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PRICE TRANSMISSION IN THE SUPPLY CHAIN OF INDEPENDENT OIL PALM SMALLHOLDERS IN WEST SUMATERA, INDONESIA: A CASE STUDY IN DHARMASRAYA DISTRICT

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ABSTRACT

This study employs the price relationship equation statistical test and the Error Correction Model (ECM) regression to analyse the transmission of crude palm oil (CPO) prices at the exporter level and its effects on the selling price of fresh fruit bunches (FFB) at the smallholder's level in Dharmasraya Regency, Indonesia. Data were collected through both quantitative and qualitative surveys, involving 150 respondents, including independent smallholders (117), small collectors (25), large collectors (10) and palm oil mills (3). Results revealed a price transmission elasticity of less than 1 (ET<1), indicating asymmetric price transmission where small and large collectors, as well as palm oil exporters, significantly influence the FFB selling prices for independent smallholders. Furthermore, the extended supply chain contributes to narrow profit margins for farmers. To enhance sustainability in palm oil production, it is essential to establish cooperative-based mini-CPO and red palm oil (RPO) factories and implement an integrated information technology system within farmers' institutions to provide real-time data on selling and buying prices, as well as FFB quantities. This study contributes to sustainable practices in the palm oil sector by addressing price asymmetry, ultimately aiming to improve the economic well-being of smallholders and strengthen the overall sustainability of the palm oil supply chain.

Keywords: ECM regression, independent smallholders, palm oil, supply chain, sustainability.

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INTRODUCTION

Palm oil production per unit area which is higher when compared to other vegetable seed oils is an economic advantage that contributes to the community's economy. Furthermore, the Sustainable Development Goals (SDGs) specifically, Goals 1 (No Poverty), 2 (Zero Hunger), and 8 (Decent Work and Economic Growth), are significantly impacted by the production of palm oil. Expanding palm oil production in developing countries, which coincidentally have low wages, is seen to be essential in order to meet future demand for reasonably priced palm oil. Due to an increase in per capita income and global population growth, the demand for palm oil is expected to double from 120-240 t in 2050. The additional need for oil palm is estimated to reach around 7-25 million ha in the next 40 years (Ayompe *et al.*, 2021; Corley, 2009; Khatun *et al.*, 2017; Srisawasdi *et al.*, 2023).

Indonesia is the biggest exporter of palm oil worldwide (OEC, 2023). West Sumatra Province has enormous potential for the development of palm oil commodities, which are a subsector of plantation crops. In comparison to rubber and cocoa

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plantations, oil palm ranks first in West Sumatra in terms of planting area and production of plantation crops. With an average planting area of 32,947 ha (Statistics of Sumatera Barat Province, 2023a) and a total production of 103,637 t (Statistics of Sumatera Barat Province, 2023b). Dharmasraya Regency is home to some of the greatest plantation areas for oil palm. Even though oil palm is the plantation crop in West Sumatra Province that contributes the most to GDP, there is frequently an excess of fresh fruit bunches (FFB) from independent smallholders. Nesti *et al.* (2018) stated that palm oil marketing practices in West Sumatra are not yet efficient because the purchase price received by oil palm smallholders is low, inadequate and monopsony. Furthermore, the lengthy supply chains diminish profit margins, hindering the economic sustainability of local smallholders.

Several factors indicate an effective supply chain, including the ability to offer goods to customers at a low cost and the ability to fairly distribute resources so that each party is satisfied to the same extent (The meaning of fair: A comparison between the sacrifices made and the profits obtained for each component) (Emhar, 2014). Since the concept is hard to quantify, other indicators are required, including supply chain flow. A shorter supply chain is more efficient than a long one since it will involve higher expenditures for storage, shipping, transaction, packing, and damage, which will reduce the amount that smallholders receive (Zuraida and Wahyuningsih, 2015).

The efficiency indicator can be seen from the value of "price transmission elasticity equal to one (ET=1)" which is formed between two markets that interact with each other, both vertically and spatially (Arnade *et.al.*, 2017; Bekker *et al.* 2017; Bergmann *et al.*, 2016; Ceballos, 2017; Darbandi, 2018; Juliaviani *et al.*, 2017; Pejman, 2017; Vavra and Goodwin, 2005). The elasticity of price transmission (ET) can be used to find out the market structure formed where a low ET is one of the indicators that reflects the strength of monopsony/oligopsony power, leading to unequal benefits across the supply chain (Hutabarat and Rahmanto, 2004).

The two most crucial components of the pricing connection in the value chain are marketing margin analysis and market integration, often known as price transmission (Bekkers *et al.*, 2017). According to Juliaviani *et al.* (2017) and Kumala *et al.* (2015), price transmission in agricultural commodities tends to be asymmetric (if there is a price increase at the consumer level, the information is not passed on to smallholders quickly and transparently, but the other way around). According to Tan (2005), an oligopolistic market structure and competitive features are reflected in asymmetric price transmission. Usually, inefficient allocation of resources caused by monopolistic practices in trading groups, intervention by outside parties, market failures and cost adjustments are some sources of asymmetric price transmission (Hassouneh *et al.*, 2012; Rajendran, 2015).

Regarding the asymmetric price transmission of palm oil, Nakajima (2012) analysed and compared the asymmetric price transmission of palm oil between Malaysia and Indonesia. The author highlights that the palm oil industry plays an important role in employment, income generation and foreign exchange earnings in both countries. Understanding the nature of price transmission is considered important for policymakers, producers and consumers, as asymmetric price transmission can have significant implications for the distribution of benefits and risks along the supply chain. Asymmetric price transmission can affect the distribution of profits, industry competitiveness, and the final prices paid by consumers. Nesti *et al.* (2018) stated that one player in the oil palm supply chain has the power to regulate the selling price of FFB, enabling him to limit the selling price of FFB producers. The vertical integration market's inefficiency stems from this circumstance. Furthermore, Bergmann *et al.* (2016) analyse the price transmission and volatility between the European and global butter markets, as well as between butter, palm oil and crude oil. They found that changes in European Union policies have caused a sharp increase in the price volatility of dairy commodities, so it is necessary to develop appropriate risk management tools. Their analysis using multivariate VAR and GARCH models shows there are strong price transmission and volatility between European and global butter, as well as the impact of European butter price shocks on the volatility of palm oil; additionally, there is evidence that crude oil prices also impact the price and volatility of global butter.

