Gross Fixed Capital Formation yielded positive results.

Impact Analysis of the Proportion of Palm Oil Plantations on Community Welfare in Eastern Regions of North Sumatra Province.

From the first hypothesis in this study, the analysis using the proportion of palm oil plantations produced a t-statistic of -5.252 with a probability of 0.00 < 0.05. This result indicates a negative and significant effect of the proportion of palm oil plantations on the welfare level of communities in each district.

It is essential to note the Indonesian Presidential Instruction Number 8 of 2018. It involves a moratorium on suspending and evaluating palm oil plantation licensing and productivity to improve sustainable palm oil plantation governance. This moratorium provides legal certainty, preserves the environment—including reducing greenhouse gas emissions—and supports palm oil farmers in enhancing productivity. In economic development studies, there is a view that continuous

economic growth can improve community welfare. However, research indicates that economic growth does not always enhance welfare. Therefore, a more holistic development strategy is necessary, one that considers economic, social, and environmental sustainability.

The negative impacts of the palm oil industry on forest ecosystems, such as the loss of biodiversity and air pollution, are significant concerns. In response, innovation in waste management and land use planning based on sustainability and the homogeneity of natural factors is needed (Taelman et al., 2018); (Irawan & Susilo, 2021). Based on regional analysis and localization, it can be concluded that regional economic development strategies must consider the optimal types of agricultural commodities for that area (Zhang et al., 2019). Localization can serve as one solution to reduce productivity disparities among regions.

The determination of community development indicators, such as those measured by the Human Development Index (HDI), is highly relevant for assessing the impact of economic development on community welfare. The HDI provides a broader and more integrated perspective on development that is not solely focused on economic growth. Understanding that economic development is about central economic growth and enhancing human welfare across all regions is crucial. The concept of human development places people at the center, addressing basic needs and quality of life.

Impact Analysis of Productivity on Community Welfare in Eastern Regions of North Sumatra Province

Regarding the second hypothesis of this study, we focus on the variable of palm oil productivity. The analysis results show a t-statistic of 3.845 with a probability of 0.00 < 0.05, indicating a positive and significant relationship between palm oil productivity and community welfare. This finding aligns with agricultural development theory, which advocates for developing plantation sectors, particularly palm oil and rubber, within agribusiness and agroindustry. The development of plantations is expected to enhance the incomes of agribusiness and agroindustry actors in the region.

The increase in palm oil plantation productivity is influenced by factors such as production infrastructure. The marketing aspect of palm oil becomes crucial in determining farmers' income. Marketing institutions facilitate production and create cash flows and product value within productive activities. It is recognized that smooth marketing conditions can directly enhance palm oil prices at the farmer level. Therefore, effective marketing strategies must be implemented to support farmer welfare and ensure maximum yields.

Land ownership of palm oil plantations is a crucial factor in maintaining the income of smallholder farmers. Soil characteristics significantly influence plantation productivity as a local resource. Understanding these soil characteristics is key to optimizing palm oil productivity.

Palm oil productivity can be measured as the ability to produce palm oil per unit area. The production curve of palm oil indicates a positive correlation with the age of the plants, where production increases as the plants age. However, after reaching the highest productive age, production may decline. Fluctuations in palm oil production occur at intervals of 3 to 4 years, consistent with previous research findings. High productivity is considered an indicator of community welfare, aligning with the "Palm Oil for the People" program to increase productivity sustainably (Zhang *et al*., 2019). In this context, productivity becomes a key factor influencing the income of palm oil farmers. Increased productivity is believed to enhance farmers' incomes, allowing them to cover the operational costs of palm oil maintenance.

Domestic and foreign investors are crucial in enhancing palm oil plantation productivity in North Sumatra. Collaboration with investors is expected to increase the number of plantations and palm oil production, positively affecting productivity. Palm oil productivity is also crucial in evaluating the industry's success in producing goods or services (tabe-ojong et al., 2023). The higher the productivity, the greater the output, making it a parameter for the success of the palm oil industry. Infrastructure development plays a key role in efforts to improve productivity (Ibragimov et al., 2019). Adequate infrastructure can enhance community access to resources, optimize efficiency, and support palm oil productivity and regional economic development.

Impact Analysis of the Farmer Exchange Rate Variable on Community Welfare in Eastern Regions of North Sumatra Province

Regarding the third hypothesis of this study, the focus is on the farmer exchange rate (FER) variable. The analysis results show a t-statistic of -6.148 with a probability of 0.018 < 0.05, indicating a negative and significant impact of the FER on community welfare. This finding aligns with Ibragimov at al., (2019), which suggests that the exchange rate of agricultural commodities tends to decline. A short-term decrease in the farmer exchange rate (FER) does not significantly impact farmers' agrarian activities but can affect their purchasing power.

The farmer exchange rate (FER) indicates farmers' welfare, reflecting their purchasing ability. An increase in welfare is closely related to increased income, improving farmers' consumption needs. Enhanced community welfare can reduce the poverty rate among rural farmers. As a result of improved welfare, farmers' ability to meet their basic needs also increases, contributing to overall welfare enhancement. The role of farmers as human resources is crucial in efforts to improve community welfare (Wul, 2024). Without farmers' contributions, the sustainability of human life becomes challenging. However, farmers' difficulty accessing loans presents a significant obstacle to achieving the desired welfare.