Several studies on price transmission have been done by several academics, among others: Sukiyono and Asriani (2020), conducting research on the transmission and volatility of chilli prices in Bengkulu, Indonesia, have found that there is low volatility at the consumer level but high at the wholesaler and producer level. Furthermore, McLaren (2015) who has explored the asymmetry of price transmission in global markets found that monopsony power is the core cause of asymmetric price transmission. Acharya *et al.* (2011) used continuous testing methods for marketing fresh strawberries in the US to prove that price transmission is asymmetric with the finite mixture model; where the finding is that price transmission conditions depend on the harvest season. Acharjee *et al.* (2023) reported on "Price transmission asymmetry of selected fishes in Bangladesh: An econometric and value chain analysis" found that the retail price leads the farmer and wholesale price.

In Indonesia, Ridha *et al.* (2022) have researched the asymmetric price transmission in the cocoa supply chain and the findings indicate that there is a negative asymmetric price transmission between the global cocoa market and the price of cocoa paste to the price of cocoa farmers in Indonesia. For further details, *Table 1* below shows some previous studies related to price transmission in the agricultural market.

Reflecting on previous research, this study occurred intending to analyse how CPO prices are transmitted at the exporter level and how that affects FFB sales prices at the independent smallholder level in West Sumatra's Dharmasraya Regency, Indonesia. It also offers suggestions to strengthen the negotiating position of independent oil palm growers. This study examines the vertical price relationship between each player in the oil palm supply chain using the price relationship equation, formula, and Error Correction Model (ECM) regression. Thus, through this approach, this study will provide a deeper understanding of the price mechanism in the palm oil industry and provide recommendations that can improve the welfare of independent oil palm smallholders in Dharmasraya Regency, West Sumatra, Indonesia.

The urgency of addressing the issue of price asymmetry in Dharmasraya stems from the fact that this study builds upon the author's previous studies. In 2018, a study titled "The efficiency of palm oil fresh fruit bunches in West Pasaman, Indonesia (2010-2017)" (Nesti *et al.*, 2018) was conducted. This was followed by the 2019 study, "Analysis of prospects for CPO in West Sumatra Province" (Nesti *et al.*, 2019) and in 2020, "Competitive analysis of CPO in West Sumatra province compared to other provinces on Sumatra Island in the domestic market" (Nesti *et al.*, 2020).

The topic of price asymmetry is particularly relevant given that West Sumatra, and specifically Dharmasraya Regency, is a major palm oil production hub in Indonesia. Addressing this issue is crucial as it can provide valuable insights for policymakers at both the provincial and national levels to tackle price asymmetry and enhance the competitiveness of the palm oil industry. Price asymmetry, where the prices of raw materials (FFB) and the final product (CPO) do not move in tandem, is a common issue in the palm oil industry. This imbalance can affect the profitability and competitiveness of smallholder and other stakeholders throughout the value chain.

Given the critical nature of palm oil production in Dharmasraya district, West Sumatra, this study provides valuable insights for policymakers at both provincial and national levels to tackle price asymmetry and improve the industry's competitiveness. Understanding the mechanisms behind price transmission is essential for formulating effective strategies that promote the welfare of industry participants and ensure a sustainable palm oil supply chain. By focusing on these issues, this study aims to foster informed decision-making that enhances both economic and environmental sustainability within Indonesia's palm oil sector.

MATERIALS AND METHODS

Data collection was conducted using quantitative and qualitative methods. The quantitative method was conducted by distributing questionnaires to respondents randomly selected from the target population; while the qualitative method examined the description of the characteristics of oil palm smallholders in Dharmasraya district based on field visits and direct questions and answers with respondents. This research employed the purposive sampling method, selecting respondents based on specific characteristics relevant to the study. Respondents were deliberately chosen for their ability to provide pertinent information, including palm oil smallholders, the Palm Farmers' Cooperative, the West Sumatra Provincial Plantation Office and the Indonesian Palm Oil Farmers' Association (GAPKI). Purposive sampling was utilised to ensure that the sample represented all key actors in the supply chain, from smallholders and small collectors to large collectors, processing industries, and exporters. This approach allows for selecting respondents with relevant knowledge and experience related to the research topic.

The study's sample included 150 respondents from the oil palm supply chain in Dharmasraya Regency: 117 independent smallholders, 25 small collectors, 10 large collectors and 3 palm oil mills that also serve as exporters. This sample size was chosen as it was deemed representative of the population, whose exact number was unknown due to incomplete records by the Dharmasraya Regency government. To analyse price transmission in the palm oil commodities of Dharmasraya Regency, the study utilised ECM regression. Data sources included primary data from direct observations (using questionnaires and interviews) and secondary data from Statistics Indonesia. Observations covered all stages of the supply chain, from smallholders and small collectors to large collectors, processing industries and exporters. The data collected included roles and characteristics of supply chain players, profiles of independent smallholders, buying and selling processes of FFB, collection and sales activities, and the processing of FFB into CPO. The flow of information and price transmission at each supply chain level were also documented. *Figure 1* illustrates the study's flowchart.

TABLE 1. PREVIOUS STUDIES RELATED TO PRICE TRANSMISSION IN AGRICULTURAL MARKETS

No	Title	Publication and year	Author	Variable	Tools and analysis	Result	Gap
1	Analysis of Price Transmission Along the Food Chain.	OECD food, agriculture and fisheries working papers 3, OECD Publishing.	Vavra and Goodwin (2005)	Assessment of price transmission along the supply chain (prices at the farmer level to prices at the consumer level).	Qualitative descriptive (literature study) and quantitative descriptive (ECM Regression).	• The process of price transmission through supply chains has attracted the attention of agricultural economists, as well as policy makers. • Imperfect price transmission is thought to be caused by market power and oligopolistic behaviour. • Market power is an important explanation for evidence of asymmetry in price transmission but may not be the only causal factor.	The study did not observe the supply chain in an integrated manner regarding the flow of goods, information, and money.
2	*Efisiensi Harga Pada Vertical Integrated Market Studi Tentang Pasar Produk Industri Karet Alam Indonesia.*	Jurnal Manajemen dan Pembangunan, Vol. 4(1).	Tan (2005)	SIR 20 export volume per company in the observed province, total exports each year, buying price of Slabs at broker level and selling price of SIR 20 on the world market.	Using the Ordinary Least Square (OLS) regression model to explain the relationship between the purchase price of slabs at the collector's dealer and the selling price of SIR in the international market, concentration ratio, H index, and R index to measure market strength.	The operation of the imperfect competition market in the domestic natural rubber market and price competition in purchasing slabs are inefficient in vertically integrated marked natural rubber products in Indonesia. Efficiency is relatively good in North Sumatra, less so in South Sumatra and very poor in Jambi.	The study used a static OLS regression model did not include government policy variables in the model and did not carry out analysis down to the farmer level.
3	Vertical Price Transmission Between Market Operators in Hungarian Agricultural Product Chains.	Studies in Agricultural Economics (106).	Varga (2007)	The input supplier/ agricultural producer price, retailer price.	ECM	Within a few months, it is necessary to restore balance. Prices are transmitted more quickly and efficiently from processors to retailers.	The study explained the existence of asymmetric market conditions, the greatest market concentration is in retailers, while the role of exporters was not explained.

TABLE 1. PREVIOUS STUDIES RELATED TO PRICE TRANSMISSION IN AGRICULTURAL MARKETS (continued)

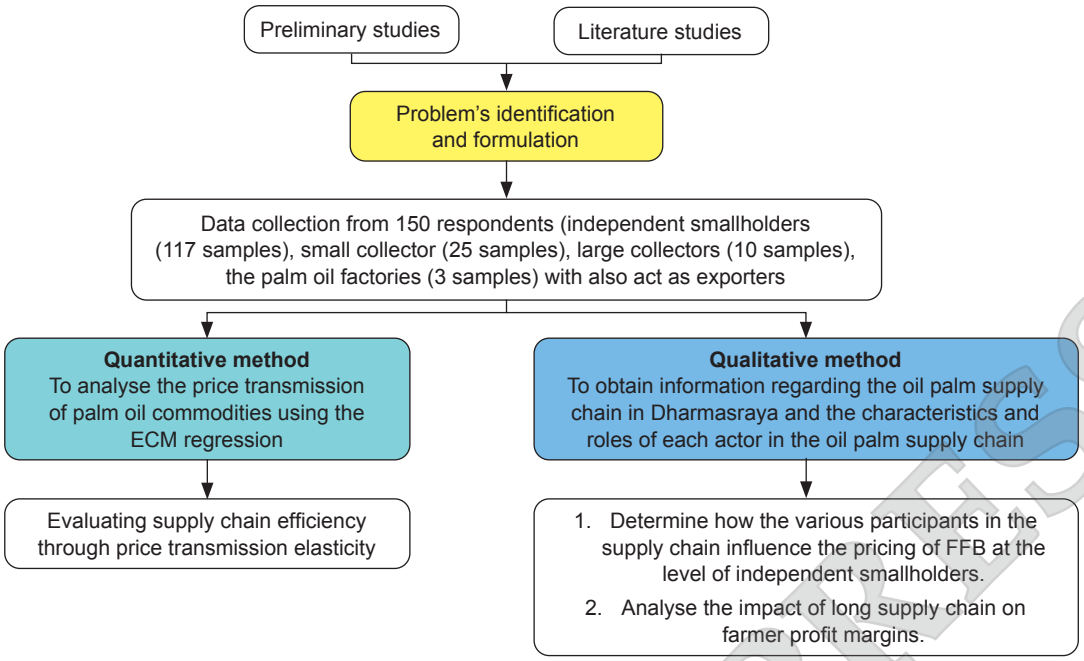
No	Title	Publication and year	Author	Variable	Tools and analysis	Result	Gap
4	Fluktuasi Harga, Transmisi Harga dan Marjin Pemasaran Sayuran Dan Buah.	Analisis Kebijakan Pertanian, 5(4).	Irawan (2007)	Prices of vegetables, prices of fruit.	Price transmission of vegetables is relatively low (49%-55%) compared to fruit and other food commodities (65%-81%). This shows that the vegetable market at the farmer level tends to be monopsony/oligopsony.	An imbalance between supply volume and consumer needs occurs more often in vegetables. Vegetable marketing margins are also relatively high. On the other hand, the prices received by farmers and price transmission from consumer areas to producer areas are low. The vegetable market at the farmer level is monopsony/oligopsony.	It did not explain the causes of the supply and demand imbalance and the government's role in it.
5	Analisis Tataniaga Dan Elastisitas Transmisi Harga CPO Internasional Terhadap Harga TBS Kelapa Sawit.	Skripsi. Depertemen Sosial Ekonomi Pertanian, Universitas Sumatera Utara.	Bisuk (2004)	Sales costs, purchasing costs, commerce costs, and consumer purchasing prices.	Using the calculation of trading margin, share margin, trading system efficiency and price transmission elasticity using the cob doughlas model.	There are two FFB marketing channels, Palm oil marketing in the research area is efficient. The CPO price coefficient is 0.98, meaning that a change in the international CPO price of 1.00% results in an FFB price change of 0.98%.	The determining factors for marketing channel efficiency were only based on trade margins and elasticity.
6	Testing International Price Transmission Under Policy Intervention. An Application to the Soft Wheat Market.	Associazione Alessandro Bartola, Phd Studies Series, 6.	Listorti (2008)	Wheat price.	Vector Error Correction Model.	Integration in grain markets has improved after 1993 because of CAP reforms and trade liberalization reforms.	Market concentration was not analysed and the role of exporters in influencing prices in the domestic market was not explained in the model.
7	Price Transmission Along the Food Supply Chain in the European Union.	EAAE 113th Seminar Chania, Crete, Greece.	Bukeviciute, *et al.* (2009)	Fragmentation, concentration and consolidation, market power along the supply chain.	ECM	Supply chain approach, possible causes of transmission are fragmentation, concentration and consolidation, market forces along the supply chain; institutional arrangements and business practices.	The title relates to food supply chains in Europe, but it was not empirically tested.