The exchange rate directly impacts farmers' profits and incomes. A decline in farmer exchange rate (FER) can lead to minimal profits or even losses for farmers. Low farmer income levels can reflect higher poverty rates. Improving FER requires implementing policies focused on enhancing price indices and production quantities. Growth in the plantation sector should not only stimulate production but also positively impact farmers' welfare. Integrating these aspects into agricultural policies is expected to create an environment that supports the growth of the plantation sector and overall farmer welfare.

Hsiao (2024) states that the income levels of palm oil farmers are aligned with their expenditures. Unmarried individuals tend to be satisfied with their income, while married individuals feel less satisfied. Consequently, they are adequately happy with the income they receive. Although the community widely pursues plantation farming, the welfare levels of smallholder farmers remain low. Production patterns, value addition, and farmer efficiency are relatively poor, particularly in low-grade Fresh Fruit Bunch (TBS) production. Nevertheless, the welfare levels of smallholder farmers continue to be a concern, especially as the farmer exchange rate tends to decline. Therefore, approaches to production costs, including labor wages, can impact the NTP.

CONCLUSION

Based on the research results and analyses, several conclusions can be drawn: 1) Proportion of Value Added in RGDP: The value added in PDRB negatively affects welfare, as indicated by REM. 2)Productivity of Palm Oil Plantations: According to the analysis using REM, the productivity of palm oil plantations has a positive impact on welfare. 3) Farmer Exchange Rate for Palm Oil: Analyzed using the Random Effect Model (REM), the farmer exchange rate harms welfare. 4) Control Variables: Control variables like land area and GFJF influence welfare levels. 5) Use of Dummy Variables: Using dummy variables has proven to yield consistent results in measuring land area.

The findings imply that policy efforts should shift from reliance on palm oil expansion toward more sustainable and inclusive growth strategies. Local governments need to promote economic diversification, particularly through downstream agro-industries and MSME development, while prioritizing productivity improvements rather than land expansion. In addition, enhancing labor quality through education and skills training is crucial to prevent declining welfare associated with increased labor absorption. Strengthening rural infrastructure and encouraging alternative livelihoods can further reduce dependence on the agricultural sector and improve overall well-being.

REFERENCES

Amutabi, C. (2023). The impact of International remittances on Gross Fixed Capital Formation in Kenya: Evidence from an autoregressive distributed lag modelling approach. Cogent Business and Management, 10(3). https://doi.org/10.1080/23311975.2023.2282233

Aziz, A., Armaz, E., Nazori, M., Rosmanidar, E., Mutia, A., & Anita, E. (2024). An Overview of the Palm Oil Plantation Industry and Its Social Impact on Local Communities in Jambi Province, Sumatra, Indonesia. 3(2), 1358–1369. https://doi.org/10.55299/ijec.v3i2.839

Baka, W. K., Rianse, I. S., & Zulfikar, Z. (2024). Palm Oil Business Partnership Sustainability through the Role of Social Capital and Local Wisdom: Evidence from Palm Oil Plantations in Indonesia. Sustainability, 16(17), 3-29. https://doi.org/10.3390/su16177541

Bandyopadhyay, D., King, I., & Tang, X. (2019). Human capital misallocation, redistributive policies, and TFP. 2019.

Barkah, J. (2024). The Impact of Palm Oil Plantations on Per Capita Income in Kalimantan and Its Effect on Unemployment. 5(11), 1273–1283.

Bryman, A. (2016). Social research methods. Oxford University Press.

Chrisendo, D., Siregar, H., & Qaim, M. (2022). Oil palm cultivation improves living standards and human capital formation in smallholder farm households. World Development, 159, 106034. https://doi.org/10.1016/j.worlddev.2022.106034

Clark, T., Foster, L., Bryman, A., & Sloan, L. (2021). Bryman's social research methods. 2021.

Euler, M., Krishna, V., Schwarze, S., Siregar, H., & Qaim, M. (2017). (2017). Oil palm adoption, household welfare, and nutrition among smallholder farmers in Indonesia.

Ghozali. (2016). Application of Multivariate Analysis with IBM SPSS Program. Semarang: Diponegoro University Press.

Giacovelli, C. (2018). Single-Use Plastics: A Roadmap for Sustainability | International Environmental Technology Centre. 2018. https://www.unep.org/ietc/resources/publication/single-use-plastics-roadmap-sustainability

Hsiao, A. (2024). Coordination and Commitment in International Climate Action: Evidence from Palm Oil.

Ibragimov, A., Sidique, S. F., & Tey, Y. S. (2019). Productivity for sustainable growth in Malaysian oil palm production: A system dynamics modeling approach.