TABLE 1. PREVIOUS STUDIES RELATED TO PRICE TRANSMISSION IN AGRICULTURAL MARKETS (continued)

No	Title	Publication and year	Author	Variable	Tools and analysis	Result	Gap
8	*Analisis Harga Minyak Sawit, Tinjauan Kointegrasi Harga Minyak Nabati dan Minyak Bumi.*	Jurnal Manajemen dan Agribisnis, 7(1).	Arianto, *et al*. (2010)	Prices of vegetable oil, prices of palm oil, prices of soybean oil.	Variance decomposition.	In the long term, CPO is the most influential variable in the vegetable oil market.	It was not clear whether CPO had an effect in the short term.
9	*Analisis Transmisi Harga Jagung sebagai Bahan Pakan Ternak Ayam Ras di Sumatera Barat.*	Jurnal Peternakan Indonesia, 14(2).	Rahmi and Arif (2012)	prices at the corn farmer level, prices at the collector level, and prices at the consumer level.	To see market integration, look at the elasticity value of price transmission using simple linear regression.	The sensitivity to price changes at the corn farmer level is smaller than the price at the consumer level, so the market is less efficient. Price transmission from consumers to producers and vice versa does not work well because of the accumulation of margins on collecting traders as market players who control the market and hinder price transmission.	The study still used the OLS regression model.
10	*Transmisi Harga Asimetri dalam Rantai Pasok Bawang Merah dan Hubungannya dengan Impor di Indonesia: Studi Kasus di Brebes dan Jakarta.*	Buletin Ilmiah Litbang Perdagangan, 10(1).	Ruslan and Firdaus (2016)	The price of shallots at the farmer level, the price at the wholesale level and the price at the retail level, as well as the price of imported shallots.	Using the Houck model and ECM as well as long-term cointegration and causality tests.	The farmer-wholesaler relationship experiences price asymmetry in the short term because it is related to adjustment costs, while the wholesaler-retailer relationship occurs asymmetry in the long term. The import price of shallots plays an important role in determining the price of shallots at the producer and consumer levels. It is hoped that the ceiling price and floor price policies will prevent exploitation by intermediary traders.	The study did not examine the market structure that occurs in the shallot supply chain, making it difficult to make policies.

TABLE 1. PREVIOUS STUDIES RELATED TO PRICE TRANSMISSION IN AGRICULTURAL MARKETS (continued)

No	Title	Publication and year	Author	Variable	Tools and analysis	Result	Gap
11	An Analysis of Price and Volatility Transmission in Butter, Palm Oil and Crude Oil Market	Agricultural and Food Economics, 4(23).	Bergmann, *et al.* (2016)	European Union butter prices and world butter prices as well as world prices of palm oil and crude oil	A vector autoregression (VAR) model is applied to capture the effects of price transmission between these markets. This is combined with a multivariate GARCH model to account for potential volatility transmission.	EU prices are transmitted to World butter prices. The European Union butter shock affected palm oil prices. Crude oil prices are transmitted to world butter prices and world butter volatility.	The study did not analyse price transmission upstream [suppliers (farmers)].
12	Study of Transmission of Price from Farm to Retail Shop in Saffron Market	American Scientific Research Journal for Engineering, Technology and Science,32(1).	Pejman, *et al.* (2017)	Marketing margin, the price at the supplier level and the price at the consumer level	ECM regression	Shows symmetrical price transmission from producers to wholesalers in the short term, and wholesalers have more power than producers.	It has not explained the role of the government in determining price policy.
13	Transmisi Harga Kopi Arabika Gayo di Provinsi Aceh	Jurnal Agribisnis Indonesia, 5(1).	Juliaviani, *et al.* (2017)	The price of Arabica coffee at the farmer level, the price at the export level	Using the ECM to see the speed of price transmission in the short term and long-term transmission	The ECM shows that the speed of price transmission in the short term is asymmetric, while in the long term, the transmission is symmetrical, indicating that in the long term, the Gayo Arabica Coffee market in both areas is efficient.	The study did not analyse the causes of asymmetric transmission and government policies in dealing with this.
14	Price Transmission Analysis for the Nicaragua Rice Market	International Journal of Food and Agricultural Economics, 6(1).	Darbandi (2018)	Analysing the relationship between wholesale and retail level prices of the Nicaraguan rice market	The autoregressive distributed lag (ARDL) approach is used to check the stability of long run coefficients, cumulative sum of recursive residuals (CUSUM), and Granger causality test.	There is significant evidence supporting asymmetry between the wholesale and retail sectors, indicating market inefficiencies and distortions between the two markets.	The study did not analyse the relationship between prices at the wholesale and retailer levels to prices at the farmer level.



Source: Primary data (2023).

Figure 1. Flowchart of the study.

Research Hypothesis

H_0=There is an indication that the price transmission in the supply chain of independent oil palm smallholders in Dharmasraya is symmetrical.

H_1=There is an indication that the price transmission in the supply chain of independent oil palm smallholders in Dharmasraya is asymmetrical.

Regression Assumption Testing

Regression assumption testing criteria for price transmission are outlined as follows (Arnade *et al.*, 2017; Bekker *et al.*, 2017; Bergmann *et al.*, 2016; Ceballos, 2017; Darbandi, 2018; Juliaviani *et al.*, 2017; Pejman *et al.*, 2017). When the elasticity of transmission (ET) equals 1 (ET=1), a 1% change in prices at the buyer level results in a 1% change at the producer (smallholders) level, indicating a perfectly competitive market where the marketing system is efficient and symmetrical, with complete price information passed along. If ET is less than 1 (ET<1), a 1% price change at the buyer level leads to a less than 1% change at the producer level, reflecting an imperfect competition market where the marketing system is inefficient and asymmetrical, with incomplete transmission of price information. Conversely, if ET is greater than 1 (ET>1), a 1% price change at the buyer level results in a greater than 1% change at the producer level, signifying an imperfect competition market with an inefficient and asymmetrical marketing system where price information is not fully transmitted.

Classical Assumption Testing

Classical assumption testing involves several criteria to ensure the validity of a regression model, as outlined by Mardiatmoko (2020). Multicollinearity is assessed by examining the variance inflation factor (VIF); if no VIF value exceeds 10 or 5, multicollinearity is considered absent between the independent variables. Autocorrelation is tested using the Durbin-Watson method, where the Durbin upper (DU) and Durbin lower (DL) values from the Durbin-Watson Table are compared with the Durbin-Watson (DW) statistic. No autocorrelation is indicated if DW and 4-DW both exceed DU, or equivalently, if DU < DW < 4-DW. Heteroscedasticity is evaluated using the Breusch-Pagan test, with the presence of heteroscedasticity indicated by a significance <0.05. For normality, the residuals of the data are considered normally distributed if they closely follow a diagonal line in a point distribution plot. Lastly, the linearity test checks the relationship between the predictor variable (X) and the response variable (Y), with a significance value greater than 0.05 suggesting a linear relationship.

Data Stationarity Testing and Cointegration Testing

To analyse data stationarity, the unit root test and the Augmented Dickey-Fuller (ADF) model are utilised. If the unit root test indicates that the time series data is non-stationary, the next step

involves performing a degree of integration test to determine the level at which the data becomes stationary. As outlined by Hadri (2000), Kao (1999) and Pedroni (1999), the process includes conducting a cointegration test to examine if the data in the model are cointegrated. The Engle-Granger test is commonly employed for this purpose and requires the data to be equally integrated. A negative result for the null hypothesis (H_0) from this test indicates cointegration. If cointegration is not found, the next step is to analyse the regression form of the estimation model. Conversely, if cointegration is present, the price relationship can be modelled using an ECM.

The price connection equation model with ECM was used to further evaluate the model if the test results indicate cointegration. Using four independent variables and the ECM, the functional connection was simultaneously examined and analysed in this ECM regression to determine the role that exporters play in short- and long-term price regulation of FFB:

$$\Delta log\ Pp_t = \alpha_0 + \alpha_1\ \Delta log\ Pk_t + \alpha_2\ \Delta log\ Pa_t + \alpha_3\ \Delta log\ Pe_t + \alpha_4\ D_t + \alpha_5\ EC_t + \varepsilon_t \quad (1)$$

with:

$$EC_t = log\ Pp_{t-1} - \beta_0 - \beta_1\ log\ PK_{t-1} - \beta_2\ log\ Pa_{t-1} - \beta_3\ log\ Pe_{t-1} - \beta_4\ D_{t-1} \quad (2)$$

where, Pa = the actual price of palm oil sales at the small collector level, Pb = the actual price of palm oil sales at the large collector level, Pe = the actual price of CPO export sales, Pk = the actual price of kernel export sales, ΔPp_t = Difference from FFB price realisation of sales at the level of self-sufficient smallholders, α_1, α_2, α_3 = Short term coefficient, β_1 = Long term coefficient, α_4 = Unbalance correction coefficient, $\Delta log\ Pe_t$ = Difference log of the actual price of CPO export sales (FOB), $\Delta log\ PK_t$ = Difference log of the actual price of kernel export sales (FOB), $\Delta log\ Pa_t$ = Difference log of the actual price of FFB sales at the collector level, ε_t = Error term.

The efficiency value (elasticity) was shown on each regression coefficient in the equation.

Assumption Testing

Multicollinearity test. *Table 2* displays data from the multicollinearity test findings. *Table 2* demonstrates that the independent variables' partial correlation coefficient, which is less than 0.8, is comparatively low. There are no indications of multicollinearity between the independent variables, according to this figure.

Heteroscedasticity test. *Table 3* presents the findings of the heteroscedasticity test for this regression model. Upon obtaining an Obs*R-square value of 7.749412 from the Breusch-Pagan-Godfrey test, which was larger than α=5%, it was possible to infer that the regression model employed did not exhibit heteroscedasticity.

Autocorrelation, normality, and linearity. *Table 4* shows the findings of the autocorrelation test used in this investigation. Based on *Table 4*, Chi-Square probability value of 0.1680>5% significance threshold, it can be said that autocorrelation is absent from the model.

TABLE 2. MULTICOLLINEARITY TESTING (α=5%)

Item	Log (Pb)	Log (Pa)	Log (Pe)	Log (Pk)
Log (Pb)	1.000	0.766	0.767	0.727
Log (Pa)	0.766	1.000	0.788	0.722
Log (Pe)	0.767	0.788	1.000	0.704
Log (Pk)	0.727	0.722	0.704	1.000

Source: Primary Data (2023).

TABLE 3. HETEROSCEDASTICITY TESTING (α=5%)

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	2.700890	Prob. F (3,86)	0.0506
Obs*R-squared	7.749412	Prob.Chi-Square (3)	0.0515
Scaled explained SS	66.90308	Prob.Chi-Square (3)	0.0000

Source: Primary Data (2023).

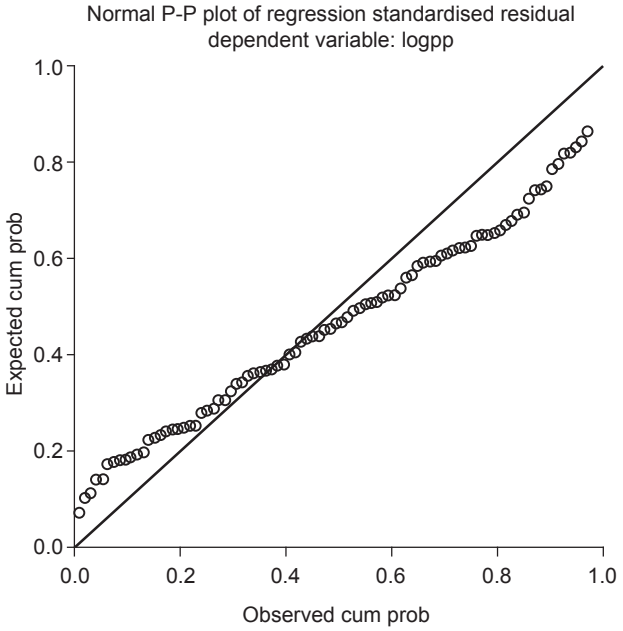
TABLE 4. AUTOCORRELATION TESTING (α=5%)

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.733815	Prob. F (2,84)	0.1829
Obs*R-squared	3.568026	Prob. Chi-Square (2)	0.1680

Source: Primary Data (2023).

Figure 2 illustrates the regularly distributed data. The distribution of the data points is mostly close to the straight line, so it can be said that the regression model has met the assumption of normality.

Table 5 displays the outcomes of the linearity test with an F statistic value of 0.6704, surpassing the significance level of 5%. This indicates that the model accurately captures the relationship between the actual selling price of FFB at the independent smallholder level in Dharmasraya District and the actual prices of FFB sales at the collector level, CPO export sales (FOB), and kernel export sales (FOB) at the local level.



Source: Primary Data (2023).

Figure 2. Normal distribution test.

TABLE 5. LINEARITY TESTING (α=5%)

Ramsey RESET Test			
	Value	**df**	**Probability**
t-statistic	0.427028	85.00	0.6704
F-statistic	0.182353	(1.85)	0.6704
Likelihood ratio	0.192872	1.00	0.6605

Source: Primary Data (2023).

Unit Root Test and Integration Degree Test

Based on the unit root test with the ADF method starting at the level, it was found that all variables were not stationary. Therefore, the stationary test was repeated for the first differentiation and stationarity of the data was achieved after performing the first differentiation at a 5% significance level.