Irawan, B., & Soesilo, N. I. (2021). The Impact of Palm Oil Industry Downstream Policy on CPO Demand in the Downstream Industry. Journal of Economics and Public Policy, 12(1), 29–43. https://doi.org/10.22212/jekp.v12i1.2023

Koizumi, Y. (2022). The Expansion of Oil Palm Smallholders and Migrants' Upward Social Mobility in a Frontier Area of Riau Province, Indonesia (English Translation). Geographical Review of Japan Series B, 95(1), 37–53. https://doi.org/10.4157/geogrevjapanb.95.37

Kripfganz, S., & Kiviet, J. F. (2021). kinkyreg: Instrument-free inference for linear regression models with endogenous regressors. Stata Journal, 21(3), 772–813. https://doi.org/10.1177/1536867X211045575

Loizou, E., Karelakis, C., Galanopoulos, K., & Mattas, K. (2019). The role of agriculture as a development tool for a regional economy.

Luke, S. H., Advent, A. D., Shawn, A. A. K., Adhy, D. N., Ashton-Butt, A., Barclay, H., Dewi, J. P., Drewer, J., Dumbrell, A. J., Edi, Eycott, A. E., Harianja, M. F., Hinsch, J. K., Hood, A. S. C., Kurniawan, C., Kurz, D. J., Mann, D. J., Matthews Nicholass, K. J., Naim, M., ... Turner, E. C. (2020). Managing Oil Palm Plantations More Sustainably: Large-Scale Experiments Within the Biodiversity and Ecosystem Function in Tropical Agriculture (BEFTA) Programme. Frontiers in Forests and Global Change, 2(January), 1–20. https://doi.org/10.3389/ffgc.2019.00075

Otieno, N. E., Dai, X., Barba, D. De, Bahman, A., Smedbol, E., Rajeb, M., & Jaton, L. (2016). Palm Oil Production in Malaysia: An Analytical Systems Model for Balancing Economic Prosperity, Forest Conservation, and Social Welfare. Agricultural Sciences, 07(02), 55–69. https://doi.org/10.4236/as.2016.72006

Parveez, G. K. A., Leow, S. Sen, Kamil, N. N., Madihah, A. Z., Ithnin, M., Ng, M. H., Yusof, Y. A., & Idris, Z. (2024). Oil Palm Economic Performance in Malaysia and R&D Progress in 2023. Journal of Oil Palm Research, 36(2), 171–186.

https://doi.org/10.21894/jopr.2024.0037

Pramesti, W., & Indrasetianingsih, A. (2020). East Java Human Development Index Modeling with Spatial Regression Approach. 226(Icss), 1494–1498. https://doi.org/10.2991/icss-18.2018.312

Purba, N., Alwi, L. O., & Arif, L. O. K. (2023). Analysis of Leading Plantation Sub-Sector Commodity Growth Centers in North Sumatra. International Journal of Agricultural Social Economics and Rural Development (IJASERD), 3(1), 14–24. https://doi.org/10.37149/ijaserd.v3i1.1027

Runtunuwu, P. C. H. (2020). Analysis of Macroeconomic Indicators on the Farmer Exchange Rate of North Maluku Province: A Case Study of Smallholder Plantation Subsector. Society, 8(2), 437–457. https://doi.org/10.33019/society.v8i2.235

Santika, T., Wilson, K. A., Meijaard, E., Budiharta, S., Law, E. E., Sabri, M., ... - Poh, T. M. (2019). (2019). Changing landscapes, livelihoods, and village welfare in the context of oil palm development. 104073.

Supriatna, J., Djumarno, D., Saluy, A. B., & Kurniawan,(2024). Sustainability Analysis of Smallholder Oil Palm Plantations in Several Provinces in Indonesia. Sustainability (Switzerland), 16(11). https://doi.org/10.3390/su16114383

Syahza, A., Bakce, D., Irianti, M and Asmit, B. (2020). Potential Development of Leading Commodities in Efforts to Accelerate Rural Economic Development in Coastal Areas, Riau, Indonesia (Issue June 2021).

Tabe-Ojong, M. P., Molua, E. L., Nanfouet, M. A., Mkong, C. J., Kiven, V., & Ntegang, V. A. (2023). Oil palm production, income gains, and off-farm employment among independent producers in Cameroon. Ecological Economics, 208(December 2022), 107817. https://doi.org/10.1016/j.ecolecon.2023.107817

Taelman, S. E., Tonini, D., Wandl, A., & Dewulf, J. (2018). A Holistic sustainability framework for waste management in European Cities: Concept development. Sustainability (Switzerland), 10(7). https://doi.org/10.3390/su10072184

Wul, R. N. (2024). The role of human resource management in improving the welfare of farmers in Ngada District. 13(01), 873–882. https://doi.org/10.54209/ekonomi.v13i01

Xin, Y., Sun, L., & Hansen, M. C. (2021). Biophysical and socio-economic drivers of oil palm expansion in Indonesia. Environmental Research Letters, 16(3). https://doi.org/10.1088/1748-9326/abce83

Zhang, Y., Long, H., Tu, S., Ge, D., Ma, L., & Wang, L. (2019). Spatial identification of land use functions and their tradeoffs/synergies in China: Implications for sustainable land management. 105550.