TABLE 6. UNIT ROOT TEST RESULTS FOR EACH MODEL VARIABLE (α=5%)

Variable	**Unit Root Test**			
	Level		**1st Difference**	
	ADF	**Prob**	**ADF**	**Prob**
Log (Pa)	-2.59	0.0996	-9.31	0.0000
Log (Pe)	-2.76	0.0690	-4.61	0.0000
Log (Pk)	-5.29	0.0000	-4.61	0.0003
Log (Pp)	-2.57	0.1023	-9.11	0.0000
Log (Pb)	-2.63	0.0912	-9.50	0.0000

Source: Primary Data (2023).

Cointegration Test

Table 7 shows the outcomes of the unit root test at the error correction term (ECT) level. It is possible to conclude that the data is cointegrated since the unit root test for ECT results shows that the stationary residual at the level has a probability value of 0<5%. If it is established that ECT is stationary at levels, then work on creating the ECM regression equation may proceed.

Price Relationship Equation Statistical Test between Pp and Pa, Pb, Pe, Pk

This model examines the degree to which the real selling price of FFB at the independent smallholders' level in Dharmasraya District is influenced by the actual price of FFB sales at the collector level, the actual price of CPO export sales (FOB), and the actual price of kernel export sales (FOB).

In *Table 8* the prob value (F-statistic) of 0.0000 demonstrates that the relationship model between the price of Pp with Pa and Pb is good; however, partial testing reveals that the regression coefficient of the actual price of kernel export sales is not significant at the 5% significance level.

The following is a regression model using ECM (Equation 3):

$$D[\log\log(Pp)] = 0{,}00627 + 0.657202 * D[\log\log(Pa)] + 0.205981 * D[\log\log(Pb)] + 0.156501 * D[\log\log(Pe)] + 0.003630 * D[\log\log(Pk)] - 0.865389 * ECT(-1) \quad (3)$$

The regression coefficient in the ECM indicated the price transmission elasticity value, or the efficiency of the FFB supply chain system in Dharmasraya Regency. With positive independent variable regression coefficient values less than one and all independent factors having a substantial influence on the dependent variable, the regression equation showed a short-term equation. The pricing elasticity value (ET) of less than 1 (ET<1) indicates that various factors influence the selling price of FFB at the independent smallholder level. The constant value of 0.00627 suggests that if smallholders do not sell their FFB to small collectors, the FFB selling price would be 0.63%. The coefficient Pa of 0.657202 indicates that 65.70% of the FFB price from small collectors is transmitted to independent smallholders. The Pb coefficient of 0.205981 shows that 20.60% of the price from small collectors reaches the smallholders, while the Pe coefficient of 0.156501 demonstrates that 15.70%

TABLE 7. ECT UNIT ROOT TEST RESULTS AT LEVEL (α=5%)

Null Hypothesis: ECT has a unit root				
			t-Statistic	**Prob.***
ADF test statistic			-8.514757	0.0000
Test critical values:	1% level		-3.505595	
	5% level		-2.894332	
	10% level		-2.584325	
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
ECT (-1)	-0.906101	0.106415	-8.514757	0.0000
C	4.28E-05	0.000518	0.082598	0.9344
R-squared	0.454549	Mean dependent var		5.42E-05
Adjusted R-squared	0.448280	S.D. dependent var		0.006583
S.E. of regression	0.004890	Akaike info criterion		-7.781057
Sum squared resid	0.002080	Schwarz criterion		-7.725133
Log likelihood	348.2570	Hannan-Quinn criter		-7.758516
F-statistic	72.50109	Durbin-Watson stat		1.989814
Prob (F-statistic)	0.000000			

Source: Primary data (2023).

TABLE 8. ECM REGRESSION COEFFICIENT WITH FOUR INDEPENDENT VARIABLES

Dependent Variable: D [Log (Pp)]				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	0.00627	0.000525	0.119551	0.9051
D [Log (Pa)]	0.657202	0.035352	18.59035	0.0000
D [Log (Pb)]	0.205981	0.030358	6.785038	0.0000
D [Log (Pe)]	0.156501	0.041872	3.737605	0.0003
D [Log (Pk)]	0.003630	0.003201	-1.134192	0.2600
ECT (-1)	-0.865389	0.111106	-7.788838	0.0000
R-squared	0.977241	Mean dependent var		0.001766
Adjusted R-squared	0.975870	S.D. dependent var		0.031814
S.E. of regression	0.004942	Akaike info criterion		-7.717067
Sum squared resid	0.002027	Schwarz criterion		-7.549293
Log likelihood	349.4095	Hannan-Quinn criter.		-7.649442
F-statistic	712.7835	Durbin-Watson stat		2.031256
Prob (F-statistic)	0.000000			

Source: Primary data (2023).

of the price from CPO exporters is transmitted to them. Additionally, the Pk coefficient of 0.003630 reveals that only 0.36% of the price from palm kernel oil (PKO) exporters is transmitted to smallholders. The ECT coefficient of 0.865389 indicates that 86.50% of the adjustment is needed to achieve efficient price transmission. These findings highlight that small collectors, large collectors and palm oil exporters play a significant role in determining the FFB selling price at the independent smallholder level.

RESULTS AND DISCUSSION

Roles and Characteristics Description

In the oil palm supply chain of Dharmasraya District, various sector plays distinct roles. Independent oil palm smallholders are smallholders who cultivate their land and manage the entire process from planting to harvesting. Typically owning around 2 ha, these smallholders produce 1.5-2.0 t of FFB per ha every 20 days. However, they

cannot sell their FFB directly to palm oil processing mills. Instead, their produce must first go-through small collectors who act as intermediaries. Small collectors buy FFB from these smallholders, managing about 200 independent smallholders each, and transport the FFB to large collectors. They use motorised carts and scales to facilitate this process, conducting transactions and weighing the FFB directly at the smallholders' holdings or homes.

Large collectors, purchase FFB from small collectors, then sell it to palm oil processing mills. Typically, each large collector works with three small collectors, handling an average daily production of 40 t, equivalent to five trucks with a capacity of 8 t each. The FFB is sent to various factories; some of which have their plantations and some that do not. Mills without plantations generally offer higher prices but enforce stricter FFB quality standards, whereas those with plantations offer lower prices and have more lenient sorting criteria.

In the export sector, there are 15 CPO exporters. Among them, 12 operate their palm oil mills, and nine of these also own palm oil plantations. Three exporters focus solely on exporting without having mills or plantations. Consequently, many exporters fulfil dual roles, both processing FFB into CPO and handling its export. Additionally, two CPO companies exclusively distribute their product domestically, sending it to Java and other Indonesian islands.

Respondent Data

Independent smallholders' data. Data obtained from 117 independent smallholders showed that 60% of independent smallholders had primary school education, 20% had junior high school education and 20% had senior high school education. Meanwhile, based on gender, 75% are male. Almost all independent smallholders in Dharmasraya Regency live around their holdings, so they can manage their plantations at any time and most of their main livelihood relies solely on the results of their oil palm plantations. As many as 76% of respondents in Dharmasraya Regency stated that the FFB seeds they used produced good quality FFB. 80% of respondents stated that the time they harvested FFB was in accordance with the standard time for a good harvest. As many as 62% of independent smallholders stated that the FFB that had been harvested was not completely sold to collectors. As many as 64% stated that the FFB selling price set by collectors was far below the current standard price. Furthermore, as many as 64% stated that FFB pricing was not transparent. As many as 94% stated that the price set by the collector could not be negotiated. Furthermore, 70% of independent smallholders stated that the equipment used for harvesting was adequate and 30% stated that capital for production and harvest was considered adequate.

Small collectors' data. A summary of questionnaires from small collectors in Dharmasraya Regency reveals several insights into their operational challenges. About 60% of small collectors find their transportation means for distributing FFB adequate, yet the same percentage reports that the distance for collecting FFB from smallholders is quite far. Road infrastructure is considered poor by 80% of the small collectors. In terms of FFB quality, 70% of them believe the quality is substandard. Transparency in the selling price to large collectors is a concern for 80%, and 60% report that not all FFB sold to large collectors is sold. Regarding equipment, 50% consider it adequate, but 60% indicate that the FFB weighing equipment has never been calibrated. Most notably, 90% of small collectors feel that the benefits they receive are insufficient. The primary issues faced by these collectors include the instability of FFB prices and inadequate wages for transport workers.

Large collectors' data. From the large collector respondents interviewed in Dharmasraya Regency, the characteristics of large collectors were obtained, namely that all respondents were 100% male. Judging from the level of education, 50% had a junior high school education and 50% had an elementary school education. The location of large collectors is not far from the plantations of independent smallholders and small collectors. On average, the respondents' livelihood only works as a large collector and only a small portion also work as smallholders.

A summary of questionnaires from large collectors in Dharmasraya Regency provides several key insights into their operations. About 60% of large collectors believe that their transportation means for delivering FFB to the mill are adequate, but 80% find the distance to the processing mill quite far. Similarly, 80% report that road infrastructure is poor. The quality of FFB from small collectors is deemed unsatisfactory by 60% of the large collectors. Regarding pricing, 80% of large collectors say that the selling price to mills is not transparent, with prices frequently fluctuating between mills. Furthermore, 100% of large collectors report that they are unable to negotiate the selling price, having to accept the price set by the mill. As for the FFB delivered to mills, 20% is reportedly sold, while 70% is not sold due to poor quality. Despite these challenges, 83% of large collectors consider their FFB collection equipment adequate, and 80% feel that the profits from their activities are sufficient.

TABLE 9. INDEPENDENT SMALLHOLDERS' DATA

Number	Questionnaire output	%
1	Education	
	Primary school	60%
	Junior high school	20%
	Senior high school	20%
2	Gender	
	Male	75%
	Female	25%
3	FFB quality	
	Good	76%
	Not good	24%
4	Harvest time	
	According to standard	80%
	Not according to standard	20%
5	Number of FFB harvests sold to collectors	
	All FFB harvests sold to collectors	38%
	Not entirely sold to collectors	62%
6	Selling price of FFB at collector	
	According to standard	36%
	Below standard price	64%
7	Offer selling price of FFB from smallholders to collectors	
	Price negotiations cannot be carried out	94%
	Price negotiations can be carried out	6%
8	Equipment for harvesting FFB	
	Adequate	90%
	Inadequate	10%
9	Capital for FFB production and harvest	
	Adequate	70%
	Inadequate	30%

Note: Standard price means the selling price of fresh fruit bunches that is in accordance with the price set by the plantation service, so 36% is standard, meaning independent smallholders receive the selling price of fresh fruit bunches from collectors according to the price set by the plantation service, 64% is below the standard, meaning smallholders receive a price from collectors below the price set by the plantation service.

Source: Primary data (2023).

Palm oil processing mills. A recapitulation of questionnaires from palm oil processing mills in Dharmasraya Regency reveals several key points. About 60% of the factories indicated that the quality of FFB sent by large collectors did not meet company standards, and 80% reported that many FFB deliveries were rejected due to non-compliance with these standards. Additionally, 60% of the mills noted that the FFB selling price was determined by the mill's set price at the time, and 80% stated that large collectors could not negotiate this price, having to accept whatever was set by the mills. Regarding government policy on FFB prices, 70% of the mills rated it as unsatisfactory. Furthermore, 20% of the mills mentioned that FFB deliveries from collectors occur daily, though the quantity is limited because 80% of the mills operate at maximum production capacity.

Exporter. Some palm oil processing mills' owners also act as exporters, so that with their monopsony power they can regulate the amount of FFB supplies belonging to independent smallholders that enter the mill, thus exporters can regulate the selling price of FFB from large collectors so that this directly impacts the low selling price of FFB received by independent smallholders so that on the one hand large profits are obtained by exporters from selling CPO abroad, while on the other hand exporters with their monopsony power are able to reduce the selling price of FFB to independent smallholders.

An overview of the Oil Palm Supply Chain in Dharmasraya District

Direct interviews were conducted to gather information on the FFB supply chain flow in Dharmasraya Regency. The process started with the delivery of FFB owned by independent smallholders to collectors and subsequently transported to the ramp, which serves as a collection point for FFB to be loaded onto trucks. Once the truck is fully loaded, it is taken to the cooperative, and then

transported to the palm oil processing mill. *Figure 2* and *3* illustrate the autonomous smallholders' supply chain flow in Dharmasraya Regency.

Figure 3 illustrates the general flow pattern of the oil palm supply chain in Dharmasraya, which consists of three main flows: Physical, information, and money. The physical flow moves from upstream to downstream, starting with FFB harvested by independent smallholders. These are collected and distributed by small collectors using land transportation to large collectors, who then transport the FFB directly to palm oil mills. The information flow is reciprocal, with independent smallholders notifying small collectors about the FFB harvested and receiving information on the selling price in return. Small collectors inform large collectors of the FFB quantities and prices, while large collectors update the palm oil mills on the FFB volume and relay the CPO production figures to exporters for international distribution. The money flow involves payments for the FFB purchased along the supply chain, starting from exporters, and moving towards the independent smallholders. Payments for FFB are made directly in cash by small collectors to the farmers, providing immediate capital and meeting daily needs.

Specific Findings

The findings of this study reveal significant inefficiencies in the oil palm supply chain in Dharmasraya District, highlighting how these inefficiencies adversely affect not only the profitability of independent smallholders but also the sustainability of the agricultural system. The extended supply chain results in increased transportation, storage, packaging and damage costs, which diminish profit margins for all players, particularly smallholders. This economic strain can lead to unsustainable agricultural practices, as limited financial resources prevent smallholders from investing in environmentally friendly techniques and technologies.

Furthermore, as illustrated in *Figure 3*, the flow of information regarding palm oil prices in the Dharmasraya District is still somewhat not transparent. A key aspect of sustainability is transparency, both in economic transactions and in the flow of information. The study illustrates that the lack of transparent pricing information limits smallholders' ability to negotiate fair prices, forcing them to accept predetermined rates set by small collectors. This issue aligns with the findings of Rahayu *et al.* (2021), which indicate that insufficient transparency restricts smallholders' access to equitable pricing structures. By contrast, Saragih (2015) underscores that transparent communication among supply chain partners fosters trust, which is essential for building sustainable relationships within the agricultural sector.

Another significant issue in selling FFB to other supply chain members is the fluctuation in FFB prices. This volatility often causes financial difficulties for smallholders. To obtain higher prices, smallholders would need to bypass the intermediaries and sell directly to palm oil mills (Pratama, 2020). However, as shown in *Figure 2*, FFB from independent smallholders cannot be sold directly to palm oil processing mills but must go through small collectors and then large collectors. Consequently, the margins earned by independent smallholders are divided between small and large collectors. Independent smallholders are generally unable to meet the pre- and post-harvest handling requirements set by the mills. Due to limitations in capital, human resources, and technology, independent smallholders have limited bargaining power, leading to a significant portion of their FFB being rejected by the mills. As a result, the extended distribution process by independent smallholders contributes to an inefficient palm oil supply chain. Collectors act as distributors or intermediaries, facilitating the delivery of FFB from independent smallholders to the mills.

From the price relationship model [Equation (3)] stated before, indicates that the role of small collectors, large collectors and exporters of palm oil is influential in determining the selling price of FFB at the independent smallholder level. The functional relationship between the selling price of palm oil end products (CPO and PKO) in the world market and the purchasing price of FFB at the

Noted: → - physical flow; ← - money flow; ↔ - information flow.

Source: Primary Data (2023).

Figure 3. Physical flow, information flow and money flow of oil palm supply chain.

domestic market in West Sumatra shows that price information is not fully transmitted from mills to collectors and from collectors to smallholders; The price is completely set by the millers which is also the exporter, so the oil palm supply chain in West Sumatra is not yet efficient. Since FFB price is determined at every level of the supply chain flow from exporters to smallholders, it is proven that monopsony market power is in operation. These dynamics highlight the need for reforms that not only enhance economic equity but also promote sustainability. For instance, fair pricing structures can incentivise smallholders to adopt sustainable agricultural practices, aligning their economic interests with environmental stewardship.

Given the information above, to foster a more sustainable supply chain, the development of an integrated information system for smallholder organisations is paramount. Such a system would facilitate the transparent dissemination of information regarding selling prices, purchase prices, and FFB quantities. Increased transparency would empower smallholders to negotiate better terms, promoting economic resilience and fostering sustainable practices. Additionally, government support through outreach programs, access to high-quality seeds, and education can enhance crop quality and productivity, leading to sustainable agricultural growth.

Furthermore, as suggested by Teten Masduki, Minister of Cooperatives and SMEs, the government could assist by establishing cooperatively run small CPO and red palm oil (RPO) facilities to process smallholders' FFB. This is particularly important since oil palm smallholders face challenges in selling their harvests even after the ban on CPO and its derivatives was lifted (VOA Indonesia, 2022). Establishing cooperatively run mini-CPO and red palm oil (RPO) facilities would not only reduce dependency on intermediaries but also enhance local value-added processing. This shift can contribute to sustainable development goals (SDG), such as promoting decent work and economic growth (SDG 8) and fostering sustainable agriculture (SDG 2). By providing smallholders with the tools and resources to process their produce, we can create a more equitable and environmentally sustainable supply chain.

An increase in the supply of FFB from more productive trees will likely boost CPO production from the downstream sector and meet the demands of the cooking oil industry, both domestically and for export. This could positively impact the Indonesian economy and enhance the bargaining power of independent oil palm smallholders. Achieving supply chain efficiency will enable these smallholders to compete with or surpass plasma smallholders in terms of FFB prices.

The research recommends establishing smallholder cooperatives and mini-CPO mills to eliminate intermediaries and integrate them into the smallholder institutions. An integrated information system within these cooperatives would facilitate access to crucial data, such as palm oil prices and availability, thus improving transparency and efficiency in the supply chain.

CONCLUSION

This study provides a comprehensive analysis of the oil palm supply chain in Dharmasraya District, uncovering the intricate challenges faced by independent smallholders, small collectors, large collectors, and exporters. Our findings reveal that the price transmission elasticity (ET) is below 1, indicating that the real sales prices received by independent smallholders for FFB are significantly influenced by the pricing dynamics at both small and large collector levels, as well as by CPO and kernel export prices. This situation underscores the substantial impact that palm oil exporters, large collectors, and small collectors have on FFB pricing, highlighting the urgent need for structural reforms to empower independent smallholders and ensure they receive fair compensation for their produce. Moreover, the study illustrates how the lack of pricing transparency and the monopsony power held by larger market players restrict smallholders' bargaining power, jeopardising their economic viability. To promote sustainability within this supply chain, it is essential to establish independent smallholders' institutions and integrated information systems. These initiatives would empower smallholders by enhancing their access to market information and improving their negotiation capabilities, ultimately fostering a more equitable and resilient supply chain. By increasing transparency and advocating for fair pricing practices, smallholders will be better positioned to invest in sustainable agricultural methods, which are critical for ensuring long-term environmental health and economic stability. This research is still limited to one district so the results need to be studied in further research for a wider area. The advantage of this research is that the topic studied discusses the characteristics of actors in the oil palm supply chain and important problems in the oil palm supply chain so that it can be studied comprehensively. This study can be a starting point for further research that explores the relationship between actor characteristics and oil palm supply chain performance and the research model needs to be developed by adding other factors, such as financial access, technology and policy, to provide deeper insights.

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